THE INTERNATIONAL PLANT PROPAGATORS' SOCIETY

Combined Proceedings
Volume 60
2010

IPPS
Sharing Plant Production Knowledge Globally

AUSTRALIAN REGION
EASTERN REGION, NORTH AMERICA
REGION OF GREAT BRITAIN AND IRELAND
IPPS JAPAN REGION
NEW ZEALAND REGION
SOUTHERN AFRICAN REGION
SOUTHERN REGION OF NORTH AMERICA
WESTERN REGION

ISSN 0538-9143

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Business Office. Memberships are processed at the regional level, with dues being allocated to both international and regional expenses. Contact the regional secretary-treasurer (http://www.ipps.org/regions) in your area of the world for membership information and applications. Correspondence regarding replacement copies of proceedings, claims, and changes of address should be sent to a regional secretary-treasurer.

At-large memberships are processed by the International Office.

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SOUTHERN REGION OF NORTH AMERICA

WESTERN REGION

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TECHNICAL SESSIONS:

*INFORMATION IN THE FRONT OF THE PROCEEDINGS HAS BEEN CHANGED TO COINCIDE WITH THE LIST OF PAPERS PRESENTED AT THE ANNUAL MEETINGS

DEDICATION

Dale Deppe was selected to receive the 2010 International Award of Honor from the Board of Directors of the International Plant Propagators' Society. He is a member of the Eastern Region of North America.

This Volume 60 of the *Combined Proceedings* of IPPS is dedicated to him as part of the award. It recognizes individuals who have given exceptional and distinguished service to IPPS and achieved outstanding accomplishments in the field of plant propagation and production.

Dale's horticultural career began at the age of 14, working for 25¢ an hour planting onions. Always finding a way to maximize his return on investment, he soon moved to ornamental horticulture when he learned that a local nursery was paying $1.00 an hour. It was while working for the local nursery that his passion for ornamental plants and the nursery industry was realized.

After graduating from Michigan State University, he worked as the Propagation Manager for Zelenka Nursery for 12 years. In 1981, he and his wife, Liz, started their own nursery with 20 acres of land, two young kids, and a lot of enthusiasm. It started with one homemade Quonset house, and within the first few years of operation he was able to double the size of the operation.

Spring Meadow Nursery is now a world market leader in new and exciting flowering potted liner shrubs. The nursery has state-of-the-art propagation facilities including retractable roof greenhouses, flood floor irrigation, high pressure fog systems, traveling booms, bottom heat floors, and computerized controls. Over 35 acres of established stock plants serve as the source of true-to-name cultivars from around the world and a trialing area for potential introductions. Their best new varieties are introduced and marketed under the Proven Winners® "ColorChoice®" brand.

A consistent leader in the nursery industry in both state and national nursery associations, leadership positions have included his service as President of the Horticultural Research Institute in 2006. He has shared his knowledge with his peers as a speaker at trade shows, workshops, area and annual IPPS Eastern Region meetings as well as writing for trade journals and magazines. His diligent work resulted in recognition as 2003 Nursery Grower of the Year by Nursery Manager Pro Magazine. Dale's method of identifying and marketing new plant material has made his nursery one of the largest providers of proprietary plant materials in the country.

Dale joined the IPPS Eastern Region in 1971. He is a Past President of the Eastern Region (2000) and served at the International level as Alternate International Director (2003–2004) and International Director (2005–2006). His service to the Eastern Region of IPPS has been extraordinary, having served on the Membership Committee during 1986 and 1987, the Award of Merit Committee from 1993 to 1995, the Fellow Recognition Committee from 1996 through 1998, and the Evaluation Committee from 1994 to 1995 and again from 1997 through 2001. He was also active on Local Site Committees in 1993 and 2006, on Program Committees in 1995, as chairman in 1999 and again in 2001. He served on the Nominating Committee from 1999 through 2001 and the Long Range Planning Committees in 1991, 1992, 1995, and 1996 and again in 2001. Dale also served on the Executive Committee as Eastern Region 1st Vice President in 1999, as Eastern Region 2nd Vice President in 1998, and as a member of the Eastern Region Board of Directors from 1993 through 1995. He was also heavily involved in the establishment of the IPPS Eastern Region Foundation. He served as its first Executive Director and continues to serve as a Director on the Foundation's Board.

He was named a Fellow of the Eastern Region in 1999 and in 2008 received the highest honor the region bestows on its members, the Award of Merit. Dale has had outstanding accomplishments in the field of plant propagation and promotion. He has also provided exceptional and distinguished service to the International Plant Propagators' Society's Eastern Region of North America and has served with distinction on the International Board of Directors. Dale's professional life has been a living example of the IPPS motto "To Seek and to Share."

Jim Johnson, International President 2010

The International Plant Propagators' Society, Inc.

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1989 — **Mr. James S. Wells***	*Eastern*
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2006 — **Jörgen H. Selchau**	*G.B.&I.*
2007 — **Richard E. "Dick" Bir**	*Eastern*
2008 — **Thomas Edward Welsh**	*New Zealand*
2009 — **David Hutchinson**	*Great Britain and Ireland*
2010 — **Dale Deppe**	*Eastern*

IPPS HONORARY MEMBERS

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1968 — **Dr. F.L. Skinner***	*Eastern*
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1974 — **Martin Van Hof***	*Eastern*
Dr. John Wister*	*Eastern*
1978 — **Al Fordham***	*Eastern*
1979 — **Dr. William E. Snyder***	*Eastern*
James Wells*	*Eastern*
1980 — **Paul Bosley, Sr.***	*Eastern*
Harvey Gray*	*Eastern*
Case Hoogendoorn*	*Eastern*
Bruce Macdonald	*G.B.&I.*
Roy Nordine*	*Eastern*

1981 — **Dr. Ronald de Fossard**	*Australian*
John Roller*	*Eastern*
Richard Vanderbilt*	*Eastern*
1982 — **Dave Dugan**	*Eastern*
Roy Halward*	*Eastern*
Carl Orndorff*	*Eastern*
Ralph Synnestvedt*	*Eastern*
1983 — **Dr. Hudson T. Hartmann***	*Western*
Riley Roach*	*Southern*
1984 — **Oliver A. Batcheller***	*Western*
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Richard Martyr	*G.B.&I.*
1989 — **A. Thomas Wood**	*G.B.&I.*
1990 — **Bruce A. Briggs***	*Western*
1991 — **Bob Ticknor**	*Western*
2002 — **David Byers**	*Southern*
John Machen, Sr.	*Southern*
2006 — **Ben F. Davis II**	*Southern*
2007 — **Don Hartman**	*Western*

*Deceased

REPORT FROM THE INTERNATIONAL OFFICE – 2010 ACTIVITIES

"The mission of IPPS, with a focus on the global community of those involved in horticultural plant production, is to share knowledge, information, and skills; to provide guidance and support for lifelong career achievements; to increase recognition of the profession; and to maximize the integration of research, education, and horticultural knowledge."

In the year 2010, the International Board of Directors embraced the technology that can join people around the world by arranging its first telephone conference of the Board. The technology, much less expensive and cost-effective now, allowed a time to be established when every Director and Alternate Director could conceivably be available at a reasonable hour. Building on the success of this activity, the Board agreed to hold at least three (3) conference calls in 2011 in addition to the in-person meeting.

Another significant leap into the age of technology was the launch of the PubHort website housing abstracts and full papers from 56 volumes of the Combined Proceedings. For the first time, the general public around the world has the ability to read all the abstracts from these many years of shared knowledge. If desired, they can read and save or print the full papers for a small fee. However, as a member benefit, all IPPS members now have the ability to download up to ten of the full papers at no charge. They can, of course, download more than the complimentary papers for the same small fee. The PubHort website, managed by the International Society for Horticultural Science (ISHS), will be updated each year with the abstracts and papers from the current year's Proceedings.

Volume 59 of the Combined Proceedings was completed in late summer and distributed to all members in book and/or CD formats. Libraries around the world continue to purchase copies to keep their collections up to date. Members and nonmembers continue to be able to purchase back issues of the Proceedings as long as inventory lasts. Editor Charles Heuser thanks Mr. Warren Roberts and Ms. Keppy Arnoldsen for their editorial help.

MEMBERSHIP

Overall membership in IPPS dropped slightly in 2010, with regions reporting as follows:

Region	2010 Members	2009 Members	Change
Australia	232	274	-42
Eastern	471	520	-49
Great Britain & Ireland	161	231	-70
Japan	66	58	+8
New Zealand	210	214	-4
Southern African	72	60	+12
Southern	273	266	+7
Western	297	311	-14
At-large members	5	5	0
TOTALS	**1,787**	**1,939**	**-152**

The newly developed At-Large Member offering attracted five members in 2010 from various areas of the world — from countries outside the geographic scope of the current regions. Future development of this option is expected.

HIGHLIGHTS OF THE 2010 INTERNATIONAL BOARD MEETING

On September 23, 25, and 28, the International Board of Directors met in Jersey City, New Jersey; Lenox, Massachusetts; and Warwick, Rhode Island, with James Johnson presiding at the meeting. All eight regions were represented.

Highlights of the meeting are as follows:

- Minutes of the September 2009 meeting were approved.
- Activities of the International Office were reviewed, including the reported levels of staff time needed to manage the IPPS international operations.
- Year-end membership for 2010 was recorded at 1,787 from all regions, a decrease of 152 in the reported numbers compared to the previous year.
- Five at-large memberships were acknowledged.
- Five-year membership plaques were distributed to 78 members for 2010, as reported by the regions.
- Financial reports through eight months of the fiscal year, August 31, 2010, were reviewed, as well as the investments as of that same date. Investments reported 4% in earnings so far in 2010, after a drop in 2008 and a rebound in 2009.
- A year-end projection on income and expenses for 2010 reflected the likelihood that operations will end with a small loss of just under $1,400, close to the budget projection for this year.
- The International Editor presented reports regarding publication of Volume 58 distributed in September of 2009, and Volume

59 just being mailed in September of 2010, with fewer books and CDs produced due to declining membership. Noted was that 50% of members take the Proceedings in book format; 21% take the Proceedings in CD format; and 8% take the Proceedings as both the book and CD, leaving 21% that do not receive the Proceedings at all with their memberships.

- The Board reviewed the final activities associated with mounting the first 56 volumes of the Combined Proceedings on the PubHort website of the International Society for Horticultural Science.
- The Board agreed to allow those members whose dues do not include the Proceedings to receive ten (10) free downloads of papers from the PubHort website — the same as those members whose dues include the Proceedings in book or CD format. The cost of this membership benefit is to be supported by all members, with details to be developed by the Finance Committee.
- Reports from the various Regions, presented by their Directors, were reviewed.
- Estimates for production of Volume 60 were approved.
- The investment broker handling IPPS' Board-restricted funds (W. Craig McLean of MorganStanleySmithBarney) met with the Board to discuss a proposal to move some or all investments to Australia for a better return. The Board approved a recommendation from the broker for a new investment strategy that allows more global opportunities and more flexibility without more risk, leaving the funds invested in the U.S.A. Other options will continue to be researched for the future.
- The Board agreed that the International Secretary-Treasurer would be excused from participating in the International Tour and attending the International Board Meetings, saving that expense in the annual budget. Instead, electronic recording of the Board's meeting will be arranged, with minutes transcribed by the International Secretary-Treasurer afterwards.
- Another cost savings was approved by eliminating a telephone line for the International Office, leaving email as the primary contact for IPPS, since the phone line was rarely used.
- Plans to implement an international newsletter were moved to the Editor's Advisory Committee to explore ways to launch this initiative with minimal cost to IPPS.
- A proposal from the GB&I region for a membership recruitment subsidization activity was reviewed by the Finance Committee and further Board consideration was not recommended.
- A change in the Board structure was discussed and recommended, as follows:
  - A position of "Chair" was added to manage the affairs of the Board for a one-year term, with up to two additional one-year terms possible. The individual in this position will be elected by the Board existing at the time of nomination and election, and the chair will be part of the existing Board.

  - The position of President will be retained as the representative of the region hosting the International Tour and Meeting, but will not carry responsibility for the Board's management.
  - The position of Second Vice-President position was eliminated, to avoid additional officers in the new structure.
  - All changes will be presented to the membership for voting as Constitution changes over the next year, with implementation possible for the 2012 year. The Board will review the proposed language changes no later than November 15, 2010.
- The Board discussed a preliminary budget for 2011, with a final decision planned for a Board conference call no later than November 15, 2010.
- The Board approved the previous changes made in the Constitution language based on approvals from the meeting in 2009, ready for presentation to the membership.
- A new schedule for the International Tour and International Board Meetings was approved for regions to follow, probably beginning with the 2012 International Tour in Japan. The Board-approved policy requires a minimum of seven (7) days attendance by International Board members, to include the regional conference, a tour, and a minimum of 16 hours of meeting time for the International Board.
- The recipient of the Award of Honor for 2011 was identified and approved.
- Preliminary plans for the 2011 International Tour in the Australian Region and the 2012 International Tour in Japan were reviewed.
- Officers for 2011 were elected as follows: Greg McPhee (Australia) as President, and Nobumasa Nito (Japan) as Vice President. The Second Vice President position was left vacant in view of the proposed change in the officer structure.
- Changes in the Restricted Funds were discussed, moving funds supporting the 50-year index to other areas of support.
- Approval was given for IPPS to enter into a partnership with FloraCulture for IPPS members to receive FloraCulture International only if the members so requested.
- To provide more continuity in Board activity throughout the year, the Board agreed to participate in at least three conference calls at other times of the year (approximately quarterly).
- Approval was given for the International Editor's continued participation in the International Tour, region's conference, and Board meeting, with an expectation that articles about the tour stops will be prepared by Board members and collected by the Editor to put with photos for an overview of the tour for the website and international newsletter.
- Exploration will begin on how to reduce the paper used for Board member meeting packets, utilizing electronic files and on-screen projection of reports if feasible.

SUMMARY OF THE 2010 INTERNATIONAL TOUR, EASTERN UNITED STATES

September, 2010

The northeastern seaboard of the United States is but a portion of the Eastern Region, but the area reflects much of the history of the settlement of the country. The history is alive and well, both from the days of the Pilgrims, who first settled what is called "New England," through much of the colonial times leading to the American Revolution, which gave the country its independence in 1776.

IPPS International President Jim Johnson and Eastern Region Director Alan Jones spent a great deal of time organizing and hosting the tour group through some of the best gardens and production nurseries in the U.S.A., as well as giving a flavor of the history and beauty of this area. We always appreciate how much work and planning is required to put these tours together. Our thanks go not only to the more visible leaders, but also to the IPPS members who help out with various tasks, to the Regional Secretary-Treasurer (Margot Bridgen) for office support, to the representatives of the nurseries and other tour stops who take time for gracious interaction with the tour participants.

The tour began in Philadelphia, Pennsylvania, with visits to two outstanding display gardens near the city — Mt. Cuba Center and Longwood Gardens. Both are well known for their gardens but also as horticultural institutions whose mission includes teaching and displays that help the general public appreciate garden design. The day ended with dinner hosted by IPPS member Steve Castorani of North Creek Nurseries in Delaware, known for its large selection of perennials, grasses, and ferns with an emphasis on new introductions and Eastern North American natives and their cultivars.

Day two focused on historic Philadelphia, with a visit to the symbol of America's freedom, the Liberty Bell and Independence Hall. The afternoon visit to Chanticleer Gardens showcased one of the most beautiful pleasure gardens, converted from a private estate and opened to the public in 1993.

The next days were spent in New Jersey, known as "The Garden State" for good reason. First, the group was treated to WheatonArts, absorbing the history of the birthplace of the American glass industry. The museum showcases the finest collection of American glass with a fully operational Glass Studio along with other studios for artists demonstrating traditional crafts of pottery, wood, and flameworking. A wine tasting at Bellview Winery set the stage for the next day's visits to Lucas Greenhouses, Centerton Nursery, Overdevest Nurseries, and dinner hosted at Blue Sterling Nursery.

George and Louise Lucas built a huge greenhouse facility starting in 1979 that has become a major resource for the retail industry, noted for excellence in product and service. Ray and Marlene Blue purchased Centerton Nursery in 1975 and now have three generations involved in its operation. They have developed a number of well-known product brands including the Hasslefree® Rose line and the Happy Ever Appster® daylily line. Ed and Gail Overdevest have helped the expansion of their diversified production nursery, with container production involving over 2.7 million square feet of coverable growing space. Blue Sterling Nursery owners Jim and Barb Smith are frequent International IPPS Tour participants, and their nursery specializes in clonal dwarf and slow-growing conifers, but also includes rare, miniature, slow-growing, and unique plants gathered from their travels around the world.

A visit to Pine Island Cranberry Company gave the tour group a look at cranberry production in a 1,400-acre bog, followed by a visit to Pinelands Nursery & Supply, owned by Don and Suzanne Knezick and one of the largest native plant nurseries in the U.S.A. Next, Scott and Craig Daum of Four Seasons Nursery and Landscape Co. showed off their family nursery that supplies the entire northeastern coast with quality landscape material. The day finished with a visit to Grounds for Sculpture, with 240 works of art in a park-like setting.

Princeton, New Jersey, is a university town and also the site of the Governor's residence, called Drumthwacket, considered one of the most elegant of America's executive residences, with acres of landscapes grounds surrounding the estate home. In the area, the group toured Pleasant Run Nursery and were hosted for lunch by Richard and Heidi Hesselein. The afternoon included time at Kube Pack, a greenhouse operation owned by the Swanekamp family, with a specialty in plugs and rooted cuttings.

The next day took the tour into New York City for a visit to Central Park, America's first and foremost major urban public space, as well as time at the Metropolitan Museum of Art. Also in the city is Battery Park City, with urban parks and public art installed on a 92-acre community development site along the Hudson River shoreline with 13 parks and playgrounds covering nearly 36 acres of open space. The group also visited the Highline, a wonderful public park situated high above the city on a former railroad that lifted freight trains away from the city streets. And finally, a visit to the Bronx Zoo allowed time in 265 acres of parkland and naturalistic habitats for the 4,000 animals who call it home.

Moving into the next state, Massachusetts, the group visited the Norman Rockwell Museum in Stockbridge, dedicated to the enjoyment and study of one of America's most noted artists. Nearby was Naumkeag, a quintessential country estate that served as a summer home during its prime in the "gilded age." The gardens in various areas of the estate grounds keep a visitor interested and fascinated with the creative display of plant material and hardscape additions. Windy Hill Farm Nursery provided a wonderful dinner hosted by Dennis and Judy Mareb and a tour of a fine retail garden center including a pick-your-own apple operation.

Two nursery stops the following day offered diverse operations. Hillside Nursery offers a specialty line of Cypripedium orchids and selected woodland perennial plants, primarily through mail-order purchase. Nourse Farms has been a family-owned, premier grower of small fruit plants for over 75 years. For local culture, the group visited the Bridge of Flowers in quaint Shelburne Falls, originally a trolley bridge that was turned into a 400-foot garden walk after it was retired from use. And time spent at Yankee Candle, the flagship store for this "Disney World of Candles," provided the chance for the tour group to help the local economy.

The last tour day started with a visit to Old Sturbridge Village, the largest outdoor history museum in the Northeast. This visit back in time to a rural New England town included authentically costumed staff and a wonderful tour by a local woman whose personal enthusiasm for plants and gardens added extra insights for the interest of our group.

The University of Connecticut in Storrs provided a look at the Waxman Conifer Collection and the New England Invasive Plant Center. And the day and tour culminated with a memorable dinner hosted by owner Mark Sellew at Prides Corner, a market leader selling more than a dozen branded plant programs and over 2000 varieties of plants.

Once again, everyone involved in IPPS was reminded of the camaraderie, the shared knowledge, the respect and appreciation for different cultures, and the friendships over many years that have become a hallmark of IPPS.

Patricia E. Heuser
International Secretary-Treasurer

(NOTE: Much of the description information about the tour was prepared by President Jim Johnson)

Financial Report for 2010

OPERATING FUND

OPERATING INCOME

Interest Income from operating funds	**$ 345**
Dividends from investments	**7,305**
Membership dues received, all regions and at-large	**111,746**
Miscellaneous Income	**369**
Sales of Proceedings to Libraries, others	**8,525**
Total Income	**$128,290**

OPERATING EXPENSES

Award expenses and tour host gifts		**$ 1,596**
Banking Fees		**563**
Board & Committee Expenses		**17,791**
International Board Meeting costs	1,914	
Airfare for travel of Directors to Intl. Board Meeting	15,795	
International Conference Calls	82	
Copying Costs for meeting book and general office		**557**
Credit Card Fees to process dues and Proceedings orders		**702**
Professional Liability insurance		**1,503**
Management Fee - The Heuser Group		**24,000**
Office Expense - supplies		**692**
Postage, Shipping & Mailing		**16,003**
Postage and mailing for Proceedings books and CDs	13,906	
General office postage costs	219	
Shipping Proceedings to libraries and others ordered	541	
Shipping 5-year membership recognition plaques	1,148	
Shipping materials for Intl. Board meeting	189	
Printing		**34,045**
Current volume design and layout and images	17,565	
Current volume printing cost	13,220	
Production of CDs	3,212	
Printing letterhead, envelopes, mailing labels, etc.	48	
Professional Fees		**21,403**
Editor's Honorarium	17,400	
Editorial assistance	2,085	
Botanical Editor's fee	700	
Accountant's fee for filing tax returns	755	
Database consulting and maintenance fee	463	
Telephone and Fax Expense		**585**
Staff Travel & Costs		**6,025**
Travel costs for Intl. Sec-Treas. and Editor for Intl. Tour and Board mtg.	1,075	
Registration fees for Intl. Sec-Treas. and Editor tour	4,950	

Website Maintenance and Internet Expenses	**2,292**
Total Expense	**$127,757**
Excess of cash receipts over expenses on operations	**$532**

2010 SUMMARY OF CASH RECEIPTS AND EXPENDITURES

Beginning cash balance, January 1, 2010		**$300,985**
(including Restricted Funds)		
Income from operations		**$128,290**
Less expenditures from operations		**($127,757)**
Less expenses from Restricted Funds		**($22,730)**
Purchase of metal plates for 5-year membership plaques	366	
Purchase of 300 5-year membership plaques (for inventory)	8,672	
Scanning costs for past volumes for PubHort website	838	
Purchase of 250 metal lapel pins for membership	816	
Final payment to ISHS for PubHort website use	8,038	
Additional payment to Editor for PubHort preparation work	4,000	
Other financial activities		
Unrealized gains/losses on investments	$13,951	
Broker's fee for 2010	($372)	
Ending cash balance, December 31, 2010		**$292,367**

IN MEMORIAM

It is with the deepest regret that the death of the following member during 2010 is recorded:

Region	Individual	Affiliation
Southern	**Suzy Gilbert Strong**	Gilbert's Nursery
Eastern Region, North America	**David Dugan**	Retired — charter member of IPPS, joining of 1951
Region of Great Britain & Ireland	**David Miller**	Retired, Guernsey Clematis Nursery, Channel Islands

The International Plant Propagators' Society, Inc.
Regional Officers and Committees

AUSTRALIAN REGION

OFFICERS

President — **LIONEL SACH,** 18 McGregor Court, Mooloolah QLD 4553
First Vice President — **MARGY CLEMA,** Whistlepipe Gardens, 281 Holmes Road, Forrestfield WA 6058
Second Vice President — **ROBERT REYNOLDS,** P.O. Box 1059, Epping NSW 1710
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Tony Page, 2000
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Arda C. Berryhill, Sherwood, Oregon, 1992

Andrew T. Leiser, Davis, California, 1993

Edwin S. Kubo, Sacramento, California, 1994
Joseph Solomone*, Aromas, California, 1995
Edsal A. Wood*, Wilsonville, Oregon, 1996
Stanley E. Sorenson*, Clayburn, British Columbia, 1997
Ralph S. Moore*, Visalia, California, 1998
Dale E. Kester*, Davis, California, 1999
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Steve McCulloch, Olympia, Washington, 2003
Jim McConnell, Yamhill, Oregon, 2006
Verl L. Holden, Silverton, Oregon, 2007
David W. Burger, Woodland, California, 2008

*Deceased

LIST OF PAPERS PRESENTED AT ANNUAL MEETINGS

THIRTEENTH ANNUAL MEETING — SOUTHERN AFRICAN REGION

THIRTY- EIGHTH ANNUAL MEETING — AUSTRALIAN REGION

FORTY-THIRD ANNUAL MEETING — REGION OF GREAT BRITAIN AND IRELAND

INTERNATIONAL AT LARGE MEMBERS

TECHNICAL SESSIONS

SOUTHERN AFRICAN REGION

Twelfth Annual Meeting

March 11–12, 2010

PRETORIA, SOUTH AFRICA

Ways to Increase Energy Efficiency in Nurseries©

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INTRODUCTION

As we move into uncertain times concerning the use of energy, particularly as it relates to global warming, peak oil and rising costs, it is timely I believe that as an industry we should all be reviewing how each of our businesses can reduce our use of all of the forms of energy that we currently consume.

While many of us are locked into the use of electricity for instance, there are ways that we may be able to reduce our usage by partially supplementing this source of energy. I have attempted in this paper to explain a number of possibilities that I believe might be useful in reaching this goal.

The oil price shock of the 1970s gave the industry a wakeup call in regard to energy conservation, particularly to those that used heating oil exclusively to fire their boilers. As a direct result of this event, which probably now pales into insignificance with the more recent price rises for oil, many nurseries adopted at least some form of energy conservation and in many cases a switch from oil to gas.

Currently we face another challenge with global warming and the possibility of governments imposing either a carbon tax or an emissions trading scheme on industry. So with a combined onslaught of high oil prices as well the rising cost of gas and a carbon tax, there is no way that we can ignore any longer the need to be more conservative.

Many of us, particularly in warmer parts of the world, have been fairly slow to adopt any major change and it is fair to say that after the 1970s oil shock many nurseries failed to make continuing improvements to their structures and other areas of operation. There was a range of inefficient heating devices, thermally inefficient green house structures, inefficient lighting and inadequate or expensive cooling systems.

Lighting for instance in Denmark is an essential part of winter growing so in some cases large growers built their own generating plants, powered by oil and then sold excess electricity into the national grid. Some of these are struggling to stay viable because of the cost of oil and of course the downturn of the last few years in prices for green life. Infrared heating used in the USA in the 1980s is now used much less along with gas-fired heat exchangers.

Probably one of the better legacies from the 1970s was the use of double skinned greenhouses using polyethylene. This practice has continued, particularly with the advent of longer life UV treated polyethylene that has better light penetration and allows the option of using a thinner material as the second skin.

In those regions of the world that need cooling as well as heating, there have been many advances in the development of efficient materials that can be used to build wet walls. At Narromine Transplants we have used a wet wall designed by Munters and using their CELdek system which is as long as the as the propagating greenhouse, positioned at bench height with extraction fans three spans away. We have found great benefit in propagation from this system.

What can we do to save energy using the existing equipment we have available to us?

- Check temperature at crop height, early in the morning
- Make sure temperature is consistent across the crop
- If average temp is higher than needed reduce the thermostat setting
- Buy an infrared thermometer
- On the propagating bench monitor the temperature of the medium
- Ensure you cover as much of the bench as possible with the crop-Keeping a greenhouse one-degree warmer than needed increases gas consumption by 10% to 15%
- Make sure the greenhouse is air tight
- Air temp should also be uniform from crop to top of roof
- Use circulating fans to equalise temperature
- Install a thermal screen if you can afford it
- Reducing air temp near the roof by one degree may lower fuel use by 10%

There is available a large range of energy saving equipment, here are a few ideas:

- Double polythene coverings wall and roof
- Thermal screens roof and walls
- Skirt propagating benches
- Installing moving benches to eliminate aisle ways and maximise crop area
- Insulating propagating benches to eliminate heat loss
- Thermally efficient heaters, gas or electric
- Hot water mats for propagating benches
- Solar hot water and greenhouse heating

We have experimented for some time with solar hot water for use in the propagating house. We have used four banks of evacuated tube solar collectors, which feed hot water into a heat bank fitted with three large copper coils. Cool water from the return end of the bench goes through the heat bank coils and then back to a mixing tank where the water, if necessary, is then brought back to the desired temperature using a gas heater. The water is then pumped through specially designed rubber matting at a slightly higher temperature than is required on the top of the bench. We believe we are saving slightly in excess of 30% of our propagating bench heating costs using this system.

Some other possibilities for heat savings involve the use of water or Trombe walls; Phase Change materials (solid to liquid) in glazing and walls and thermally efficient polyethylene covers often with special covering to improve growth rates.

These are just a few ideas that we can adopt to help us save energy, we will need to keep thinking of new ideas so that we can remain environmentally sound as an industry and continue to be competitive.

Water Supply Shortage Response Plans (Restrictions) for the Green Industry in the Rand Water Supply Area in South Africa©

Leslie Hoy
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INTRODUCTION

Which of the two gardens would you prefer to have?

A

B

Figure 1. Would you prefer Garden A (L. Hoy) or B (N. Koneight)?

PROBLEMS THE WORLD IS FACING

To feed the growing world population irrigated lands have increased by 2% per year using more water. In the last few years droughts have been experienced in China, England, U.S.A., Brazil, Australia, India, etc. Parts of the Eastern Cape Province are currently experiencing the worst drought in 100 years. As more people seek greater amounts of water wars are predicted to erupt.

The world in general is becoming warmer. Between 1900 and 1990 the earth's surface has warmed between 0.7 and 0.8 °C. The worst case scenario of global warming could result in sea levels rising by as much as 72 m. Between 1940 and 1989, average summer temperatures in South Africa increased between 0.8 °C and 2.7 °C negatively impacting on evaporation (Ashwell and Hoffman, 2001).

In many areas of Asia and Africa, demand for water has exceeded supply. Simply put the world and South Africa simply don't have enough water to "feed" the ever expanding populations.

Extracts from the 5th World Water Forum in Istanbul 2009 [(Fauchon, 2009) President of the World Water Council]. "We are, thus, confronted by a major challenge: the demand for water is ever-increasing and, at the same time, we must protect, value, stock, and even re-use water resources. We must establish harmonious sharing of water between man and nature... Sharing water is a difficult task and an essentially political responsibility, for the future of water depends… But to increase indefinitely the water supply is expensive… We can no longer accept to continue to spend more money on producing water that we then waste and dirty… We must say it again loudly and clearly, as we did in Istanbul: The time of easy water is over."

PROBLEMS THAT SOUTH AFRICA FACES

South Africa faces many climatic and rainfall related problems, including:

- Climate Change.
- Increased frequency of floods and drought.
- Gauteng will experience hotter summers, warmer winters, less rain and increased evapotranspiration.
- 10% to 20% decrease in summer rainfall over the central interior.
- The Cape area could lose as much as 30% of its rainfall.
- The population could be doubling every 20 to 40 years.
- El Niño is in itself a mystery that comes and goes and its specific affects are not clearly understood.
- More and more water storage facilities are required to address assurance of supply. SA has limited ability to build more dams as resources are almost at an end.
- The SA Weather service are currently predicting a dry summer (Nov. 09 to March 2010)
- South Africa's water situation is predicted to move from one of water stress to absolute scarcity.
- South Africans are all familiar with the continuous water problem that are experienced, such as:
  - Water quality problems experienced in many areas.
  - Water supply interruptions.
    - Droughts in some parts of the country while there are floods in others, e.g., Gauteng, Limpopo, Cape Town, and Eastern Cape.

When considering the total estimated available water for the period 1995–2025, the devastating fact is that South Africa's water situation will move from one of water stress to absolute scarcity. It will mean that available water per capita will reduce from 1266 m^3 (1995) down to 997 m^3 (SADC, IUCN, SARDC, World Bank, 2002).

Some South African Rainfall and Evaporation Information.

- The world average temperature is around 860mm/annum
- Average rainfall for SA is 497 mm/annum
- Approximately 65% of SA receives less than 500 mm/annum
- 21% receives less than 20 mm/annum
- Evaporation ranges between 1100 mm to 3000 mm per annum
- In the Upington area evaporation can be as high as 4000 mm/annum (South Africa Department of Water Affairs, 1986)
- Evaporation is therefore on average more than the rainfall received
- Shallow dams with large surface area are therefore also not desirable

Currently George municipality (Dam water levels at only 18.6%) are experiencing a serious drought and very strict water restrictions are in place.

Similarly the Nelson Mandela Bay Municipality are also in a similar situation and the dam levels are only at 45% as the water crisis deepens. They are also currently building a R500 million pipeline from the Orange River, to supply the Nelson Mandela Bay Metro from Gariep Dam near Venterstad (353 km as measured on a straight line).

Because South Africa has such diverse climatic areas stretching across many areas one area may be experiencing drought whilst others excessive rain and flooding.

Where does the water go to (Table 1)? Only 30% of irrigation water (Agricultural water use) from dams is used — the rest is wasted through evaporation, leaking pipes, canals, and poor irrigation methods. Up to 15% of water in Vaal system (which supplies Gauteng with water) is used illegally mostly by farmers. Municipalities, who use 15% of the total water, waste up to 30% of it due to leaking infrastructure, etc.

Table 1. Where does the water in South Africa go?

%	Location
48	Agriculture
18	Ecology/ environment
15	Municipalities
8	Industry
7	Forestry
3	Mining
1	Eskom

Household Water Use Patterns for the City of Cape Town. The estimated water use in the garden in Cape Town is approximately 35% of the water supplied for domestic purposes (Davies and Day, 1998).

Water Wise has focused on the green industry because studies have pointed to the fact that gardens account for up to 31% to 55% of demand (different sources quote different amounts used), and as a result potential savings are large.

Survey interviews with residents of Alberton (Gauteng province) in 2000 on their **perceived** water use provided some surprising results, such as garden water use accounting for as little as 10% of the total water bill for township residents and 14% middle and upper income groups (Bill and Veck, 2000).

Another important potential water user that needs to be considered in the South African context is golf courses. Some statistics on their water use:

- There are 500 registered golf courses, plus golfing estates in S.A.
- There are approximately 500,000 golfers
- Golf courses use as much water as 1.2 ML to 3 ML/day
- Should 500 golf courses use water at 1.2 ML/day, the annual amount used will amount to as much water in a year as 3,042,000 households (using only the 6,000 L of free basic water), or 24 million people (at the per person rate of 25 L/day, considered the minimum anyone needs).

DROUGHT

Depending on the timing, length, and intensity of the drought it is described differently. The categories of droughts, in ascending order, include

- Meteorological drought
- Agricultural drought
- Irrigation drought
- Hydrological drought
- Socio-economic drought (National Drought Mitigation Center, 2006)

Droughts seem to occur in cycles. Some researchers refer to 7 year drought cycles; others refer to 9–10 year cycles, and still others to 14 year cycles. The fact is that droughts do occur in some form of cycle and are almost impossible to predict in the long term.

Some Recent South African Drought Statistics.

- The drought of 1991–1992 in SA
  - There was a reduction of 1.8% of real disposable income.
  - There was only a 0.5% increase in consumer spending.
  - 49,000 agricultural jobs were lost.
  - 20,000 formal sector jobs lost. (SADC and World Bank).
- Unfortunately no published statistics are available for 1994/95 drought which hit especially Gauteng very hard
- Recent drought in the Cape (2005)
  - 50% less bedding plants sold,
  - Nursery sales were down 15% to 20%
  - Up to 25% of some nursery staff was laid off.

People's reaction to drought can be easily depicted in the Hydrological Illogical Cycle. In this cycle one moves from a period of rain, to apathy, to drought, awareness (that water is decreasing), concern (that the drought is increasing in intensity), and finally panic (when there is absolutely no water left). Once it then rains again the cycle starts all over again.

COMMENTS AND OBSERVATIONS FROM THE DROUGHT OF 1994/5 IN GAUTENG

The following are some of my own comments and observations from the drought of 1994/5 in Gauteng.

- It was only when very little water was left in the Vaal dam water supply system that Government imposed water saving targets of 30% on to Rand Water (RW) and RW then passed this on to municipalities.
- The municipalities also then at the last minute imposed water restrictions onto the end user, these being mainly gardeners and green industry.

- There was also none if any discussion on the actual restrictions and they were unilaterally imposed.
- Very little was done proactively to mitigate the negative side effects on the green industry.
- Similar events occurred in Cape Town in 2004/5.
- The same seems to have been repeated in Port Elizabeth (Nelson Mandela Bay Metro) in 2009/10.

RESEARCH PROCESS UNDERTAKEN FOR THIS STUDY

The study commenced in 2004 and was completed in 2009 through the University of South Africa (UNISA). The title: *A proactive water supply shortage response plan, focusing on the "green industry" in the Rand Water, water supply area.* The two supervisors' were Prof. J. Hendrick and Prof. L. Brown.

Where Does the Green Industry Fit into this Research?

- Generally the water that is used by the green industry, in the residential and office complex units, is referred to as domestic water use, whilst for wholesale growers; this water usually falls within the agricultural sector use.
- The green industry contributes significant jobs and finances to the South African economy in direct, as well as indirect benefits, such as social wellbeing, physical health, psychological aspects, and many more.

For the purposes of this study the green industry is defined as, "The bodies constituted of and limited mainly to the South African Green Industry Council (SAGIC), but inclusive of the general gardening end users.

- South African Nursery Association (SANA)
- South African Landscapers Institute (SALI)
- Institute for Environment and Recreation Management (Africa) (IERM)
- Landscape Irrigation Association (LIA), amongst others"

The Gardening end users were defined as being — the public that Rand Water serves (supplies water to), with home gardens.

My Perceptions on How the Green Industry Is Often Seen.

- Landscaping, gardens and garden centres are not always regarded as a priority.
- It is often the first to be hit by water restrictions (e.g., domestic water)
- It is often perceived as a disposable industry or luxury that can be done without.

But,

- In 1999 the green industry market in U.S.A. was estimated at $50.9 billion.
- In 1999 the S.A. ornamental horticulture industry was estimated at being worth R1.3 billion (unpublished figures).
- In 2007 the S.A. industry was re-estimated as being worth R3.3 billion. Although currently no thorough researched estimates are available of size and value of the S.A. Green Industry.

The research process undertaken (Fig. 2) was one of action research and should be seen as an upward spiral.

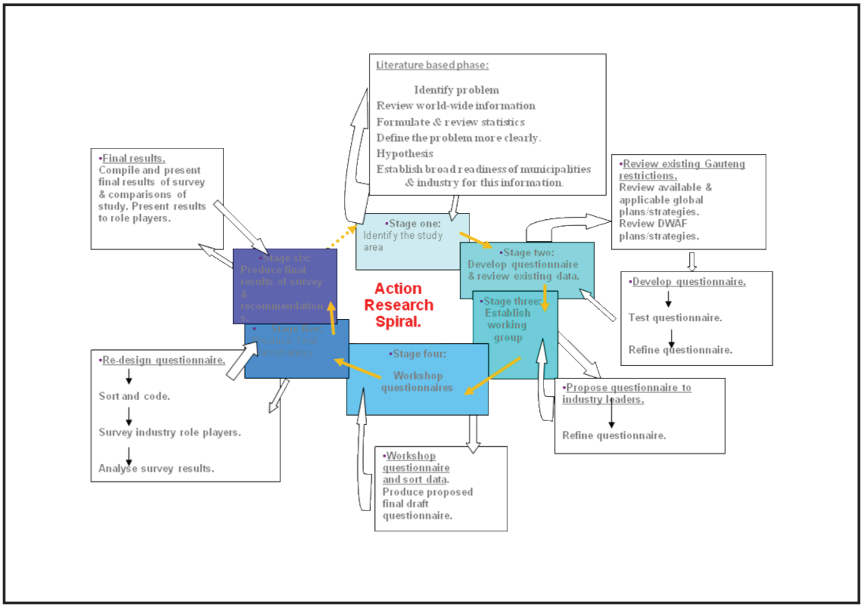

Figure 2. Action research spiral model.

Only limited trends of data are shown, for reasons of time in the presentation (a full copy of the study is available from the UNISA library).

SOME PERTINENT INFORMATION ABOUT RAND WATER AND IT'S SUPPLY AREA

Area of Supply. Rand Water's main area of supply is Gauteng as depicted in Figure 3.

Some Basic Statistics about Gauteng.

- It covers an area of 1.54% of S.A.
- It generates 40% of S.A.'s GDP (2009)
- It accounts for 10% of Africa's GDP
- 19.1% of S.A. population reside in the province (2001)
- 89% of the province is urbanized (Koh, 1998)
- 9.8% of its population are without running water

Rand Water's water sources come from various sources as depicted in Figure 4.

Distance Water Is Pumped. As if Rand Water does not have enough challenges in water source, it still has to transport the water over vast distances and mountain ranges. It is required to pump water 70 km from the purification station to the foot of the Klipriversberg mountains where it is then pumped up over the ridge. The total height pumped is 375 m. Once the water is pumped over this ridge, it is gravity fed for approximately 200km to its furthest municipality.

Bulk Water Suppliers in South Africa. When compared to other bulk water suppliers in South Africa, Rand Water's daily supply far outstrips other suppliers. It is therefore a strategic role player in this region (Fig. 5).

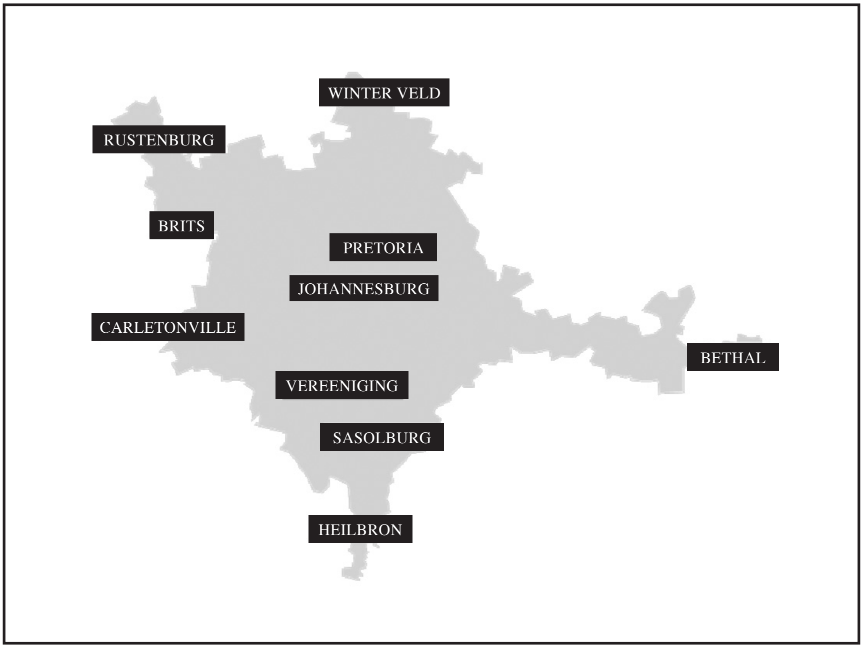

Figure 3. Rand Water's area of supply.

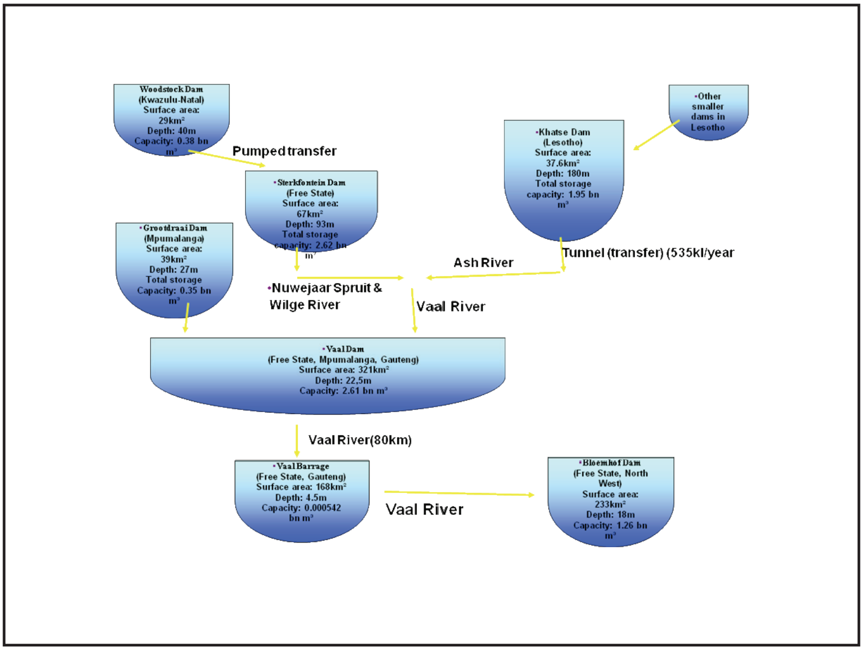

Figure 4. Sources of water for Rand Water.

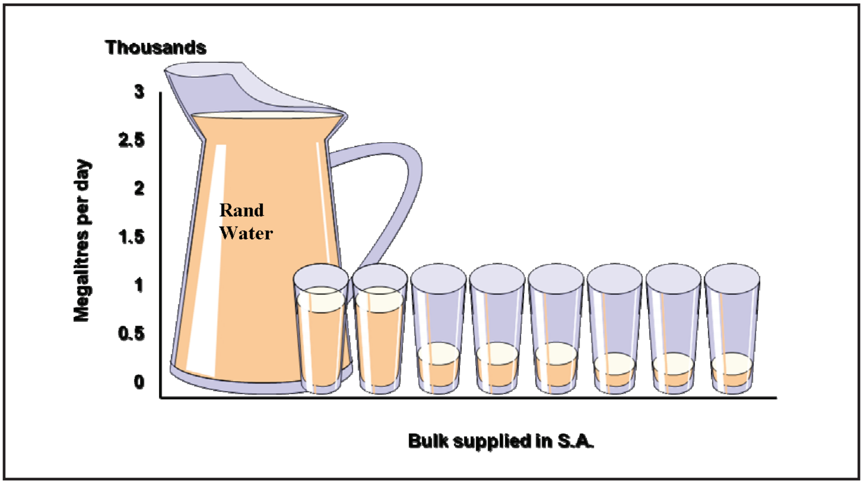

Figure 5. Amount of water supplied by Rand Water in relation to other bulk suppliers.

RESULTS FROM GAUTENG 1994/5 WATER RESTRICTIONS

The current restrictions (1994/95) for various municipalities (21 examples were obtained) in Gauteng were used as a basis for comparison in Table 2.

Unfortunately there was not much in common between the restrictions of the different local authorities. Some differences were however only very subtle, but the potential impacts were huge.

Results from Gauteng 1994–1995. Gauteng municipalities only had one level of water restriction introduced at a 30% water saving level.

Table 2. Gauteng-water restrictions traced.

Akasia	Kempton Park / Tembisa
Alberton	Krugersdorp
Benoni	Meyerton
Boksburg	Midrand
Eastern Vaal Metro	Northern Pretoria Metropolitan Substructure
Edenvale/Modderfontein Metropolitan substructure	Pretoria
Fochville	Randfontein
Gerniston	Southern Pretoria Metropolitan Substructure.
Heidelburg Town Council	Springs
Heidleberg	Westonaria
Johannesburg	
Johannesburg Transitional Metropolitan Council	

Table 3. Results from Gauteng 1994-1995 nurseries and garden centers.

Criteria of comparability* (Main criteria identified in the by-laws available) description	Total municipalities	Total with this restriction	Municipalities investigated % of total
Surcharges and offences	21	11	52
Period of restrictions	21	2	10
Residential gardens – watering hours and months	**21**	**21**	**100**
Garden hoses	21	13	62
Recreation facilities	21	19	90
Government and municipal parks/facilities	21	17	81
Bona fide nurseries	**21**	**14**	**67**
Bona fide landscapers	**21**	**19**	**90**
Free running water from municipal system	21	16	76
Toilet systems	21	18	86

Nurseries/Garden Centres (Table 3). Only 14 of the 21 local authorities (67%) mentioned restrictions for bona fide Nurseries. The number of hours that nurseries were allowed to irrigate, ranged from 14 h (three local authorities or 14%) to 168 h (one local authority or 5%) per week. When considering days to water, all 14 municipalities allowed watering for a total of seven days per week.

Water Restrictions by Local Authorities That Apply to Residential Gardens (Table 4). Of the total of 21 local authorities, 10 (48%) permitted residents to apply water for 2 days per week, 9 (43%) permitted 3 days watering, and 2 (10%) permitted watering for 7 days per week.

The inconsistency in this message between the highest and lowest, within one province, is huge (38%). Similarly, 29% of municipalities allowed only 2 h watering per dwelling per week, 29% allowed 3 h watering per week, compared to 9% of municipalities that allowed 48 h watering per week per dwelling.

Problems with the Gauteng Data. No consistent common thread can be found across the local authorities' restrictions.

Research Problems Encountered.

- Access to data was difficult.
- Current municipal staff employed know very little if anything about these 1994/95 restrictions.
- Very few staff who were contacted knew who could help or who to speak to for data.
- The author had more information dating back to 1995 than municipalities themselves.

Table 4. Water restrictions by local authorities that apply to residential gardens.

Criteria of comparability* (Main criteria identified in the by-laws available) description	Total municipalities	Total with this restriction	% of total municipalities investigated
Car washing and Commercial car wash facilities	21	21	100
Swimming pools – private	21	18	86
Use of buckets	**21**	**16**	**76**
Sprinklers and drip irrigation	**21**	**13**	**62**
General notice on using water sparingly	21	4	19
Leaking taps	21	7	33
Water use for pubic and residential gardens by religious groups	**21**	**4**	**19**
Mine dumps	21	1	5
Lawns	**21**	**5**	**24**
Paved areas	21	9	43
Boreholes	21	7	33
Water features	21	4	19

Current By-Laws. Currently the by-laws are being rewritten. They do refer to restricting water at the certain times; however no specific reference or addendum is available for drought, drought management plans or even water restrictions.

No reference as to how, when and what restrictions are to be introduced.

With this in mind Gauteng could end up going done the same path again.

RESULTS FROM INTERNATIONAL WATER DROUGHT RESPONSE PLANTS

Simultaneously to the analysis of the Gauteng restrictions, copies of water restrictions, from six available institutions in the U.S.A. and Australia were chosen.

The reason that these two countries were chosen was that:

- Climatic conditions are similar (in the broad sense).
- They are seen to be the leaders in the field of water conservation strategies.
- They have similar large water storage systems and piped bulk reticulation.
- Intermittent droughts are experienced.
- The green industry in those countries also experience a negative impact, during periods of drought, and
- A fair amount of information on water restrictions is available on the internet.

International examples chosen are found in the following:

U.S.A.	Australia
Poway, California	Sydney
Fort Collins, Colorado	Victoria
Arlington, Texas	South East Water Authority

The International restrictions considered had between 4 to 7 levels. To ensure common assessment, data, including the amount of anticipated water to be saved, some local authorities were collapsed into four levels.

The average maximum water saving being:

- Level 1: 7.9% (rounded to 8%)
- Level 2: 19.2% (rounded to 20%)
- Level 3: 31.1% (rounded to 30%)
- Level 4: 39.5% (rounded to 40%)

It is possible to observe a general trend of reduction in the average numbers of days and hours permitted to water as restrictions progress from Level 2 to Level 4 (Table 5).

Table 5. International residential watering hours compared.

Level	Days / week	Hours per week	Hours per day
1	3.1	36	5.14
2	3.5	41.67	5.95
3	1.71	15.33	2.19
4	0	0	0

Nurseries/Garden Centres and Landscaping Companies. No evidence was found to indicate that these categories of business are ever included in water restrictions/water shortage response plans.

Problems Experienced with the International Data.

- Interpretation of results was not easy.
- Terminology used was not same as that used in South Africa.
- Feedback to questions from international sources was slow and poor.
- Some examples had good detail while others not.
- Funding to engage these sources was limited to email and telephonic discussions.

RESULTS FROM SOUTH AFRICAN GREEN INDUSTRY SURVEY (2008).

As part of the research project Green Industry members were surveyed on various factors ranging from water use in 1994, to the affects of the 1994/95 drought, their water conservation habits, and the impact of the Rand Water's Water Wise campaign.

Some Key Aspects from This Green Industry Survey.

- Survey was conducted in 2008 (completed thesis in 2009)
- Participants were asked questions dating back to 1994/95.

- Respondents (65%) indicated that in some way they were affected by the 1994/95 drought.
  - The Green Industry sector responses were: SANA 51%, IERM 32%, LIA 14%, and SALI 13%.
- Only 19% of respondents thought that in 2008/09, the local authority had water restrictions in place (this is a greater percentage than what the author established).

Additional data received from the Industry is shown in Table 8.

- Only 35% of replies from industry indicated that they had not been affected by the drought at all.
- 58% responses indicated that RW was their bulk supplier, while 32% were not sure.
- Only 33% of supplies received assistance from Rand Water in 1994/5.
- Gardening magazines seem to be responsible for the most successful communication of the water conservation message (55%) followed by newspapers (50%) and radio adverts (45%).
- Fifty seven percent (57%) of respondents feel that The Water Wise® brand assists in the promoting of water conservation.
- Respondents indicated that they mostly make use of; training (27%) to raise awareness about water conservation, followed by displays (23%), newsletters (23%), and talks (23%).
- 94% felt that plants should be sold with instructions on the correct watering.

Problems with Green Industry Survey.

- The survey was possibly far too long.
- Many respondents did not complete the survey making their data invalid (and could not be used).
- Of the possible 776 names supplied by industry only 85 valid interviews were completed.
- The author tried to measure too many items in the survey.
- The questions were in themselves very complex.

COMPARISON DATA OF ALL THREE DATA SETS

Once the data from all three data sets was completed they were then analysed against each other. The data sets being; Gauteng 1994/95, International, and Survey of Green Industry 2008.

Each of the three data sets was given the same weighting.

A general trend of reduction on hours of water can be seen in watering of residential gardens, office parks, industrial parks, and all government and municipal grounds and facilities (excluding lawns) as one moves from Level 0 to Level 3 (Table 6).

The data from Watering of new landscapes, nurseries, and garden centres (bona fide) was possibly negatively impacted due to the fact that no international data was available and the 1994/95 restriction were only available in Level 3 (Table 7).

Table 6. Watering of residential gardens, office parks, industrial parks, all government and municipal grounds, and facilities (excluding lawns).

	Level	Mean h/day	Mean days/week	Mean h/week
Gauteng	0	n/a	n/a	n/a
International	0	5.14	3.10	15.94
Survey	0	4.46	3.49	15.57
Average comparative total	**0**	**4.80**	**3.30**	**15.75**
Gauteng	1	n/a	n/a	n/a
International	1	5.95	3.50	20.83
Survey	1	3.09	2.77	8.56
Average comparative total	**1**	**4.52**	**3.14**	**14.70**
Gauteng	2	2.86	1.19	3.40
International	2	2.19	1.71	3.74
Survey	2	2.65	2.36	6.25
Average comparative total	**2**	**2.57**	**1.75**	**4.47 l**
Gauteng	3	n/a	n/a	n/a
International	3	0.00	0.00	0.00
Survey	3	2.08	1.80	3.74
Average comparative total	**3**	**1.04**	**0.90**	**1.87**

PROPOSED NEW RESTRICTIONS

Because of the manner in which feedback was given in the survey it was concluded that it is not possible to draw a straight line distinction between the compared data above and the proposed restrictions. Other research factors have also been considered.

Recommendations for Rand Water Supply Area.

- There is a need to have four levels of restriction measures making up one response plan.
- The first level is for restrictions that need to be permanently implemented.
- Levels 1 to 3 are to be progressively introduced.

Amount of water that could be saved through introduction of each level of restriction as seen in Table 8.

Table 7. Watering of new landscapes, nurseries, and garden centres (Bona fide).

	Level	Mean h/day	Mean days/week	Mean h/week
Gauteng	0	n/a	n/a	n/a
International	0	n/a	n/a	n/a
Survey	0	3.80	4.85	18.42
Average comparative total	**0**	**1.90**	**2.43**	**9.21**
Gauteng	1	n/a	n/a	n/a
International	1	n/a	n/a	n/a
Survey	1	3.39	4.22	14.29
Average comparative total	**1**	**1.69**	**2.11**	**7.15**
Gauteng	2	3.46	7.00	24.21
International	2	n/a	n/a	n/a
Survey	2	2.57	3.82	9.81
Average comparative total	**2**	**2.01**	**3.61**	**11.34**
Gauteng	3	n/a	n/a	n/a
International	3	n/a	n/a	n/a
Survey	3	2.41	3.41	8.20
Average comparative total	**3**	**1.20**	**1.70**	**4.10**

Table 8. Amount of potential water to be saved.

Levels	Amount of potential water to be saved (%)
0	8
1	20
2	30
3	40

Level 0 (8% Water Saving Required).

- The following restrictions would be applicable to all levels (0 through to 3),
- Water restrictions must apply to all sources of water — municipal, as well as other sources, such as boreholes and dams.
- Users, who exceed the anticipated percentage of water saving, should pay a heavy fine.
- Users, who do not abide by the water restrictions, should pay heavy fines as determined by municipal structures.
- All surface runoff water must be captured on site and recycled.
- The use of water retention granules and wetting granules by landscape contractors must be enforced.
- Mechanisms such as moisture meters and rain sensors should be compulsory for automated irrigation systems.
- All new landscapes will be zoned into high, medium, and low water use zones.
- Plants must be sold with labels indicating which high, medium, and low water use plants are.
- The use of mulches in new landscapes should be compulsory.
- No watering should be allowed between the hours of 10h00 and 14h00 (October to February).
- The use of grey water is encouraged in the garden!
- In all cases where hosepipes are used, a trigger nozzle must be fitted.
- No washing down of paving.
- Although the watering of residential gardens, office parks, industrial parks, all government and municipal grounds and facilities, recreation facilities (private, commercial, government and local authority), lawns (Inclusive of residential, business, industrial and government), and watering of new landscapes, nurseries and garden centres (bona fide) was addressed in this section it was felt by the researcher that these restriction should not be applied at this stage at this level.

Level 1 (20% Water Saving Required).

- All general restrictions from Level 0 to apply.
- Hand held hosepipe should be used.
- Watering of residential gardens, office parks, industrial parks, all government & municipal grounds and facilities (excluding lawns), for 3 days per week for a total of 5 hours per day and no more than 15 h/week.
- Watering of recreation facilities (Private, commercial, government, and local authority), for 3 days/week for a total of 7 h/day and no more than 21 h/week. [This includes Bowling greens, playing surface/turf, golf course fairway, golf course green, golf course rough, cricket outfield, cricket pitch, athletics tracks/fields, horse racing tracks, tennis court (Grass).]
- Watering of lawns (Inclusive of residential, business, industrial, and government), for 3 days per week for a total of 5 h per day and no more than 15 h/week.

- Watering of new landscapes, nurseries, and garden centres (Bona fide), for 4 days/week for a total of 2 h/day and no more than 8 h/week.
- Use of watering systems (all nurseries, landscapes, lawn, recreation facilities) except for drip irrigation systems, are prohibited.
- Car washes and washing of cars to be restricted.
- Filling of new swimming pools to be restricted.
- Refilling of existing swimming pools to be restricted.
- Use of water features and fountains to be restricted.
- Use of watering systems (all nurseries, landscapes, lawn, recreation facilities) to be restricted, except for drip irrigation systems. (This restriction may best be suited at Level 2) .

Level 2 (30% Water Saving Required).

- All general restrictions from Level 0 to apply.
- Use of bucket and watering cans must be introduced.
- Environmental rehabilitation projects including mine dumps to be restricted.
- Watering of residential gardens, office parks, industrial parks, all government and municipal grounds and facilities (excluding lawns), for 3 days/week for a total of 2 h/day and no more than 6 h/week.
- Watering of recreation facilities (Private, commercial, government, and local authority), for 3 days/week for a total of 4 h/day and no more than 12 h/week.
- Watering of lawns (Inclusive of residential, business, industrial, and government), for 1 days per week for a total of 2 h/day and no more than 2 h/week.
- Watering of new landscapes, nurseries, and garden centres (bona fide), for 4 days/week for a total of 2 h/day and no more than 8 h/week.

Level 3 (40% Water Saving Required).

- Watering of residential gardens, office parks, industrial parks, all government and municipal grounds and facilities (excluding lawns), for 1 day/week for a total of 1 h/day and no more than 1 h/week.
- Watering of recreation facilities (private, commercial, government, and local authority), for 1 day per week for a total of 1 h/day and no more than 1 h/week. (This includes artificial turf)
- Watering of lawns (Inclusive of residential, business, industrial, and government), for 1 day/week for a total of 1 h/day and no more than 1 h/week.
- Watering of new landscapes, nurseries, and garden centres (Bona fide), for 2 days per week for a total of 1 h/day and no more than 2 h/week.

Water Restrictions Should Not Be Static. Water restrictions should not be seen as static, but rather as a flexible range that could move from Level 0, to Level 1, to Level 3, then back down to 2 and possibly even back up to Level 3 before rains come and it starts moving down to Level 0. The example of this can be seen in the City of Santa Fe (U.S.A.). Levels of restrictions should be variable depending on the available water in the system. They may also need to change on a year by year basis.

BENEFITS OF A SINGLE MANAGEMENT PLAN FOR THE RAND WATER SUPPLY AREA

- All stakeholders are able to buy-in up front.
- All stakeholders can be informed what is expected.
- All stakeholders know the measures to be implemented and the different levels.
- Customers receive one focused message.
- GIC & others are able to be proactive about their own industry.
- By doing this we as citizens are proactive in securing our future water resources.
- It will reduce existing confusion amongst municipal employees regarding what water restrictions are and how to impose them.

SOME CHALLENGES STILL TO BE ADDRESSED

- How the mindset of people in general will be changed with the introduction of the proposed restrictions?
- Policing of the steps especially those in Level 0.
- What mechanisms will be used to implement the system?
- Some of the recommendations for Level 0 may not be practical and could be changed/reduced.
- Currently the Department of Water Affairs only announce restrictions at 30% level and their "announcing" system will need to be adapted/ changed to accommodate this.
- How announcements are and will be made may also need to be addressed.
- A final Level 4 of zero watering may have to be imposed at some stage!

PROPOSED WAY FORWARD

I believe that what is produced provides a very sound basis to take that matter further in a manner that will benefit the Green Industry, Municipalities, Water Boards, Government and the environment that we live in.

This proposal:

- Has been presented to municipalities at RW forum and received a positive response.
- Currently I am busy addressing industry for additional buy-in.
- Once this is completed it will be taken to Local Government (Gauteng Legislature) for input and comments.

Thereafter it is proposed to take it to the Department of Water Affairs for further processing.

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Lean Production Basics: Implementing Lean Manufacturing Principles in a Bedding Plant Nursery©

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INTRODUCTION

Production Nurseries in South Africa face many problems. When times are tough, it becomes clear that these problems have to be addressed to continue running a profitable business.

Rising input costs, energy shortages, and poor demand impact the bottom line. We are in business to make a profit. Profit = sales price less costs.

The usual reaction to remain profitable is to cut costs. Purchase the cheapest raw materials, pay the lowest wages, and use less fertilizer, and so on. However, buying cheaper often means getting poor quality, and to stimulate sales, higher discounts are offered. This is a downward spiral, which over time is not sustainable.

Business owners and managers lose sight of what the biggest cost factors are:

- Production losses
- Over production
- Discounts
- Unproductive labour
- Poor inventory control, running out of raw materials or too high inventory levels
- Poor management, which contributes to costly inefficiencies

A better way to react is to FOCUS ON THE COSTS YOU CAN CONTROL and to become more efficient. We came across the story of Toyota and Lean Manufacturing Principles and realized that these principles can also be applied in a production nursery.

LEAN MANUFACTURING PRINCIPLES

These are sound and proven principles developed and applied by Toyota over many years. Extensive research has been done on the Toyota Production System and Lean Flow Principles. The Lean Enterprise Institute is actively promoting the implementation of this system and principles worldwide. See <www.lean.org> for more information.

What follows is an attempt to summarize these principles and tools and to encourage the reader to do more research and to discover how they can be implemented in his or her own situation.

The ultimate aim of applying Lean Manufacturing Principles is to eliminate all waste from a production system.

It is a production system based on three principles:

- Eliminate waste
- Make products and materials flow
- Base supply on customer demand

What Is Waste?

- It is any activity that consumes time, resources, or space and does not add any value to the product or service.
- It is all the unreasonable work that management imposes on people and machines because of poor planning and organization.

FOCUS ON THE PROCESS

The Toyota Production System focuses on the PROCESS. If the process is right, the result will be right. People use processes to make products.

A process is simply a set of actions that must be performed correctly in the right sequence at the proper time in order to create value for some customer.

Average people managing brilliant processes can achieve excellent results. Often brilliant people, forced to manage mediocre processes, fail and leave.

LEAN MANAGEMENT VERSUS TRADITIONAL MANAGEMENT

Lean Management.

- It is a system to make people think
- Line managers are process experts
- Go and see management, problems are solved at the point of value creation
- Learning by doing approach
- Employees are part of a continuous improvement process
- Focus is on processes to achieve results
- Avoid problems proactively by design
- Focus on managerial responsibility

Traditional Management.

- Management will think, employees will work
- Generalist managers with weak process knowledge
- Problems are solved far from the point of value creation
- Training is usually done away from the work place
- Planning and direction is top down
- Focus is on results only
- Problems are reworked when they happen
- Focus is on managerial authority

IMPLEMENTATION OF THE PRINCIPLES

There are various tools to implement these principles.

The 3 Ps of Lean Action:

- PROBLEMS
- PROCESSES
- PLANS

Define and solve the right PROBLEMS through reconfiguring the right PROCESSES by getting agreement and implementing the right PLANS.

Go and take a walk thorough your nursery. Take a camera along, look critical. You will be amazed at what you will see if you really look. It is usually not what you would expect!

Ask yourself:

- What keeps me as manager awake at night?
- What frustrates my staff most in trying to do their work?
- Is this the best way to do it or is there a better way?
- Does this flow?

Value Stream Maps and Process Flow Charts. Walk with a piece of paper and a pencil and draw a flow chart of every point where you create value. Go and look at each process, how things get done, and draw a process flow chart. By doing this many inefficiencies will become clear.

The Five S House Keeping System.

- Sort: Remove all unnecessary stuff from the work place
- Set in order: Organize the workplace
- Shine: Keep the workplace clean
- Standardise: All repetitive work, define the processes. Use visual communication and visual standards that are displayed where the work gets done to show how it should be done and what output is expected! Don't write long process descriptions that get filed and never read again! A better way is to use pictures and diagrams and make posters with Power Point.
- Sustain: Implement practices that maintain discipline.

Continuous Improvement. No problem is solved forever. No process is perfect. A system needs to be in place to avoid solving the same problems over and over again!

There is a scientific method to follow: PLAN – DO – CHECK – ACT.

Do the planning, design the process. Do the work, implement the process. Check the results, are they what you expected? Make changes and improve.

Achieve continuous improvement by involving employees to:

- Identify problems when they happen
- Make suggestions
- And rectify problems before you proceed to the next step

When a problem occurs the Lean Manager does the following:

- Go SEE: go to the work place and see what is happening
- Ask WHY 5 times: get to the root of the problem
- Show RESPECT by involving the employee to solve the problem. It is usually the process that fails and not the person.
- Manager as a COACH: don't blame the employee, check the process and coach the employee to do the process steps properly.

OUR FOCUS TO IMPROVE EFFICIENCIES

- Documenting work place procedures using visual communication.
- Train employees at the workplace on how to do the processes correctly.
- Teaching employees basic green technical know how.
- Applying the PLAN – DO – CHECK – ACT principle to keep improving.

Propagating *Pelargonium sidoides*©

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THE HISTORIC AND CURRENT USE OF *PELARGONIUM SIDOIDES*

Umckaloabo is the name under which the ethanol extract of *P. sidoides* root is marketed in Europe. It is clear that the origin of the name is, however, not European but originated from two autonomous Zulu words: umkhuhlane (Fever and cough related diseases) and uhlabo (pleurisy-related chest pain). Both words refer to the symptoms for which the Zulu healers used this plant since before time began (Kolodziej and Kayser, 1998).

Present use in Germany, more than South Africa is centred on the treatment of acute and chronic infections of the ear, throat, nose and respiratory tract. This product was available in Germany since the early '80s on shelves carrying herbal remedies.

The existence of this plant and its healing ability was however known to western science as early as 1897 when an English national named Stevens, afflicted by tuberculosis, was treated in South Africa with a traditional Zulu remedy. On his return to England, he started to market the product. It was available in England until 1909 when a legal dispute with the British Medical Association caused the removal of the product from the shelves (Kolodziej and Kayser, 1998).

THE MORPHOLOGY AND GROWTH HABIT OF *P. SIDOIDES* AND HOW THIS IMPACT ON PROPAGATION

The basic growth habit of this plant is semi-decumbent. It is herbaceous and the simple leaves, are arranges in rosette form on the squat aerial branches on which the internodes are not visible. The leaf placement appears crowded. The rather diminutive branches are covered with vestiges of the petioles and stipules of the previous season's growth. *Pelargonium sidoides* is a geophyte and has condensed underground, root like stems which are the main locus of the active ingredients that makes this plant so popular (Dreyer and Marais, 2000; Van der Walt and Vorster, 1988).

Most *Geraniaceae* have visible stipules. The stipules of *P. sidoides* are narrowly triangular with acute apices and a membranous appearance. The leaf base tends to wrap around the aerial stem and stay behind even after the leaf had died. The stipules stay behind with the leaf basis (Dreyer and Marais, 2000; Van der Walt and Vorster, 1988).

The inflorescence of *P. sidoides* is branched and has 2–4 pseudo umbels. They each carry somewhere between 3 and 16 flowers. The pedicel is about 3mm long. The flowers are present all year round. Flower production peak in summer (Dreyer and Marais, 2000; Van der Walt and Vorster, 1988).

CURRENT PROPAGATION TECHNIQUES AND THEIR LIMITATIONS

Pelargonium sidoides can be propagated from seed, stem cuttings, root cuttings and leaf cuttings. Each of these methods has strengths and limitations for large scale propagation (Table 1).

Though the seed germinate with ease, it is currently not the solution for large scale propagation. The availability of large quantities of seed is problematic since pollination outside if the natural habitat of the plant is nearly non-existent.

Manning and Goldbatt (1995) list 28 species of *Geraniacea* and *Iridaceae* that form part of a pollination guild of intensely purple and crimson flowers with long, slender perianth tubes pollinated exclusively by two long-tongued flies of the family *Nemestrinidae*. These flies forage for nectar while hovering and have mouth parts 20–50mm long. Given the length of the perianth tube of the flowers in this guild, their nectar is not available to bees, wasps and other flies, but only to the long proboscis flies.

Pelargonium sidoides is not one of the species listed in the guild, but it displays the same morphology as the other flowers in the guild. De Wet, Barker, and Peter (2006) also refers to pollination by long proboscis Nemestrinid flies in *P. reniforme*, a species very closely related to *P. sidoides*. This confirms the notion that the very low percentage of natural pollination in areas outside the natural habitat of this plant is the result of the absence of the natural pollinator and that bees and other potential pollinators are not interested because they are unable to reach the nectar. Pollination by hand is relatively simply and it has a high success rate. The main drawback is the cost associated with this time consuming and rather tedious task.

Table 1. Methods of propagation of *Pelargonium sidoides*.

Method	Strengths	Limitations
Seed	Easy germination	Limited supply, hand pollination
Stem cuttings	Reasonable availability	Tendency to rot as a result of short internodes
Root cuttings	Easy	Limited supply of roots
Leaf cuttings	Significant availability	Slow, need for stem tissue association
Tissue culture	Good success rate	Cost

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Better Modelling Your Irrigation System©

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INTRODUCTION

A national survey of nurseries belonging to the Nursery and Garden Industry Australia during 1999, covering subjects such as, average water use, water costs, maintenance costs and hand watering labour, determined that there was reform needed in the way in which we had been previously operating. These findings were despite the fact that the industry had entered into a program to better use a diminishing resource in the mid 80s. Subsequently, a series of new programs and workshops were created and then taken to the industry on a nationwide basis, the results have been pleasing.

The Australian state and federal governments continue to regulate each catchment so it is has become critical for nurseries to carry out regular water audits to ensure that they are able to supply information to the authorities on usage, run off and water sources.

How much do you know about your production irrigation system? There are a number of steps you can take to build a management tool that will help you better understand your particular circumstances. These include daily, weekly, monthly water use and diagnostic leaks. All this information can then be translated into a chart that will give you a picture of usage over a twelve-month period from which you can also calculate how much is water worth to your business.

As part of this process you also need to calculate which plants require most water; which plants require most frequent watering, which plants require the least amounts of water and then how you will meet these demands and will you, need a separate system?

An efficient irrigation system will save water and labour; maintain quality plants, reduce the volume of throwaways; produce plants faster and will save you money. Additionally, if you can collect and recycle runoff you could reduce your consumption by up to sixty percent. An efficient drainage and storage system can also collect and use rainfall which is cheap and high quality.

Many nurseries are surrounded by urban sprawl and those communities are becoming more aware of the quality of water that flows into catchments and ground water aquifers. You need to be in the driver's seat and regularly check the quality of your runoff. Don't wait for the authorities to close you down while you remedy the problem and probably give you a fine as well.

If you are using water from a mains water supply then you may be subject to restrictions based on daily timing, this is the mechanism most used to reduce consumption. Restricted watering times will have an impact on you without any reduction in water use if you don't change your irrigation practice. Therefore the knowledge that you build up regarding your plant water usage will give you a tool to better manage the amount of water you have available and hopefully save water under these circumstances. In addition, adequate staff training will be required to ensure they have the awareness needed to help you implement a new action plan.

A full system evaluation will be needed initially and then on a regular basis, to check pumping systems, filters, sprinkler/dripper performances and system hydraulics. While all of the components of an irrigation system are important, sprinkler and dripper performances are perhaps what will eventually need most attention, so measurements need to be taken from each block and recorded. The equipment required for this is quite simple and readily available, comprising a100 ml measuring cylinder, 250 ml beaker, a set of catch cans, a tape measure and a pressure gauge. Using these tools you can calculate the mean application rate (MAR) the coefficient of uniformity (CU) and the scheduling coefficient (SC).

Once you have all your information together it is advisable to recruit the help of an irrigation specialist who can check the hydraulics system, comment on the adequacy of pumps, piping and valves and make suggestions on nozzle selection to suit your different requirements.

Finally, if you are not already recycling your runoff water then this should become a priority after you have reworked your irrigation system. You will almost certainly need help with this as it entails ensuring that you minimise downstream pollution, that the drainage system matches the slope, soil and rainfall intensity and if it meet the regulations for your area.

Drainage storages require good management if you are to feel confident about recycling runoff through your irrigation system but they may require retreatment and certainly some type of aeration to ensure that the quality and particularly the disease status of the water is at least as good as or better than where you drew the water from in the first place.

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Potential Use of Transgenic Technology in Ornamental Crops for Commercial Use©

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Ornamental plants are produced mainly for their aesthetic value, thus the propagation and improvement of quality attributes such as flower colour, longevity, flower and leaf form, plant shape and the creation of novel variation are important economic goals for horticulturists. Also, the plant's resistance to environmental stress and pests and diseases are becoming an increasing concern for the propagation specialist and consumer. Therefore, the development of new quality products through genetic transformation breeding programs has become necessary to propose better suited taxa.

INTRODUCTION

Plants, especially food and fodder crops have been engineered with novel traits using genetic modification for many years now. Millions of hectares of plants carrying transgene for the insect resistant *Bacillus thuringiensis* endotoxin (Bt toxin) and herbicide resistant genes are being cultivated worldwide. However, the use of these technologies for development of novel ornamental flowers is still limited. In an industry driven by the evolving consumer interests in novel products, the possibilities offered by introduction of novel genes into plants are enormous.

As per latest reports, close to 150 million hectares of land in the world is occupied by genetically modified (GM) crops and this accounts for up to 7% of the total cultivated area. This figure is increasing every year as more and more countries start accepting the benefits of the technology and as farmers are convinced about their potential benefits. The major GM crops that are being cultivated today include food crops- maize and soybean; canola for oil and cotton as a non-food crop. U.S.A., Brazil, Argentina, India, and China account for the largest area of cultivated GM crops. The first commercial crops were planted in 1996 and by 2010 accumulated acreage has reached 1 billion hectares worldwide strongly indicating that biotech crops are the order for the future. A record 15.4 million farmers, in 29 countries, planted 148 million hectares (365 million acres) of GM crops in 2010 (James, 2010).

Ornamental horticulture is a global industry and covers cut flowers, potted ornamentals, turf, shrubs and ornamental trees. The ornamental horticulture industry has stayed away from the influences of commercial transgenic crop plants. This short review will look at the possibilities offered by the technology to the industry.

MAJOR ADVANTAGES OF GENETICALLY MODIFIED TECHNOLOGY IN NON-FOOD CROPS

Genetically modified technology can be used to precisely transfer gene(s) for the production of plants with specific traits. These traits can be for a variety of characters leading from novel visual traits like flower colour and longevity to non-visual but important characteristics like better tolerance against disease and stress. The application of GM technology will enable faster development of novel varieties as the time required will be considerably shortened compared to conventional breeding methods. Another major advantage is that unlike food and fodder crops where the end product is consumed, which demands for extensive regulatory steps, horticultural crops may be easier to commercialize. This also means a reduction in the costs involved in developing a variety as large amount of resources are needed for the extensive field trials and subsequent safety studies required of food crops.

SOME DISADVANTAGES OF THE TECHNOLOGY

The major disadvantages include the lack of acceptance of the technology in many spheres of society and the possible public backlash. However, as GM crops get more and more acceptable with the advent of favourable aspects like marker free GM technology. It may still be required to restrict growing areas to greenhouses and restricted fields to stop cross pollination to wild relatives. The costs of setting up such an infrastructure may restrict producers from venturing into the use of technology. However, it may be only required to add on to existing labs and greenhouses rather than constructing an overall new infrastructure.

REQUIREMENTS FOR DEVELOPMENT OF A SUCCESSFUL PRODUCT

The major requirements for developing and marketing a successful transgenic horticultural plant are many. A biotechnology laboratory established as per the required regulations are the primary requirement and this has to be complemented by a well established quick and reliable tissue culture method for the plant. Gene transfer enables the introduction of foreign genes, or specifically designed hybrid genes, into host plant genomes, thus creating novel varieties with specifically designed characters. For successful generation of good varieties, very efficient transformation methodology for each plant species is essential. The method should be able to produce large number of plants in the shortest possible time and depend on many factors such as the type of genome, regeneration rate and shoot regeneration capacity. An effective transformation methodology adapted to the established tissue culture technique will ensure that the technology can be applied with relative ease.

Selection of the right trait for transformation is of utmost importance. The trait in question should be very novel for e.g., a blue rose and not a white chrysanthemum. A blue rose is of high commercial value whereas a white chrysanthemum already exists in the market. Therefore sensible application of technology is called for the development trait. The genes which will be transferred will have to be well characterized and very effective for the desired trait. It is therefore always advisable to use a trait which will enable the novel plant to stand out from the rest of myriad plants of the same species currently in market. Proper and quick evaluation method for the desired trait followed by time bound field evaluation in compliance with regulatory requirements will ensure that the plants reach the market sooner.

CURRENT RESEARCH IN THE AREA

There was little interest by companies in this regard due to the previously mentioned reasons until Suntory in Japan and Florigene, Australia, collaborated to produce the first blue hued rose variety developed by transgenic technology. This has led to researchers pondering over the possible traits that can be introduced into horticultural crops. Table 1 summarizes some of the research that has been published. The list includes many potential traits like flower colour, fluorescence, reduced flowering time, longer lasting flowers, fungal resistance, viral resistance and herbicide resistance.

Table 1. List of some ornamental and other horticultural plants which have been employed in genetic modification studies

Plant	Gene/pathway transferred	Trait acquired	Reference
rose	Delphinidin pathway	Blue coloured flowers	Katsumoto et al., 2007
Eustoma (syn. *Lisianthus*), *Osteospermum*	Green fluorescent protein	Flourescent flowers	Mercuri et al., 2002
Eustoma	*LEAFY*	Reduced flowering time	Zaccai et al., 2001
Petunia	Ethylene biosynthesis blockage	Longevity of flowers	Huang and Lai, 2007
Eustoma	BEAT and LIS	Improved fragrance	Zaccai et al., 2001
Petunia	Endochitinase and osmotin	Botrytis resistance	Esposito et al., 1998
calla lilly	Ferredoxin	Erwinia resistance like protein	Yip et al., 2007
Phaelenopsis	Cymv coat protein	Cymbidium mosaic virus resistance	Liao et al., 2004
Petunia	Ace-AMP1 resistance	Botrytis	Bi et al., 1999
snapdragon	Bar	Herbicide resistance	Hoshino & Mii, 1998
zoysia grass	Gus	-	Ge et al., 2006
creeping bentgrass	Bar	Herbicide resistance	Luo et al., 2004

FUTURE PROSPECTS

There are numerous opportunities for the application of GM technology in non-food horticulture especially in the ornamental plants. This has to be explored by the producers to come out with novel and interesting products which the customers will find appealing. The selection of the right plants and traits can lead to a successful novel plant giving excellent returns to the producer. Although the product development may require some extra investment, this is always justified by the high priced end product.

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Plant Tissue Culture: Challenging Micro-Organisms©

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Plant tissue culture is aimed at propagation of plant material; this is done by growing plantlets under sterile conditions. The major problem is to get plant material to grow under sterile conditions. To achieve this stage one has two stumbling blocks; firstly the plant material needs to be surface sterilised to the extent that no contaminants will occur on the culture medium and secondly a culture medium needs to be found that encourages the plant material to grow!

For step one, various agents are used and they all have their advantages and disadvantages. The general principle is that the fungi and bacteria which are on, and sometimes in, the plant tissue are being killed, while the plant material itself stays alive. There are no strict rules for this treatment; it depends on the size and structure of the desired plant material.

Once the material is growing without any visible infecting agents, the propagating of the material can start. This requires finding a culture medium that will encourage side-shoot formation and at a later stage, root-induction. The plant material will be "fed" by supplying macro and micro elements, vitamins and sugars in the culture medium.

The final product from the laboratory will need to be hardened off; which means that the plant material, that we so carefully manipulated to become free of micro-organisms, needs to be introduced to these organisms again, while at the same time it needs to be "taught" to use its own roots and photosynthesis for growth.

INTRODUCTION

This presentation is aimed to give you a better understanding about the process they call plant tissue culture. In principle, the procedure is nothing else than taking cuttings of plant material and by doing so; increasing the amount of plant material. Mainstream tissue culture does not do anything with the product itself; what you put in, will come out.

In tissue culture there are four main problems:

1) To get the plant material clean enough to grow on culture medium
2) To figure out which type of culture medium the crop requires
3) To keep the plant material free of fungi and bacteria during this process
4) To get the plant back from the tube into the soil

Firstly, before anything else, one needs to realise that, in theory, one single plant cell will be able to produce a complete plant structure. Failing to have a plant, or cutting, to respond in the anticipated way is basically our ignorance, not the plant's fault! However, since sometimes we are not able to figure out the plant's requirements, we cannot propagate that plant material.

TO GET THE PLANT MATERIAL CLEAN ENOUGH TO GROW ON CULTURE MEDIUM

The principle of tissue culture is very simple; get plant material, surface sterilise that plant material, propagate and multiply the material, get it to form roots and deliver it to the nursery.

However the first problem at this stage is to figure out what the correct plant tissue for the so-called initiation will be. Basically we are trying to get a growth-point transferred from the plant into a tube. This growth point will simply grow out again, this time under sterile conditions.

Another problem is how to get the product delivered to the laboratory when the complete plant structure cannot be made available, e.g., the material is overseas or a shrub that is planted out in the soil. The packing is essential for the end product. The difference between damp, moist and wet might have a huge impact on the final results. Placing all the cuttings in water and letting the material absorb the liquid (including bacteria!) will often cause all the material to become unsuccessful at initiation.

Lastly a major problem is the time frame. Sending plant material just before a weekend or public holiday will obviously cause a delay. However, many nurseries only "get around" to cutting the material towards the end of the week, expecting the laboratory to simply do it.

The next step is to surface sterilise the plant tissue. There are many options that we have for this procedure. Most commonly used are alcohol, peroxide and chlorine. However, sometimes a household detergent supplies the right combination of chemicals as well. In this process the type of plant tissue determines the concentration and the time period that the tissue is exposed to the solution. One can understand that a woody stem of a tree requires a more harsh treatment than the soft tissue of plants like for example *Agapanthus*. Particularly difficult are the plants where the growth point is underground. This subjects the growth point to a constant infection pressure and makes it is much harder to get it "cleaned up" as often organisms live around the growth point.

Once this procedure is finished the plant tissue is free of any immediate visible infectants, but please note that viruses, fungi and bacteria in low concentrations and the so-called endophytes could still be present in the material.

Viruses could be eliminated through an intensive tissue culture procedure; however this involves lifting the growth point out of the tissue and subsequently culturing it into a plant again. Viral testing must be done to check if the virus has been eliminated. This method is very costly and commercially only applied on high-value crops.

Fungi and bacteria in low concentrations; the tissue might look clean, but over time the build up of the pathogens will cause a visible infection and the cultures are lost.

Endophytes are organisms, mainly bacteria, that happily and harmlessly live in the cells of plant material. Since the do not cause any symptoms, they can only be detected through intensive research. Unfortunately, it has been known that stress sometimes can change these harmless organisms to pathogens. In tissue culture the step from multiplication, using cytokinins as hormones, to root-induction, using auxins as hormones, is such a major stress factor. Often at this stage a whole culture "turns up infected."

TO FIGURE OUT WHICH TYPE OF CULTURE MEDIUM THE CROP REQUIRES

The multiplication of the plant material is the "easiest" step. When we finally ended up with one or two visibly clean shoots, we place these shoots on the culture medium. In our laboratory we stay clear of using callus in any form. Callus, being an undifferentiated mass of cells, can grow back into a complete plant; however there is a significant chance of getting a minor or major change in the plant material through that phase. Hence our preference to avoid callus and use a normal growth point as the start of our cultures.

"Luckily" for the tissue culture laboratory there are many variables that we can work with:

1) The type and concentration of our culture medium including: macro elements, micro elements, vitamins, hormones, sugars, and agars
2) The pH of the culture medium
3) The temperature at which the culture is grown
4) The light intensity and day length of the cultivation light

Having listed all the options again, it makes one wonder how we ever manage to cultivate anything at all! Luckily we do find combinations that work and over time we are able to fine-tune the composition and improve on the appearance of the final product. Although our environment of cultivation is highly controlled, there are so many options that we can forever improve on our methods and our products.

In some instances it takes us quite a while to figure out the requirements of a crop and the speedy production that was anticipated does not materialize. One of the major disappointments for our customers is the realisation that it usually takes 1 to 1 $^1/_2$ year from initiation to final product.

TO KEEP THE PLANT MATERIAL FREE OF FUNGI AND BACTERIA DURING THIS PROCESS

Once the product is clean and multiplying, the propagation is done by cutting the plant material under sterile conditions. Having a good discipline in the work areas will reduce the chance of infection during this process. Over the years we have found that the operators need to understand the concept of sterility before being able to work adequately. We found that the laminar flow-bench itself provides everything one requires to keep the cultures sterile and in our setting we stay clear of "confusing" items as hairnets and latex gloves.

In our opinion, the staff is not supposed to bring their heads into the flow bench, and we prefer to have that problem sorted out (often by sending the staff member to the optician!) than fighting the symptoms by providing hairnets. Also the use of latex gloves creates the impression that the staff member's hands are sterile, which in fact they are not! All the measurements create a false sense of security, while making the person who needs to wear them quite uncomfortable.

TO GET THE PLANT BACK FROM THE TUBE INTO THE SOIL

The finished product for the laboratory is a small rooted plant that resembles a seedling of that crop. This plant has been "spoiled" and although it has formed roots, our opinion is that these are hormonally induced and not really functioning as roots yet. Also the stomata have not been "taught" how to operate properly as inside the tubes, the plants are in a very high relative humidity. Lastly, the photosynthesis process has not yet been operation, supplying the plant with a lot of sugar in the culture medium has made the material "lazy" and quite inactive. Except for growth that is!

Now that the plant is taken out of its sterile and optimal environment, it needs to adjust to the harsh condition outside. This transfer is often a bottle neck in the process. While trying to cope with the reality of feeding itself and regulating their stomata and root system, the plants are also exposed to various fungi and bacteria. As soon as they are touched by human hands, the first "load" of organisms is re-introduced to the plants. Most of them quite harmless, but some might be very harmful. The common damping off fungi; *Fusarium*, *Pythium,* and *Rhizoctonia*, can cause major losses in the cultivation of the tissue culture products.

At this stage it is important that the optimal combination of growth medium, moisture, temperature and light is found and seeing that the plants come from a completely different environment, the requirements for the plant material change rapidly during the first few days out of the flask! In the first few weeks outside the laboratory these "babies" require a lot of attention!

CONCLUSION

In theory it is possible to cultivate all plant species in tissue culture, however it is often not economical to do so. And, of course, sometimes we are still not capable of figuring out the requirements of a product! In overcoming all the obstacles that we described above, we found that experience improves the chance of success.

The process of tissue culture is often described as quick and easy, but although that sometimes is true, there are more problems than solutions and this will keep us entertained for years to come.

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Collecting and Storing Rare Seeds©

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INTRODUCTION

Western Australia possesses a rich and diverse flora comprising over 12,000 native taxa (Western Australian Herbarium, 2010) with most species (60%) being endemic to the state. The south-west region of the state is the most diverse, containing over 7,000 plant species, of which half are endemic to the region (Hopper and Gioia, 2004).

Associated with this species richness is a high number of rare, threatened, and poorly known species; currently Western Australia has 3,100 taxa listed as rare, threatened, or poorly known, with a further 13 taxa presumed to be extinct (Smith, 2010). Of these conservation taxa, 406 are protected under the state legislation and are referred to as Declared Rare Flora (DRF). The remaining taxa are known as Priority Flora. These are taxa that are poorly known and in need of further survey to ascertain their conservation status. The high numbers of threatened species, more than for other Australian States and most countries (Hopper and Gioia, 2004), in combination with high species endemism, has resulted in the southwestern botanical region being listed as one of the world's 34 biodiversity hotspots (Mittermeiser et al., 2004). A biodiversity hotspot is defined as an area containing at least 1,500 endemic plant species but also having lost at least 70% of its original habitat (Mittermeiser et al., 2004).

The Department of Environment and Conservation (DEC) is the authority responsible for managing Western Australia's flora, including its threatened flora. In order to reduce loss of genetic diversity a range of recovery actions are undertaken. These actions can range from fencing and weed control (Cochrane, 2004) through to species reintroductions (Monks and Coates, 2002), but importantly integrate in situ management with ex situ conservation. Whilst conservation of plants in situ is always the main priority, seed collection and the long term storage of this material ex situ is an important and complementary component of this strategy.

In 1992 DEC established an ex situ seed storage facility, The Threatened Flora Seed Centre (TFSC), with the primary purpose of conserving seeds of WA's conservation significant plants for use in species recovery. In 2001 DEC joined with the Royal Botanic Gardens, Kew (U.K.) in an international seed conservation partnership, The Millennium Seed Bank Project (MSBP). This project aimed to conserve 10% of the world's dryland flora, as seed, by 2010. Prior to this there were few long-term conservation seed banks in Australia, whilst now there is a facility in every State and mainland Territory.

The TFSC has always aimed to use "best practice" for the collection and storage of seeds and these practices are now reflected in the germplasm conservation guidelines for Australia (Offord and Meagher, 2009). A good quality seed collection is made up of a number of components. These include: a known plant identity; good collection data; a genetically representative sample; and viable seed that is stored under conditions that aim to maximize longevity. In all cases the collection should be made in a way which doesn't adversely impact on the source population.

A good description of the target species is essential to ensure that the correct species is collected, hence avoiding a waste of time, effort, and resources. It is also important to ensure that a herbarium voucher specimen is taken and lodged at the relevant state herbarium. This not only verifies the identity of the collected species but also "future proofs" this identity. If taxonomic changes take place then these can be tracked via the specimen to the seed collection. Good collection data is crucial to a good seed collection. Plant descriptions aid in identification, whilst site descriptions and location details pinpoint the place of collection and can aid in the selection of future reintroduction sites. Details about the number of known plants and the number of plants sampled in the source population give an indication of the genetic quality of a collection with respect to the proportion of plants sampled from the population.

Genetic diversity within a seed collection forms the building blocks for the successful utilization of seeds for establishment of new populations in the wild. The current sampling strategy used by the TFSC aims to capture a large proportion of the genetic diversity found within a population. In order to achieve this goal at least 30 individuals of an outbreeding species or 59 individuals of an inbreeding species should be sampled (Brown and Marshall, 1995). Where the breeding system is unknown a target of at least 50 plants is used (Guerrant et al., 2004). The plants sampled should be chosen at random from across the population taking into account any variation in ecotypes that may occur. The diversity across populations is also sampled with the aim of sampling all populations of DRF.

In order to conserve the species from which we are collecting seeds, we need to make sure that our collecting activities don't have a negative impact on natural populations. To avoid over collection no more than 20% of available seed should be harvested. The harvest should be conducted in a way which minimises impact to plants. Care should be taken when accessing a site to ensure weeds or diseases are not introduced to the population (Cochrane et al., 2009).

If a seed collection is to be of conservation value it needs to be viable when required for use. The most reliable method of determining seed viability is by a germination test under controlled conditions. If seeds germinate they are clearly viable, however if they do not they may be nonviable or dormant. This can lead to underestimation of the true viability of a collection; however it is a good reflection of how many seedlings we can produce based on our knowledge at a point in time.

The two main factors that will affect the longevity of seeds are temperature and seed moisture content. Seeds are stored at the TFSC according to internationally accepted standards for seed conservation (FAO/IPGRI, 1994); seeds are dried to a low moisture content (ca. 3%–7%) then frozen at -20 °C. Under these conditions orthodox seeds, that is seeds that can be dried to low moisture content without loss of viability (Roberts, 1973), should hopefully remain viable for decades, if not hundreds of years. Germination re-tests are conducted periodically to check that the viability of collections is being maintained. A review of the retest data from 375 seed collections from the TFSC found that declines in germination were evident in only a small number of collections. Many of the declines appear to be collection-specific, as other collections of the same taxon did not decline (Crawford et al., 2007).

So how successful has DEC's seed conservation program been? One measure of success is a target adopted by countries around the world as part of the Convention on Biological Diversity's Global Strategy for Plant Conservation (2002). Target 8 of this strategy was to have seeds of 60% of threatened plant species in accessible ex situ collections, preferably in the country of origin and 10% of them included in recovery and restoration programmes by 2010. The Department of Environment and Conservation has successfully met this seed collection and reintroduction target for Western Australia. To date, seed samples from 75% (293 taxa) of WA's extant DRF and 26% (708 taxa) of the Priority taxa have been collected and stored. These collections are often referred to as insurance policies against extinction in the wild (Offord and Meagher, 2009) however in order to claim on this insurance policy we need to be able to successfully re-establish plants back into the wild from our stored collections, a sometimes difficult process (Cochrane et al., 2007).

The DEC has an extensive flora reintroduction program which aims to improve the conservation status of endangered species. These reintroductions are carried out to complement the conservation of existing populations, not to mitigate actions that may affect the populations. The Department currently has 46 species in seed-based reintroductions. There are many challenges associated with reintroducing species back into the wild, but these reintroductions have resulted in significant increases in the number of plants for many of these threatened species (Cochrane et al., 2007). For example, the critically endangered *Grevillea batrachioides* is known from only one natural population of 56 plants, but reintroduction of 94 plants has effectively trebled the known number of plants in the wild.

Ex situ seed conservation aims to conserve high quality, genetically representative samples of conservation-significant species for future use. By adhering to good collection and storage protocols the TFSC has underpinned one of Australia's most ambitious flora reintroduction programmes. This program has resulted in significant improvements in wild plant numbers, a true measure of the value of ex situ seed conservation.

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Collecting and Propagating Local Provenance Plants©

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INTRODUCTION

Increasingly, local provenance plants are being requested to be used in local remnant restoration projects. This presentation will focus on what we as a nursery see as our contribution to the best possible outcome for restoration projects, the supply of an increasing number of species sourced from local provenance material.

LOCAL PROVENANCE

Local provenance plants are desirable as it is likely that locally adapted populations will have a higher survival and reproduction rate in their local environment than plants from the same species sourced from further away. Hereford (2009) reviewed many papers looking at local adaptation and showed that on average, plants from a local area will have approximately 1.5 times greater survival and reproduction compared to foreign populations of the same species grown at the same location.

Secondly the use of local provenance plants conserves local genetic diversity and reduces the risk of genetic pollution. The risk being that hybridisation between local and nonlocal types may reduce survival and reproduction in future generations (Hufford and Mazer, 2003).

Defining just how local is local enough is strongly debated. Often geographical proximity is suggested with various distances from a restoration site being advocated (e.g., Krauss and Koch, 2004). However, geographic proximity is unlikely to be suitable in all cases as we observe significant changes in vegetation over very small distances on the Swan Coastal Plain, most often associated with the soil type and topography.

Florabank <www.florabank.org.au/> recommends that provenance be considered in the following manner when collecting seed for revegetation and I think this applies equally well regardless of what propagation material is being collected.

1) Get the taxonomy right first.
2) Get the physical and genetic quality right.
3) Only collect from large populations or pool multiple collections from smaller populations.
4) Store seed under best conditions from collection right through to use.
5) Match the site conditions.

COLLECTING PROVENANCE PROPAGATING MATERIAL

In the majority of cases we like to collect propagation material from the actual remnant site or from other nearby sites containing the same species and site conditions. We aim to collect from healthy, vigorous populations containing a significantly large population size to avoid potential inbreeding problems that may occur in some remnants.

We produce local provenance plants from seed, cuttings, or divisions collected from wild populations. In Western Australia, this requires two separate licences from the Department of Environment and Conservation (DEC), one to collect from private property and other to collect from Crown land. These licenses require the land owners or managers permission and returns for all material taken must be submitted quarterly to the DEC.

Seedlings. Raising plants from seeds is often the cheapest and most efficient way and is very successful for many of the most widely used plants in restoration including *Acacia*, *Eucalyptus*, *Melaleuca*, *Banksia*, *Hakea,* etc. Locating, collecting, extracting, cleaning, treating, and germinating seed from the diverse range of plants that occur in our area [southwest Western Australia (WA)] ranges from being relatively straight forward through to having one or more of these steps being totally limiting.

One of the biggest challenges is to produce plants of suitable size on time. We have a very small window for restoration planting in WA, when it rains the plants have to be ready to go. However, by the time some seed are ripe for collecting it is too late to grow them to sufficient size for planting. So, for these species seed from the previous season needs to be sown early to ensure it is ready for planting. For example, *Ancanthocarpus priesii* requires months of warm stratification to germinate and thus seed collected in the current season would never be ready in time.

The actual amount of seed we require is relatively small so it is much better for us to collect and store seed when it is available. We find it most important to record locations and timing of seed collection as it can be incredibly frustrating to find seed too immature to collect on one trip and then shed on your next trip.

There is no doubt that this is more expensive and difficult than just buying seed of unknown provenance and that the increased cost must be passed on to the client.

Many of the seed collected require elaborate extraction and germination pretreatments before sowing and for many species some trial and error is required before a suitable method is established. We also find that the temperature over summer in our nursery (when we need to germinate the seed) is too hot for many species to germinate consistently and an incubator set at 15 °C is required for best results.

Cuttings. We also grow a lot of plants for restoration by cuttings. In most cases this is from wild collected material however stock plants from some species from various provenances have been established in our nursery where continual collection from the wild is unfeasible.

Most of the cutting collection that we do is for species which are difficult or inconsistent from seed. These include *Myoporum*, *Eremophila*, *Grevillea*, *Hemiandra*, *Pimelea*, *Leucophyta*, *Hibbertia*, *Atriplex*, *Carpobrotus*, and *Spinifex*. As with seed collecting it is our aim to collect some cuttings from as large as number of plants as possible, always looking for the healthiest individuals and rejecting anything with signs of pests or disease.

Collecting cuttings has the advantage over collecting seed of being available when we need it (over summer), however has the disadvantage of having to be carefully handled especially as we are often collecting it at the hottest time of the year in Perth. We collect as early as we can in the morning, filling foam boxes lined with wet newspaper with the cuttings and getting them back to the nursery before the heat of the day sets in. We find cuttings collected in this manner and stored wrapped in damp newspaper can last well in a fridge up to weeks if required.

As the cuttings are wild collected, extra care and attention is paid to any signs of pest or disease when processing and any suspect material is rejected. Cutting material should then be washed and surface sterilised prior to treating as per normal cutting propagation.

Divisions. For some monocots, no reliable method of seedling production is currently available and for these species division is the best bet. We have used this method to propagate many species otherwise considered difficult including species of *Lepidosperma*, *Hypolaena*, *Lomandra*, *Dianella*, *Agrostocrinum*, *Machaerina* (syn. *Baumea*), and *Schoenus*.

This is a long-term project and plants are not generally available for several years. The ideal situation is to get some provenance-correct seed to germinate. We find that if we sow enough seed and wait long enough (well over a year sometimes) we can raise some seedlings. Vigorous individuals are then selected as stock for future divisions.

These juvenile plants can be manipulated in pots to multiply and regular divisions can lead to a bulking of material over time, similar to multiplying plant shoots as done in tissue culture. This is a relatively slow process to begin with and it may be years before numbers are high enough to begin to sell plants. Then, of course a proportion must be kept each year to ensure stock for the following year.

Another method we have used although I prefer not to, is to initiate wild-collected rhizomes into pots. We have successfully done this with five species of *Lepidosperma* (*L. gladiatum*, *L. longitudinale*, *L. squamatum*, *L. angustatum*, and *L. gibsonii*) and with species of *Machaerina* and *Schoenus*. Although this can be quite successful for some species there are several reasons why it is not recommended. Firstly it can be a lot of hard work retrieving wild rhizomes in the first place especially *L. gladiatum*. Then there is the possibility of damaging both the plant you are collecting from and other surrounding plants, with the disturbance you are causing damaging what may already be a fragile remnant. Finally there is the possibility of spreading soil-bourn pest or disease.

We have developed a protocol which we believe addresses these concerns but should only be used after it is determined that obtaining seed-raised stock plants is not possible. Our method involves firstly only collecting from sites believed to be free of *Phytophthora*. Secondly new actively growing rhizomes are targeted and cut from the adult plant with a minimum amount of soil disturbance. If done correctly these are similar to a rooted cutting. All soil is washed from collected rhizomes on site and then treated as if cuttings for the purposes of transport.

Back at the nursery, any old leaves and roots are removed and new leaves are trimmed. The rhizomes are then completely submerged in disinfectant before being rinsed and planted. Surviving plants can then be divided in subsequent years.

CONCLUSIONS

Regardless of the method of propagation, all plants to be planted in restoration projects being sold by our nursery are treated with the highest degree of hygiene. By following the nursery accreditation guidelines we are doing our utmost to ensure that we are not adding to the problems of our remnant vegetation by introducing weeds or any other pests or diseases. By supplying provenance-correct plants we are increasing the likelihood that they will survive and reproduce in the remnant and not contribute to potential genetic pollution in future generations.

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The Checklist of Australian Native Plant Cultivars©

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INTRODUCTION

The Australian Cultivar Registration Authority (ACRA) was established by the International Commission for the Nomenclature of Cultivated Plants (ICNCP) in 1962, to register and record the names and descriptions of Australian native plant cultivars. Over the years ACRA has registered over 400 cultivars thereby playing a major role in the preservation of their identity and history. However, these represent a very small proportion of the cultivars for which there are published names and descriptions.

The idea of having a single website which could be used to research Australian native plant cultivar names and descriptions has, until now, been a pipe dream. The Checklist of Australian Plant Cultivars Project aims to address this need.

BACKGROUND HISTORY OF ACRA

When the Society for Growing Australian Plants (SGAP, now called the Australian Native Plants Society Australia, ANPSA) was formed in the late 1950s, it seemed only natural that the Society should have a role in the registration of the cultivars of Australian native plants (Walter, 2007).

Correspondence was initiated by the publication branch of the newly formed SGAP with the Royal Horticultural Society in England, between 1959 and 1962.

In February 1962, the South East Region of SGAP accepted an offer from the 'International Commission for the Nomenclature of Cultivated Plants (ICNCP) to undertake the registrations of cultivars of genera endemic to Australia, and to act as the national registration authority, in conjunction with the National Herbarium (in Melbourne) (Brickell et al., 2004).

Initially the new ACRA committee had two members from the National Herbarium (with Jim Willis as Chairman) and two representing SGAP. Over the years, the ACRA committee has been significantly expanded, and it now includes representatives of most major Australian Botanic Gardens, ANPSA, and the nursery industry.

Since 1973, staff of the Australian National Botanic Gardens (ANBG) have filled the roles of Registrar and Secretary of ACRA (on a part-time basis), and the ANBG has also provided office space, storage of herbarium specimens, database and administrative functions, and in more recent years a website at <http://www.anbg.gov.au/acra>.

SO WHAT IS A CULTIVAR?

A cultivar is a plant that has been selected for a particular character (or combination of characters) that is clearly distinct, uniform, stable in these characters, and when propagated by appropriate means retains these characters.

THE ROLE OF ACRA

Over the years ACRA has performed three major functions in regard to the cultivars of Australian plants:

1) A registration function
2) The recording of published names
3) An advisory role for plant breeders rights applications

Cultivar Registrations. The registration process creates a comprehensive description of each cultivar. This description can then be used to identify the cultivar and compare it with others.

The description of the cultivar records:

- The parentage (if known)
- History of the cultivar
- The derivation of meaning of the cultivar name or epithet
- The names of the raiser or breeder, nominant and introducer (when known)
- Indicates one or more recognizable attributes or characters
- Indicates how the cultivar differs from similar cultivars
- Records the colour codes for leaves and flowers (from the Royal Horticultural Society colour charts)
- Includes a photo or photos

The ACRA description also includes cultivation and propagation information.

The guidelines for registering cultivars are recorded in the *International Code of Nomenclature for Cultivated Plants* (2004), often shortened to the *Cultivated Plant Code,* and have been adopted by ACRA for all cultivars of Australian plants.

To date ACRA has registered over 400 cultivars with full descriptions and these can be found at <www.anbg.gov.au/acra/acra-list-2009.html>. Many of these cultivars represent a documentary history of the Australian Plants Society and its role in developing Australian plants. For example, many of the Poorinda hybrids bred by Leo Hodge in the 1960s and 1970s have been registered or recorded with ACRA.

Although by no means comprehensive, the descriptions on the ACRA website provide a reference point for the horticultural industry and the public alike.

Recording of Names. In 1962, the newly formed ACRA committee sent letters to nurseries and members of the nursery industry and horticultural societies throughout Australia asking for lists of names of known cultivars. Gradually over time, lists of names of cultivars were compiled, and eventually a card system was developed to record all the information gathered.

Plant Breeders Rights. As an authority on the cultivars of Australian plants, the ACRA committee plays a significant role in the assessment of Plant Breeders Rights (PBR) applications and provides advice on:

- Identification.
- Novelty.
- Distinctiveness.

The ACRA committee also comments on the comparators used to distinguish new cultivars and suggests additional potential comparators. It also processes and stores herbarium specimens of PBR cultivars in the Australian National Herbarium.

THE CHECKLIST OF AUSTRALIAN PLANT CULTIVARS PROJECT

The primary purpose of the Checklist of Australian Plant Cultivars project is to bring all the published names and descriptions of Australia's native plant cultivars together in one website location within the searchable database the Australian Plant Name Index (APNI) <http://www.anbg.gov.au/cgi-bin/apni>.

APNI is a tool for the botanical community which deals with plant names and their usage in scientific literature, whether as a current name or synonym. The information available from APNI includes scientific and cultivar names, author details, original publication details (protologue), and links to other information such as plant distributions, descriptions, and images (where available). APNI does not recommend any particular taxonomy or nomenclature.

The Checklist Project will involve a thorough search of all known publications featuring articles about Australian plants and the information gathered will include:

- All cultivar names.
- Publication references.
- A link to a pdf file of the protologue (first published description).
- A photo of the cultivar if possible.

Progress Report. The project has been funded by donations from ANPS groups and matching sponsorship by Horticulture Australia Ltd. Funding has been sufficient to employ a person (on a part-time basis) for 1 year from November 2009, to carry out the research and data entry work. The project is now at the half-way point, and there are over 4,300 cultivar names recorded in APNI and all the PBR journals have been processed.

CONCLUSION

As a result of this project, all Australians will have a "one-stop-shop" on the web for comprehensive information on all the cultivars of Australian plants. The website "publication" of these descriptions and names will promote uniformity, accuracy, and stability in the horticultural industry and significantly increase the knowledge and understanding of Australia's cultivated varieties.

The substantial financial support provided by ANPS groups throughout Australia and Horticulture Australia has been instrumental in getting this project off the ground.

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Conflicting Names: What Do You Do When Your Plant Has Alternative Names?

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INTRODUCTION

We have to remember that a major reason for plant names — nomenclature — is to assist communication. The way plants are arranged or classified is taxonomy, and the names help to exchange information about both individual plants and the way they are classified. A scientific name (plant or animal) means the same thing anywhere in the world.

I am talking about what to do when the plant you are dealing with has more than one name, not new discoveries. And I am talking about the scientific names, not the common or vernacular names which are not governed by any rules and so can be used in whatever way you wish.

Because time is short, I'll talk only about changes due to research and the application of the *International Code of Botanical Nomenclature* (the *Code*) (McNeill et al., 2006). The *Code* has been developed as an international "standard" over some 150 years. Essentially, it sets down rules for publishing scientific names. It is reviewed at an International Botanical Congress every 6 years when changes may be made, but the essential rules remain constant.

Right at the start, I wish to point out that there is no obligation to follow a name change simply because it is the latest word, or because organisations such as herbaria have adopted it. Under the *Code* and the *International Code for the Nomenclature of Cultivated Plants* (Brickell et al., 2004), scientific names of plants are available for use if they meet certain criteria, but these *Codes* give no further direction on how to choose which name to use, if a plant has more than one available name. So, how do you decide?

The problem is not new. Our current system of binomial nomenclature was devised by Carl Linnaeus, and for flowering plants it dates from 1753. Very soon afterwards, botanists began to change the names of already-published names. Linnaeus himself made changes by transferring some of his own species from one genus to another, an example being the widespread tropical paperbark *Melaleuca leucadendra* which he first published in the genus *Myrtus*. There are many reasons for changing names.

What happens is that a new species is described. In many cases, a new species is based on one or few specimens. As time goes by, more specimens may be collected, usually over a wider geographical range. Sometimes they indeed represent the same species, but quite often there is seen to be variation among these specimens. For a while they are still called by their original name, but at some stage a botanist studies them closely and decides that in fact there is more than one species in the complex. The original name is restricted to a subset, and distinct variants — that you have known by that name — are named as new species. In Australia, this has been a rather common situation since we have a very large flora and too few botanists to keep up with the research required. A good example is the honey myrtle

M. uncinata, named by Robert Brown in 1812 from specimens that he collected on Eyre Peninsula in South Australia in 1802. The name was used for this and look-alike plants from all Australian mainland States and the Northern Territory, until it was studied by a small team of botanists who divided it into eleven species (Craven et al., 2004).

I should point out that a properly or validly published scientific name is always linked to a specimen of the plant, usually a pressed specimen. It's called a "type specimen." However the species is classified later, whether in its original genus or in another, or as a species or subspecies, its name remains linked to the type specimen, so the same name can never be used for another plant.

Refinement of the taxonomy can lead to new circumscription of named species, usually in conjunction with description of new ones. In my own work, examples have been the *sphaerocarpa* group of *Banksia*. Or it can lead to plants previously known as species being redefined as subspecies or varieties. Again, an example from my own work is the placement of *Calothamnus homalophyllus* and *C. asper* as subspecies within *C. quadrifidus*.

New data, new insights or new discoveries can lead to re-definition of a genus in such a way that one or more species within it must be moved to another, or species in another genus must be moved to it. Large changes of this kind have been made by Paul Wilson, who realised that the Australian species of genera such as *Bassia* and *Helichrysum* were distinct enough from the original species in those genera (which grew outside Australia) that they had to be placed in other genera. So, our bassias became *Sclerolaena* and most of our helichrysums became *Ozothamnus* and various other genera.

Sometimes a name must be changed because we have been using it for the wrong plant. Under our type system (enshrined in the *Code*), each scientific name is associated with a specimen used by the original author to prepare his or her description, and the application of the name is always linked to that type specimen. In some cases the specimen has been lost or destroyed, and then we can use an illustration or choose a replacement specimen. Sometimes, in checking the type specimen, a researcher finds that we have been applying the name wrongly. In Australia this happened frequently because the type specimens were held in European herbaria and it was not always possible to see them — we had to go on the descriptions published in books and journals and, if we were lucky, an illustration, and often they included insufficient detail to decide which of two variations the name should be applied to. In recent decades this problem has largely disappeared because we have been able to borrow specimens or obtain high-quality images. But, if we find that we have been using a name wrongly, then a plant that has been wrongly named must be given another — either an already published but "unused" name, or a new name altogether. In my own work in *Calothamnus*, I found that the type specimen of *Calothamnus oldfieldii* is, in fact, the plant that we have been calling *Calothamnus kalbarriensis*. As a result, the name *Calothamnus oldfieldii* must be used for this plant, and the one we have been calling *Calothamnus oldfieldii* must be given a new name. There are further variants of this situation but for the present this must suffice.

We must also use the first published name. There are many cases of the same species being given different names by different botanists (sometimes even the same botanist!). Occasionally a name published in an obscure, little-known place comes to light that is earlier than one in use. Under the *Code* we usually take up the earlier or earliest one, though there is now provision for very well-known names to be conserved. An example is the Boab of northern Australia, known as *Adansonia gregorii*, named in 1857. Twenty years ago a name that had been ignored since its publication in 1841 was discovered and put forward for use, but *A. gregorii* is so well known that it has been preserved under the *Code*.

The problem of a plant being classified in different genera, even different families, has become more common around the world in recent decades. It has become especially acute with the rise of methodologies known as cladistic analysis (cladistics) and DNA (molecular) analysis. Currently the two go hand-in-hand, the data from a DNA analysis being put through a cladistic program on the computer which produces cladograms or diagrams showing possible relationships between the plants analysed. The way these diagrams are interpreted is commonly different from the results of traditional taxonomy, and some are controversial.

A major difficulty for the nonspecialist trying to understand molecular and cladistic work is the terminology. All subjects have their special terminology, including plant taxonomy. Molecular and cladistic work impose one that is almost impossible for the nonspecialist to follow. I suspect that many current practitioners of these methodologies would themselves have difficulty explaining the full terminology, not to mention the philosophical concepts behind them. What do you make of this sentence, on a DNA analysis, from Mast et al. (2005): "Mr Modeltest 1.1b chose the general time-reversible substitution model (GTR: Lanave et al., 1984; Tavare, 1986; Rodriguez et al., 1990) with among-site heterogeneity assumed to follow a discrete approximation of the gamma distribution (Γ; Yang 1994) and a proportion of invariant sites (I) for the cpDNA dataset, the GTR+I substitution model for the ITS dataset, and the model of Hasegawa et al. (1985) with Γ for the *waxy* dataset." Even our Prime Minister would be proud of the verbal gymnastics. But what it means is that we — the average users — are being asked to take their work on trust and believe the diagrams that they produce.

Taxonomists using DNA want their audience to believe that their data are all that is needed as a basis for a classification. Sometimes, morphological attributes are placed on a cladogram, showing where changes are thought to have occurred or what the uniting character is for a clade (branch of the cladogram). Occasionally a full morphological analysis is done as well. But it's the DNA that is paramount. When I discussed the situation in banksias and dryandras with an experienced botanist who is familiar with these plants, he said, "If that's what the DNA says, then that's how it has to be." An even more extreme view has been expressed in a paper by Mike Crisp and Bernard Pfeil at the Australian National University: "We reject the idea that some kind of objective level of character difference or distinctiveness is an appropriate guiding principle for circumscription of the generic (or any other) rank" (Pfeil and Crisp, 2005). In other words, it doesn't matter what they look like. The diagrams (cladograms) produced in a cladistic analysis of DNA are also taken by the practitioners as "evidence" of how the plants are related and so how they should be classified when, in fact, they are only hypotheses.

There are further problems with DNA analyses but I have time to mention only two:

1) Only small parts of the DNA are used, and they are commonly those that show general relationships, not those that have a large effect in controlling differences. To put it another way, the genes

chosen for analysis are those that show how organisms are related, not those that show how they differ.

2) Usually only one plant of a species is sampled, and in order to repeat an analysis you would have to have access to the *same samples* used in the first analysis — this is possible if they have been preserved according to proper protocol — and samples from different plants of the same species might produce different results.

This means that the DNA database is good as far as it goes, but is very narrow. In contrast, in a morphological study, the characters used are expressions of scores or hundreds of genes, and we can look at multiple specimens going back several hundred years, including those that previous botanists looked at — such as (in the case of Proteaceae) Robert Brown, Carl Meisner, and George Bentham in the 19th century, Lawrie Johnson and Barbara Briggs in the 20th.

There are also problems with the cladistic methods used to analyse the DNA data, and again I have time to mention only the major one.

Cladists use similarity in the way that taxa have evolved to group them, and all taxa within a group that have a common ancestor are termed monophyletic. If, from such a monophyletic group, you take out some and classify them differently, it makes the remaining ones paraphyletic, and this concept is inadmissible in cladistics. In other words, strict cladistics does not allow a taxonomic group to evolve from another. This is not logical since, in a cladistic analysis of a whole family of plants — which evolved from a single ancestor — the only way the family can be monophyletic is to call them all a single genus. And then you should add other families, until you make all flowering plants one genus — then add the mosses, the green algae, etc. OK, you could be logical and do that, but for communication by plant names it would be pretty horrendous. It's the major reason why cladistics is causing problems around the world, and why many taxonomists see it as a useful tool but not one to be followed blindly.

The *Dryandra* and *Banksia* Case. As a practical example of the effect of these methodologies, I take the merger of *Dryandra* with *Banksia* since I have a fair understanding of the plants. *Banksia* was named in 1782 and true banksias now total 78 species and another 20 subspecies and varieties. *Dryandra* was named in 1810 and contains 95 species and 40 subspecies and varieties. Until Mast and Thiele's research over the past 15 years, there has been no suggestion that they should be merged as a single genus. There are four papers that provide the background to the merger and the major basis was a DNA analysis (Mast, 1998; Mast and Givnish, 2002; Mast et al., 2005; Mast and Thiele, 2007). I believe that there are flaws in the scientific basis that weaken the case for this merger.

First, only 11 taxa of *Dryandra* (out of 135) were analysed for DNA, compared with 84 (out of 98) for *Banksia*. The authors considered the number of dryandras adequate because they sampled from each of the three subgenera, but there are 24 series — groupings within the subgenera — in *Dryandra*, some highly distinctive. It's a massive assumption to take a sample of 8% as the basis for such a huge reclassification. The small sample is possibly the reason why *Dryandra* comes out in all the cladograms as a single group while *Banksia* is a diverse group on several branches — morphologically; *Dryandra* is at least as diverse as *Banksia* and I would expect this to show up in any analysis. It is impossible to verify whether all the samples were correctly identified, since cultivated material with no vouchers cited was used for four taxa, and no source or voucher was cited for a further six taxa.

Second, the few characters imposed in Fig. 1 of Mast and Thiele (2007) show inadequate understanding of the morphology. Below the first branch they give "Flowers in condensed heads" as a unifying character for the whole group, but above the fourth branch they have "Capitate inflorescence" to distinguish dryandras from "true" banksias — these phrases mean much the same thing (and true banksias don't have heads of flowers). Species on the first branch are said to be distinguished by having spathulate cotyledons, but spathulate cotyledons also occur in other species of *Banksia* and many of *Dryandra*. Then, above the first branch they give "Beaked follicles" leading to the remainder of *Banksia* and all *Dryandra* — but not all species of *Dryandra* have beaked follicles. Finally, their "Involucre of conspicuous bracts" as a unifying character distinguishing *Dryandra* from *Banksia* is incorrect. All species of *Banksia* and all species of *Dryandra* have an involucre of bracts subtending the inflorescence. It is correct that in most species of *Banksia* these are inconspicuous (in fact, in many they fall by anthesis), but in several species such as *B. goodii* and *B. victoriae* they are conspicuous and persistent. Conversely, in most species of *Dryandra* the involucre is conspicuous, but in some it is not, e.g., *D. concinna* and *D. sessilis*. The appearance of a third branch on the cladogram compared with a similar one in the previous paper (Mast et al., 2005) is not explained. Then, it is impossible to work out what species of true banksias are on each branch — this in a "classification" claimed to improve our understanding of these plants. We are not told which species are included in their new subgenus *Spathulatae* — there's a reference to a group called by an informal name *Phanerostomata* in previous papers, but those papers do not provide the full answer. The distinguishing feature of this subgenus — spathulate cotyledons — occurs in a number of species of *Banksia*, and also in *Dryandra* — they may be broad or narrow, but they are still spathulate. So, as described, it is rather meaningless. We are not told if *Banksia* subg. *Isostylis* is recognised by Mast and Thiele, or if they consider it part of subg. *Banksia*.

Thirdly, whereas Thiele and Ladiges previously gave a detailed analysis of the morphology of true *Banksia*, there is no such analysis for *Dryandra* in the papers on which the merger is based. Mast et al. (2005) acknowledged that "we do not have the morphological data that might help to place it [*Dryandra*] when analysed in concert with that sampled in *Banksia* by Thiele and Ladiges (1996)."

Their results, in fact, confirm that *Dryandra* is a "good" natural group, whereas *Banksia* contains several groups that come out as distinct — very similar to what I concluded in my revision, based on the morphology, published in 1981. Two features that provide clear unifying characters for *Dryandra* are the flat or slightly concave or convex receptacle on which the flowers are borne, and the loosely arranged common and floral bracts of the inflorescence (not to be confused with the involucral bracts subtending the inflorescence). These have been overlooked in all the cladistic analyses, including Thiele and Ladiges (1996).

Fourthly, in assessing a cladogram, the researcher decides where to draw the ranking line across it and what rank to give each group above the line. Mast and Thiele (2007) drew it low down, choosing to regard the whole lot as one genus. A line marking genera drawn higher on the cladogram would have left *Dryandra* as a genus and left *Banksia* in several groups, the upper three of which are "unresolved" branches and further work should have been done to clarify these. We have been given no explanation why this was not done — there is a mention of "fine-scale taxonomic sampling" being carried out in Mast's laboratory, without explaining what they meant by this.

Finally, as is common in cladistic analyses, the published background papers abound with statements of uncertainty that you might expect with an hypothesis — this may/might be the case, this suggests …, this seems/appears …, this could have …, if such and such … . The paper by Mast and Givnish (2005) that provides most of the DNA analysis on which the *Dryandra*/*Banksia* merger is based contains more than 20 such uses — not a convincing argument for such a major change.

Going back to the taxonomy — information in a classification — Kevin Thiele claims that combining the genera gives us a "new understanding" of their relationships (Thiele, 2008a, 2008b). In fact, we already knew that *Dryandra* is closely related to *Banksia*, and their new classification obscures relationships because they have placed all 95 species of *Dryandra* in a single series within *Banksia* while retaining a comprehensive infrageneric classification for the taxa of *Banksia* in the strict sense.

Likewise, their claim that an expanded *Banksia* is "a single, easily recognised genus" (Mast and Thiele, 2007) makes no sense to those who have no difficulty recognising a *Banksia* or a *Dryandra* when they see one, even if it is a species that they have never seen before. In the 1980s, the Banksia Atlas project involved 421 people recording banksias across Australia. Of these, 185 were in Western Australia, making 5143 records. No one ever recorded a *Dryandra* in mistake for a *Banksia*.

Thiele (2008a) argues that, because some species of *Banksia* are related more closely to *Dryandra* than to other banksias, keeping the genera separate is a "serious anomaly." When a new organism evolves from a member of a large group, it is going to be more closely related to that member than the others. At some point it may then become different enough to be called a new genus, and this is what has happened with *Dryandra*.

Finally, they even acknowledge that their results are preliminary, stating (Mast and Thiele, 2007) that their new classification "is the least disruptive option at present" — in other words, try this for size, spend hundreds of hours and thousands of dollars changing all your labels, your conservation lists, your databases — but we may change the classification again later. The least disruptive option was to retain the status quo. Despite more than 10 years' work, they have made no advance in our knowledge of taxa below generic rank in *Dryandra*.

In short — this research has, essentially, confirmed a taxonomy that we already had but, by making unjustified changes to the names of dryandras, has confused the nomenclature and the taxonomy — and the users.

THE AUSTRALIAN PLANT CENSUS

Now I turn to the acceptance of the merger of *Dryandra* with *Banksia* by Australian herbaria. Because botanists sometimes have different views on the correct names, and each herbarium takes an official line, the Australian herbaria have established the Australian Plant Census in order to provide a nationally agreed list of names. It's a database of the accepted scientific names for the Australian vascular flora, both native and introduced. In 2004, the herbaria established a committee to "make judgements on any contentious conflicts" (Orchard, 2006). The committee's decisions are meant to represent the considered opinion and nomenclatural research of about 35 people in Australian herbaria and user groups.

Guidelines were developed for the Census. In a paper published in 2005, discussing alternative taxonomies, Tim Entwistle and Peter Weston wrote that "for day-to-day business and pleasure, we [I assume that they meant the above committee] must deliver what the customer wants" (Entwisle and Weston, 2005). Note those words — what the customer wants. This means you. Five of the guidelines are relevant to this discussion:

Guideline 1. Where possible, named taxa should be monophyletic based on current reliable evidence. This is qualified by Entwistle and Weston: "… there are times when we need to accept higher taxa [above species] that are not monophyletic, at least in the short term [earlier defined as "e.g., 10 years"] … [such as] when different lines of evidence (especially molecular vs. morphological) are in conflict." In the case of *Dryandra* and *Banksia* this guideline was not followed. There is conflict, and the merger was adopted less than 5 months after it was published.

Guideline 2. Minimise taxonomic change (across Australia as a primary focus). In their discussion, Entwistle and Weston (2005) say that "accepting stability … should result in both information gain and minimisation of nomenclatural confusion." The transfer of *Dryandra* has done just the opposite — established some 135 new name combinations and lost information — all the subdivision within *Dryandra*.

Guideline 3. Change is more acceptable in groups that are not "charismatic," are not economically important, or do not have a substantial "interest group." Dryandras occur naturally only in Western Australia and are both charismatic and economically important, but it's possible that committee members in other States may not be aware of this, or even that there are significant "interest groups" for *Dryandra* and *Banksia* (Australian Plants Society Study Groups).

Guideline 4. The "preferred name" should be as scientifically defensible as possible, but its acceptance does not imply that it is necessarily the "best name" on scientific and/or social grounds. In my opinion, the merger of *Dryandra* and *Banksia* is not based on sound science.

Guideline 5. Avoid epithets already in use in possible congeners. Eighteen species names in *Dryandra* are also used in *Banksia*, so these have to be changed when all are called *Banksia*.

Guideline 6. **The preferred name is that used in most states and territories ("majority rules").** Fair enough, but the decision should still be based on good science. I'll comment further on this shortly.

Discussing changes in the nomenclature of orchids, Barker and Bates (2008) wrote that "Herbaria … tend to adopt a conservative approach in the adoption of new names, preferring to wait until there has been sufficient testing of new concepts and hence greater stability and acceptance of these names … Rushing in and adopting name changes as they occur can lead to a later reversal of a decision and an unnecessary confusion of names." A similar cautionary approach was given in regard to splitting taxa by Thiele and Brown (2008), who argued that the position accepted for the Census with respect to certain orchids "is to retain the traditional genera … until compelling evidence for the need to segregate is presented."

All these guidelines and considerations advise caution when deciding whether to adopt taxonomic and nomenclatural changes for the Census, especially of large groups. Yet the Census committee has ignored them in deciding to accept the merger of *Banksia* and *Dryandra*. As far as I am aware, there has been no publicised report on how the committee reached its decision. I have been advised that the only herbarium where a discussion took place was the Western Australian Herbarium, where Kevin Thiele, one of the authors of the change, is director. The others all simply agreed in response to a request by email. No approach was made to what they call customers (users) such as those who know the plants well, the horticultural trade, the Banksia and Dryandra Study Groups (and other members) of the Australian Native Plants Society. It would be interesting to know if all those involved in the decision read the background papers? If they did — even worse if they did not — and still voted to accept the change, then all I can say is, "heaven help Australian plant systematics until the cladistics fad passes."

Many "customers" are continuing to use *Dryandra*. The Banksia and Dryandra Study Groups have considered the change and rejected it. The Wildflower Society of Western Australia continues to use *Dryandra*. Very importantly, the Botanic Gardens of Adelaide list *Dryandra* in their 2010 catalogue of plants being grown there, despite the Garden's own herbarium accepting the merger 3 years ago. Clearly, many people with a working knowledge of these plants have rejected the merger. But we are left with the situation of Australian herbaria using one nomenclature and the "customers" another.

The names of all species (except one) of *Dryandra* are valid under the *Code* in both *Dryandra* and *Banksia*, and *you can choose* whichever generic name you prefer. But calling a *Dryandra* a *Dryandra* tells you much more about it than calling it a *Banksia*, i.e., we have better communication of information.

***Eucalyptus* and *Corymbia*.** While the Australian herbaria have adopted the name *Corymbia*, many users continue to place all gums in *Eucalyptus*. The arguments for recognising *Corymbia* as a genus also take a cladistic analysis of molecular data as "evidence" (Ladiges and Udovic, 2000) when in fact it is an hypothesis. A leading expert in eucalypts, Ian Brooker, is the only botanist I know who has studied all species, including seeing most species in the field. He considers that *Corymbia* is better classified as a subgenus of *Eucalyptus*. Because *Angophora* is part of the same morphological complex and has a similar position within it, he treats it, too, as a subgenus of *Eucalyptus*.

I note that the catalogue of the Botanic Gardens of Adelaide (2010) does not use *Corymbia*.

We even have the situation of the same author being involved in the transfer of species from one genus to another (Crisp and Weston, 1987) and then back again a few years later after further research (Chandler et al., 2002), or revising a genus (Crisp, 1995) and then transferring it to another just 7 years later (Chandler et al., 2002)!

The views of users are important (Brickell et al., 2008) — as happened in the case of *Chrysanthemum*. In some situations, the *Code* provides for a name change that may be necessary under its rules to be overturned. Some years ago, research showed that *Chrysanthemum* contained more variation than was considered acceptable in a genus and it was split into several genera. Under the rules, it meant that the "florists Chrysanthemum" was placed in the genus *Dendranthema*. This would have affected thousands of people in the horticultural industry around the world, so a proposal was made, and accepted, to change the type or defining species of *Chrysanthemum* so that the generic name would remain in use for the "florists chrysanthemum." No such case can be made for *Dryandra*. There is no "court" to which any appeal can be made. Unless the Australian herbaria reverse their decision, it seems that they will follow the merger while many users continue to recognise *Dryandra*.

CONCLUSION

Returning to the title of my talk, I may not have helped you to decide when there are alternative names for plants, but I hope you have a better idea of the issues involved. For native plants, the Australian Plant Census is a good guide but has no formal status that requires it to be followed. The biggest difficulty is understanding the scientific background and, as is clear from what I have said, this is extremely difficult even for those in the field. And I haven't even mentioned the arguments that go on between those on the cladistic bandwagon!! To a large extent it comes down to which argument you prefer, whose work you trust even which name you like.

As a general rule I would say:

1) Check what the most authoritative list for your state or country says.
2) Ask two or more botanists (if possible, with different views) for their opinion.
3) If there is a controversial nomenclature based on a cladistic study (especially one that has not included traditional taxonomic research), follow the traditional nomenclature — it is likely to be more stable in the long run.

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Australian Garden: The Cradle of Creation©

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INTRODUCTION

This year's IPPS theme, "The Cradle of Creation," could not be more appropriate when describing the current state of the Royal Botanic Gardens Cranbourne (RBGC) nursery as we prepare for Stage 2 of the Australian Garden. It is not often that one is involved with the creation of a botanic garden, particularly one that sets out to showcase native plants from all over Australia that stretch across a wide range of growing requirements and climatic conditions. With regional water restrictions and a changing climate, the Australian Garden is a timely project with the ability to influence public perceptions on the beauty and diversity of Australian flora, and on the use of Australian plants to create sustainable home gardens

Stage 1 of the Australian Garden was opened to the public in 2006, and shortly afterwards the funding for the second and final stage was secured, predominantly from the Victorian government. The design for Stage 2 was reviewed and refined in response to the continuing drought and prospect of a drier future. In the redesign process, invariably the full detail of plant selection for the landscape design is the last to be finalised, providing plenty of challenges for the nursery that has the task of sourcing and propagating the bulk of the plant material. By 2009, as time ticked by, the nursery still did not have a complete plant list on which to plan and implement production. We bided our time by seed collecting in the conservation zone for the plants needed for the new Woodland Picnic Area and to replenish seed supplies for the Growing Friends. The nursery continued to produce plants for Stage 1 garden beds that had been ravished by rabbits, bush rats, *Phytophthora cinnamomi* in some areas, or for beds where the soil ameliorant had not been properly integrated into the sands. When the first of the "final" design plans came in, hours were spent counting tiny dots representing plant numbers, checking and double checking species in context to our weed evaluation model and a plant list was created for the nursery to make a start.

The plant list was 33 A4 pages long comprising 88 families, 268 genera, and 1,012 species totalling more than 50,000 plants so far. Approximately half of the plants are being grown in house by the RBGC nursery; with planting commencing in May 2010 (the opening of Stage 2 to the public is planned for late 2011). Plus, we have grown 7,000–10,000 RBGC indigenous plants required for the new wetlands water treatment area which will be planted in June of 2010. Initially, 30,000 plants produced in house for Stage 2 does not seem to be a great number in terms of nursery production. We of course grow more than what is required in order to have backups in case our furry friends decide to gorge themselves before the opening! When not growing plants for Stage 2, there is always the sifting and repotting of terrestrial tubers and epiphytes in our Australian orchid collection, growing and maintaining display plants, propagating new plants from wild-collected plants that are coming to the end of their life span, maintaining collections, weeding, pruning, potting on, IPM monitoring, meetings, burn offs (yes, we are fire trained and do prescribed burns for asset protection and ecological sustainability of the conservation zone), nursery tours as part of the Public Programs service, and continuing to add diversity to Stage 1. So, now the 30,000 plants produced in house for Stage 2 is a number in context, especially since we're dealing with so many different species.

Seed was ordered for out of state plants, plant material collection days were organised for off-site cutting material, as well as sourcing what was not to be grown in house. Trips to Queensland nurseries were a welcomed opportunity — I even got to meet Kerry Rathie, one of the authors of *Mangroves to Mountains*, and see what he's been doing with his innovative *Brachychiton* crosses. Some plants were translocated from areas of the RBGC bushland for the nursery to use as stock plants from which to propagate, like *Hypericum calycinum* and *Drosera binata*, while seed was collected on site from other species such as *Lepidosperma concavum, Burchardia umbellata*, *Arthropodium milleflorum* and *A. strictum*, and the beautiful *Thysanotus patersonii* and *T. tuberosus* subsp. *tuberosus,* just to name a few.

There are challenges, too, in growing these plants. For example, *Lepidosperma concavum* seed heads had to be bagged because only the current year's seed that is not retained on the plant has a chance of having a viable embryo and can be germinated, which may be only one or two seeds per head.

Some cutting material has waxy stems, like philothecas, that do not respond well to rooting hormones in gel form, so alcohol-based hormones are being used. We discovered this after having done 4,000 cuttings of *Philotheca* 'Flower Girl' using the gel first — we have successfully grown *Ricinocarpus pinifolius*, both from seed and by cuttings. We have also been involved with the national recovery of *Nematolepis wilsonii,* a species endemic to the Central Highlands of Victoria where there is a single population of about 500 plants — or there were. Fires through the area have put increased pressure on this small population which may not be able to spring back without ex situ conservation.

The nursery itself is surrounded by the conservation zone and therefore we need to consider the impacts that activities carried out in the nursery may have on the indigenous flora and fauna, including invertebrates. We absolutely promote integrated pest management (IPM) and hence have greatly reduced using pesticides. We encourage local insect populations of lacewing, ladybeetle, wasps and praying mantis, and other beneficials, such as the orange snout mite. We also supplement them by buying in lacewing larvae and nematodes for the glasshouse and the orchids. We have been undertaking our own research of sorts by taking caterpillars we find on plants, especially our orchids, and rearing them to establish with what type of moth we are dealing with. In the case of the orchids, our epiphytes were nearly destroyed by a caterpillar that we believe to be of the family Plutellinae, though absolute identification is difficult, even for the experts to whom we have sent samples. This moth lays its eggs in the tips of the orchids, or in the bark, and the emerging caterpillars graze on the leaves until strong enough to bore into the orchid stems and chew and damage the new shoots. In desperation, we even tried using insecticides such as Dipel and Confidor, both as sprays and as drenches, as the orchids are in their own separate shade house enclosure, but nothing worked. In the end, we set up a moth attracting light with a fan and have hung moth repellent sachets on the walls. This has greatly reduced the moth population and this year we have lots of fresh new stems. The moth trap is checked regularly and all insects collected are identified, if possible, and counted; this information is recorded and has allowed us to analyse insect populations from season to season. This whole process has led us to set up guidelines, protocols, and excellent record keeping. The RBGC nursery is Eco-Hort certified as well as being Nursery & Garden Industry Australia (NGIA) accredited.

For those of you who have not been able to visit the RBGC and the Australian Garden, I have added a brief history and a short description of the precincts within the Australian Garden, including Stage 2, with the hopes of inspiring you to come and visit — and you are certainly welcome to visit us in the nursery!

THE ROYAL BOTANIC GARDENS CRANBOURNE

As early as 1945, committee members of the Maud Gibson trust and Managers of the Royal Botanic Gardens Melbourne identified the need to acquire land for the provision of a native botanic garden. The first 174 ha were purchased in 1970 with additional purchases over the next 26 years bringing the total to 363 ha thus conserving six vegetation communities from heath to grassy woodlands and home to an array of reptiles, mammals, frogs, and birds. The RBGC opened to the public in 1989.

THE AUSTRALIAN GARDEN

Designed by Taylor Cullity Lethlean Pty Ltd with renowned plant designer Paul Thompson, the Australian Garden is a 20-ha landscaped garden that has turned a former sand mined area into a world class and award winning public garden. The garden showcases the beauty and diversity of Australian landscapes and plants. It is the exhibition garden within the 370 ha that comprise the Royal Botanic Gardens Cranbourne.

The first 11 ha (Stage 1) opened to the public on 28 May 2006. The major features include:

- **Rockpool Waterway:** explores the role of water in shaping the Australian landscape.
- **Escarpment Wall Sculpture:** designed by Greg Clark and separating the Rockpool Waterway from the Red Sand garden, it is a 90-m-long steel structure reminiscent of the massive rock escarpments associated with Western Australian and the Northern Territory.
- **Red Sand Garden:** depicts the arid Australian landscape, the beauty and texture of the "red centre" with seasonal plantings of wildflowers along the magnetic north line.
- **Dry River Bed and Arid Garden:** explores the way water has shaped the Australian landscape and how plants have adapted to dry conditions.
- **Eucalypt Walk:** showcases stringybark, bloodwood, peppermint, box and ironbark species.
- **Ephemeral Lake Sculpture:** interprets the presence and absence of water.
- **Exhibition Gardens:** includes the Kids' Backyard, Home Garden Design Past and Present, the Water Saving Garden, the Future Garden, and the Diversity Garden, which encompasses the bio regions of Australia.

Stage 2 is currently under construction which will add an additional 9 ha to the Australian Garden with an anticipated late-2011 opening to the public. Major features will include:

- **The Weird and Wonderful Garden:** draws attention to some of the strange forms, fruit, flowers, or interesting pollination mechanisms of Australian plants.
- **The Melaleuca Spits:** floating bands of *Melaleuca linariifolia* form a significant landscape feature.
- **Continental Edge Garden:** concludes the journey of water from the arid centre to the coastal margins; it is a series of five gardens with urban themes and fingers of pleached *Ficus microcarpa* var. *hillii*.
- **Eucalypt Walk:** extends into Stage 2 with subtle changes becoming more lush as it comes to an area of Australian rainforest plants with a focus on species with Gondwanan origins.
- **North and South Display Gardens:** garden plants, cultivars, and varieties in strong-banded displays of form and colour; also, horticultural research plots as "windows" into the role of botanic gardens in researching and trialling Australian plants for cultivation.
- **The Ian Potter Lakeside Precinct:** outdoor space for community events such as festivals, live music, and theatre.
- **Howson Hill:** emerging from the waterway, the Mallee Eucalypts with understorey of flowering shrubs and ground covers lead to an observation platform.
- **Gibson Hill:** *Acacia binervia* dominates this area that leads to a second viewing platform and a fire pit for Aboriginal traditional ceremonies and storytelling.

Stage 2 will complete both the vision of the Australian Garden and the journey of water through the Australian landscape. The Australian Garden allows the public to have a glimpse of the extraordinary flora native to this beautiful country with underlying educational themes, such as horticultural techniques including espalier and pleaching, sustainability, biodiversity, and conservation. It most certainly has provided the RBGC nursery with horticultural challenges!

Grafting Western Australian Natives©

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INTRODUCTION

The Botanic Gardens and Parks Authority (BGPA) nursery specialises in the propagation of Western Australian species, and is responsible for producing approximately 80,000 plants annually for display in the Western Australian Botanic Garden and parkland areas of Kings Park; for restoration projects within the remnant bushland of Kings Park and Bold Park; for arboricultural specimen plantings; and for conservation purposes both within Kings Park and for the Department of Environment and Conservation's translocation programs. A range of techniques including growing from seed and cuttings, and the use of grafted plants are utilised to provide healthy propagules for these display, research, conservation, and restoration activities.

Grafting programs began at BGPA in the late 1970s, with a focus on *Corymbia ficifolia* (see also *Eucalyptus ficifolia*). A progression to other genera began in the early 1980s, with the project expanding and developing to the present day.

There are two major factors that influence our decision to undertake grafting as a propagation method at BGPA. One of these is to produce quality specimens for the purpose of display within the Western Australian Botanic Garden. Our garden displays are a very important conservation and education tool, and we pride ourselves on our ability to showcase the diversity and beauty of this state's flora to a very high standard. However, our specific soil type and other environmental conditions often mean that species we would like to display may struggle on their own root systems. By careful selection of rootstock-scion combinations we are slowly but surely introducing more and more grafted specimens to these displays, with many rewarding results.

The other factor that dictates our decision to graft is if alternative methods of propagation have been largely unsuccessful, or if there is very limited vegetative material available. This is often the case for threatened species. We curate a large collection of Western Australian rare and endangered species within our nursery, which is a very important conservation asset. Grafting of some of these species often allows the plant a longevity it would not otherwise have, and allows us to generate more material with which to trial further propagation methods. Examples of endangered flora that we have found respond well to grafting as opposed to other propagation methods include *Pimelea physodes, Eremophila purpurascens Pityrodia scabra,* and *Eremophila nivea.*

Major genera investigated at BGPA over the past 20 years include *Eremophila* (*Scrophulariaceae*), *Verticordia, Darwinia* (both *Myrtaceae*), *Boronia* (*Rutaceae*), *Pimelea* (*Thymelaeaceae*), *Prostanthera, Hemiandra* (both *Lamiaceae*), and *Grevil-*

lea (*Proteaceae*). There are currently many grafted specimens representing these genera on display in the Botanic Garden, having successfully determined suitable rootstocks for them. All grafting is done by hand; onto both established rootstock and cuttings. Our preferred style of graft is a wedge, or cleft, graft — many of the species worked on have very small stem diameters, often only millimetres thick, and other graft types have proven to be difficult to perform or do not provide the necessary stability. We have also had some success with side veneer grafts; although the resulting specimens tend to lack the vigour of those prepared using the wedge technique. Grafted plants are placed into a propagation tent within a glasshouse, with a single-gang fogging unit that maintains approximately 94% humidity. Capillary matting placed over a heat mat is used within this tent to avoid the need for overhead watering while at the same time contributing to creating the optimum humid environment for grafting success.

Rootstock selection is not limited to within the same genera, to provide a wide range of potential rootstocks, for different situations. We select rootstock for trialing based on availability of material, ease of its propagation, predicted compatibility and longevity, and specific tolerances to certain soil or environmental conditions. Table 1 highlights a selection of the species we have experimented with as rootstock, with their strengths and weaknesses based on both evidentiary and observational factors.

Years of experimentation have provided us with many successful combinations that satisfy all of our required rootstock criteria. Table 2 shows several combinations that have proven consistent compatibility and longevity of a selection of Western Australian species we have trialed.

While we have achieved reasonably good results for the species outlined in Table 2, there is clearly still room for improvement. Additionally, other species have proven more problematic and further investigation and trialing of reliable rootstock-scion compatibilities and longevity will be ongoing, with the aim of building up a body of supporting data for others to access.

Concurrently, the future of the BGPA grafting program includes:

1) Broadening the range of species for grafting; members of the Proteaceae family, particularly *Grevillea*, will remain a focus, and a wide range of other species we have not previously attempted will also be introduced into the program.
2) Continued investigation and trials of alternative rootstock for a wide range of conditions; while utilising Western Australian species as rootstock has been traditional, we intend to experiment with the use of Eastern Australian species, as well as exotic species.
3) Possible planting trials in other areas of Western Australia with different soil and environmental conditions to Perth; the majority of our work thus far has involved field trials on Perth's infamous sandy soils. We are currently investigating opportunities to trial selected grafted specimens on the heavier soils of the Darling Range, as well as further afield.

Table1. Characteristics of selected rootstock used at Botanic Gardens and Parks Authority nursery.

Rootstock	Strike rate	Growing on	Strengths	Weaknesses
Boronia clavata	Good	Quick	Compatibility with a range of species, hardy	Susceptible to scale and mealy bug
Boronia crenulata	Good	Quick	Thin diameter for smaller species	Susceptible to scale and mealy bug
Chamelaucium ×*Verticordia* 'Paddys Pink'	Good	Quick	Thin diameter for smaller species	Highly susceptible to botrytis in glasshouse environment
Chamelaucium floriferum ×*uncinatum*	Good	Quick	Shows good initial compatibility	Possible Phytophthora susceptibility? with a range of species
Chamelaucium ×*Verticordia* 'Jasper'	Good	Quick	Thin diameter for smaller species	Highly susceptible to botrytis in glasshouse environment. Poor vigour in Botanic Gardens
Darwinia citriodora	Good	Quick	Phytophthora tolerant? Grows in a range of conditions	Display nutrient deficiencies in alkaline soils
Grevillea preissii	Average	Moderate	Initial trials show good compatibility	Longevity not ideal
Grevillea hybrid	Good	Moderate	Quick strike rate	High losses in humid environment, susceptible to rotting
Myoporum insulare	Good	Quick	Thick diameter good for matching thicker species, hardy	Selective scion matches due to thickness. Highly susceptible to aphids and scale
Myoporum montanum	Good	Quick	Nematode tolerant? Good compatibility with range of species, quick strike rate	Susceptible to aphids and scale. High maintenance post-graft
Myoporum tetrandrum	Good	Quick	Thin diameter, good compatibility with range of species	Susceptible to nematodes, aphids and scale. High maintenance post-graft
Pimelea ferruginea	Good	Moderate	Good for coastal conditions	Relatively short-lived. Not ideal for a wide range of soil types
Westringia dampieri	Good	Quick	Hardy, good compatibility with a range of species	High maintenance post-graft

Table 2. Selected proven rootstock-scion combinations.

Scion	Rootstock	Average compatibility (%) (on established rootstock)	Longest lived specimen
Eremophila nivea	*Myoporum montanum*	53%	10 years – Botanic Garden
Microcorys eremophiloides	*Westringia dampieri*	45%	13 years – container stock 6 years – Botanic Garden
Pimelea ciliata	*Pimelea ferruginea*	86%	5 years – Botanic Garden NB: trials on this species only began 5 years ago
Pimelea physodes	*Pimelea ferruginea*	88%	6 years – Botanic Garden NB: trials on this species only began 6 years ago
Prostanthera magnifica	*Westringia dampieri*	56%	20 years – Botanic Garden 17 years – container stock

4) Continued improvement of our techniques; ongoing staff training, refining practices, and researching new findings and products can only contribute to further improving our grafting success rates.
5) The publication of our findings; there currently is limited data available on suitable rootstock, rootstock-scion compatibilities, and longevity of grafts for Western Australian conditions. A comprehensive catalogue of our data on our findings in these areas is planned for publication in the near future.

In conclusion, while grafting of Australian natives is not yet a common practice in Western Australia, we strongly believe there is definite potential for a wider use of grafted plants. Given that BGPA's mission statement is "to conserve and enhance Kings Park and Botanic Garden and Bold Park within the community and to conserve biological diversity generally," we consider grafting as a vital factor in assisting us to achieve these important outcomes.

Breeding and Developing New Australian Plant Varieties©

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INTRODUCTION

The flora of Australia is one of the most diverse and floristically spectacular in the world with estimates of more than 20,000 species (Chapman, 2009), many of which are adapted to drought and soils with poor nutrients. The diversity of genera and species is well recognised, less so is the great diversity within species.

Much of the Australian continent is semi-arid to arid or with long periods where there is little or no rain. In Western Australia the climate is undergoing a sustained period of drying while average temperatures are increasing (Fig. 1), which has a number of implications including a reduction in the amount and frequency of watering allowed for home and public gardens, and landscapes.

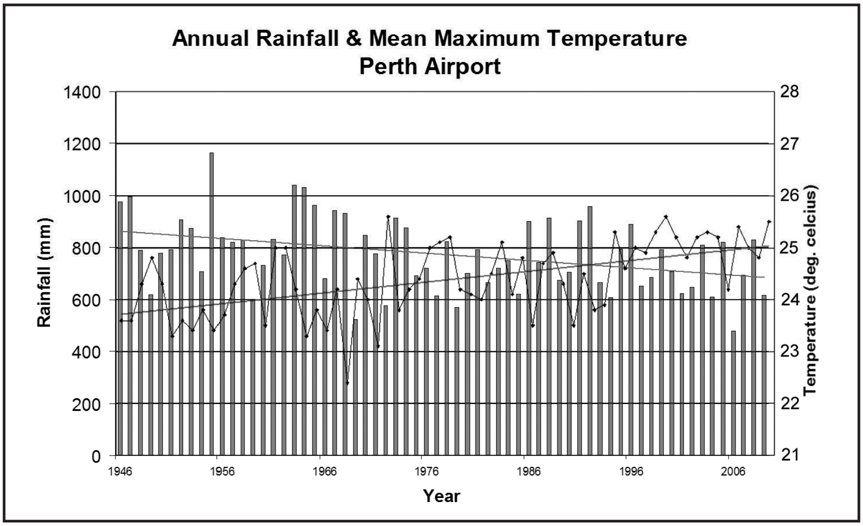

Figure 1. Annual rainfall data 1946–2009 (Department of the Environment, Water, Heritage and the Arts, 2010).

The combination of diversity, floristic impact, and efficient water and nutrient use is the most important strategic advantage for the Kings Park and Botanic Garden (KPBG) breeding program, particularly when intraspecific diversity is taken into account.

The Australian flora is generally horticulturally unimproved and many highly ornamental species are difficult to cultivate with traditional systems due to their specialised growing requirements. There are opportunities to improve the quality and presentation of species and varieties of this flora so that they are more adaptable to cultivation and more acceptable to the wider population.

DISCUSSION

The aim of the plant breeding and development program at Kings Park is to develop new Australian native plants that are site and climate adaptable, have a range of desirable horticultural characteristics, and can be grown more widely in home gardens and public landscapes. The program also has the potential to provide a long-term royalty stream through marketing superior plant varieties in partnership with leading ornamental plant producers locally, nationally, and internationally.

A number of local native plant genera have been identified as having the attributes required to successfully develop new cultivars suitable for marketing as landscape and garden plants and/or flowering pots. The attributes considered when selecting these genera included:

- Significant genetic variability.
- Site and climate adaptable.
- Low water and nutrient requirements.
- Attractive leaf and flower presentation.
- Capacity to extend the colour palette and flowering season.
- The potential to produce new varieties with compact forms.
- Ease of propagation.
- Likely market acceptance.

Plant groups currently targeted include *Grevillea*, the Haemodoraceae (including *Anigozanthos, Conostylis,* and *Macropidia*), the Goodeniaceae (especially *Scaevola* and *Leschenaultia*), and the small myrtles (including *Darwinia, Chamelaucium, Hypocalymma,* and *Verticordia*).

Kings Park and Botanic Garden has developed a model for the breeding and commercialisation of these plant groups that is underpinned by sophisticated collection programs using global positioning system (GPS) and geographic information system (GIS) and real-time mapping technologies, controlled glasshouse environments, and advanced scientific techniques using DNA analysis and plant tissue culture protocols.

A critical component of the model is the identification of commercial partners to fund these programs in exchange for the right to commercialise varieties produced under the programs. Kings Park and Botanic Garden has successfully funded the *Scaevola, Grevillea,* and small myrtles programs in this manner, and delivered a path to market that could not be achieved using solely its own resources. The success of this strategy is underscored by the 2010 international commercial release of the KPBG-bred hybrid, *Scaevola* 'Blue Print' by Ball Flora.

Other benefits of the breeding and development program include the expansion of infrastructure such as glasshouses and nursery areas, increasing specialised skills of staff, and the development of a dedicated volunteer program.

There are three main technical strategies that deliver new varieties. These are selection, controlled pollination, and biotechnical methods. The DNA analysis is used to confirm the existence of hybrids.

- **Selection.** Selection of plants with superior characteristics forms a significant part of the KPBG breeding strategy to deliver varieties that can have immediate market impact, and to provide better parents for targeted breeding strategies.

- **Controlled Pollination.** This is the main method for producing new varieties, and uses a range of technological aids such as pollen storage, environment modifications to induce flowering, specialised plant tissue culture techniques (including early embryo rescue), polyploid induction, seed x-ray, and DNA analysis for early detection of hybrids. Controlled pollination is likely to remain the main technique for new hybrid production in the medium term, particularly as induced polyploids with restored fertility become available. Greater use of backcrossing (particularly with hybrids with low fertility) and sibling crossing will deliver more variation in second and later generation hybrids, allowing greater choice for the commercial partners.
- **Biotechnology.** A small but significant project on somatic fusion between *Scaevola* and *Leschenaultia* has in 12 months delivered most of the protocols for producing protoplasts of *S. aemula* and *Leschenaultia* 'Lola', and regenerating these to the macro-calli stage. Initial attempts to fuse the protoplasts using polyethylene glycol failed due to toxic effects. Electrical fusion could not be attempted due to lack of access to the necessary equipment. Protoplasts of two taxa of *Grevillea* were also produced, underscoring the potential usefulness of this technique on a range of plant species.

GOODENIACEAE

Kings Park and Botanic Garden produced a range of interspecific *Leschenaultia* hybrids in the 1990s, eight of which were commercially released in Australia in 2000. They were trialled internationally, but were not released due to issues with *Botrytis* infection in conditions of high humidity.

Breeding within *Scaevola* has been underway since 2005 following an expression of interest process to identify commercial partners interested in partly funding the activity. Ball Australia, and its parent company, Ball Flora in the U.S.A. agreed to provide funds, and over the period 2005 to 2008 over 600 hybrids were sent for trialling. In 2010 Ball Flora released the first hybrid from this program, *S. aemula* 'Blue Print' in several international markets. Several others remain under trial.

HAEMODORACEAE

The main breeding activity in this family has been with *Anigozanthos,* which has been underway since 2008, although there was some activity in the 1970s. The 11 species of *Anigozanthos* are endemic to Western Australia and the red and green kangaroo paw, *A. manglesii*, is the floral emblem of Western Australia.

The current strategy for the *Anigozanthos* breeding program is to produce disease-resistant, long-flowering, compact varieties in a range of colours, and similar hybrids with flowering stems to 1 metre.

The black and green kangaroo paw, *Macropidia fuliginosa*, is related to *Anigozanthos* and there has been interest over the years in hybridising the two genera, but without success. Kings Park and Botanic Garden aims to examine the option of using somatic fusion to hybridise these two genera. There has been no crossing activity with *Conostylis* as yet. Many of the species have been collected and grown, and assessments and selections will begin in 2010.

A selection of *A. rufus* with iridescent orange flowers named 'Kings Park Federation Flame' was released in 2001 through the Friends of Kings Park as the Western Australian floral selection for the Centenary of Federation. Ramm Botanicals Pty Ltd gained the broader commercialisation rights through an expression of interest process and has released this cultivar in Australia in 2010, with an international release planned for 2011.

SMALL MYRTLES

The main focus of this breeding activity is selection of variants from wild populations, with some work in controlled hybridisation. Several new forms of *Hypocalymma* species have been collected, including a chance hybrid between *H. robustum* and *H. angustifolium*, as well as an upright form of *H. xanthopetalum* which grows to a metre tall.

A number of selections of *Chamelaucium floriferum* have been made, including a pure white form, and some that are compact. Robust populations of *C. megalopetalum* have been targeted, to combine with compact and unusual forms of *C. uncinatum*. The genetic range of *C. ciliatum* has been collected, including summer-flowering varieties. Some intergeneric hybridisation with *Verticordia* has been attempted, thus far without success.

Research into hybridising robust species of *Darwinia* with the "bell-flowered" species from the Stirling Range started in 2009, with a number of putative hybrids now germinated in culture. These will be deflasked in 2010, and evaluated for a range of attributes.

GREVILLEA

The *Grevillea* breeding activity has been underway since 2007. *Grevillea* has 340 species, a geographical and climate range covering most of Australia, from the tropics to alpine areas to deserts, and has significant diversity of flower colour, flower size, flowering season, flower presentation, and plant and leaf morphology.

The current strategy for the *Grevillea* breeding program is to produce hardy, free-flowering plants in a range of colours that are suitable for home gardens and broad landscaping. A major component of this strategy is to hybridise Western Australian species from the semi-arid and arid zones with those from the north and eastern parts of Australia, with subtropical and tropical climates. A number of these hybrids are now undergoing evaluation.

RESTORING FERTILITY

Many hybrids produced in the programs above are either sterile, or have very low fertility. Restoring fertility to enable recombination of the range of attributes from the original parents is a major focus of the breeding program. To date backcrosses have been produced from several hybrids with low fertility, which will be evaluated once they have flowered.

Where the hybrids are completely sterile, a program to induce increased ploidy level has been developed. Plant material is treated using the compound oryzalin either on germinating seedlings, in tissue culture, or on the stems of mature plants. Treated material will be evaluated using flow cytometry to determine whether the treatments have been successful in inducing increased ploidy. To date oryzalin seed treatment of some *Anigozanthos* hybrids have been successful in producing tetraploids.

Research has also commenced on early embryo rescue, to determine whether hybrid seed can be germinated in vitro if harvested prior to maturity. If successful this technique may enable seed from wide crosses to be rescued prior to aborting on the plant.

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Transplanting an Ancient — The Gija Jumulu Story©

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INTRODUCTION

Gija Jumulu ("Boab" in the Gija language) is the name of a giant boab (*Adansonia gregorii*) that the Gija people of the East Kimberley bestowed to the people of Western Australia and visitors to Kings Park and Botanic Garden in central Perth.

Due to the realignment of the Great Northern Highway in the Kimberley, Western Australia, a large boab tree located in a flood plain at Telegraph Creek (Fig. 1) was destined for removal. Between March and July 2008, a community-based initiative was planned to save this ancient tree. The work culminated on 19 and 20 July as the Gija Jumulu was successfully planted at Kings Park and Botanic Garden, over 3,200 km (Fig. 1) from where it originally sprouted almost 750 years ago.

The journey is the longest land journey of a tree of this size in history. Beyond all expectations the project, received broad local, national, and international media coverage with the tree even entering popular culture such as political cartoons and morning radio. A "boab phenomenon" also occurred on the journey down as people on the road and whole towns stopped to look, wave, and photograph the 36-tonne boab tree making its way through the vast Western Australian outback into metropolitan Perth.

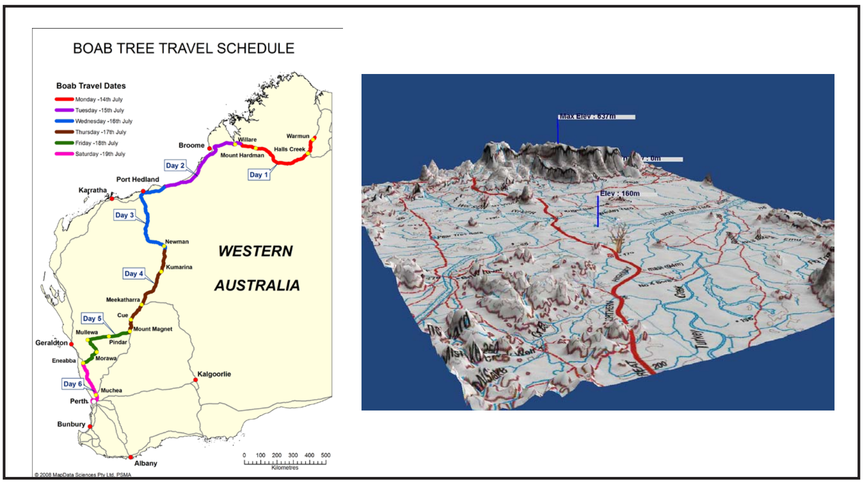

Figure 1. Planned boab journey, July 2008 (left). Boab position on floodplain, Telegraph Creek 3200 km North of Perth (right).

The project's success was based on a number of factors, including: a strong link to traditional owners and community support; detailed logistics and project planning; a strong understanding of propagation, cultivation, and physiology for boab species; and its conservation and educational aspects.

PROJECT DEVELOPMENT

In considering the project, one of the most important criteria for the Botanic Gardens and Parks Authority was that project had strong conservation links and would be a salvage activity providing long-term benefits to visitors of Western Australia's State Botanic Garden.

Integral to the project was the approval and involvement of the Traditional Owners. Shirley Purdie (Fig. 2) and her father (who spoke for the country the tree originated from) both agreed that it was worthy of support. Shirley took the idea to the Warmun community and so the gift was made.

Figure 2. Gija Elders prepare a smoking fire for the traditional smoking ceremony (left). Shirley Purdie (far right of image) and other Traditional Owners — group photo with the Gija Jumulu (right).

The first stage of the project was to determine its feasibility via a detailed logistics and project plan and to canvas a range of individuals and organisations for support. Support for the project was phenomenal with people and organisations taking a positive position from the start.

LOGISTICS

Logistic planning was vital in such a major tree transplant operation, which also involved a 3,200-km transport component. Some of the logistical considerations were:

- Transport 3,200 km by land including police and pilot vehicles.
- 40 power line lifts/inspections.
- Removal of road signs and traffic signals.
- Pruning of trees in metropolitan Perth.
- High/wide load licences.
- Sourcing site equipment in the remote North West of Western Australia.

When collecting plants for Kings Park, only small plastic bags and wet newspaper are generally required. In this case the equipment list included a 75-tonne truck, a 100-tonne crane, a 30-tonne excavator, two dozers, an elevated work platform, rollers, and water trucks.

In order to fit in with the road works master project in the Kimberly and comply with licensed times to bring the high/wide load into Metropolitan Perth, a precise schedule for mobilisation was also vital.

SITE WORKS

The first step was to confirm the extent of the underground component of tree. This was the main unknown factor in the planning process. It was discovered that the soil level had been artificially raised around the base of the trunk by up to 1.5 m due to sand mining and other activities at Telegraph Creek. In addition, a massive root ball below the surface, which had compounded itself into decomposing granite subsoil was also found.

These factors combined to dramatically elevate the estimated weight from the pre-estimate of 14–20 tonne. A new site plan was developed and the team built a hard pad next to the tree to allow a closer crane setup and the ability to lift more weight. This eventually freed the remaining anchored roots and successfully lifted the 37-tonne tree. Once new transport (appropriate for the weight) had been sourced, the project was back on schedule with the tree ready to mobilise within 3 days. Figure 3 depicts the main site processes which were:

- Excavation of roots.
- Cutting root system and applying rooting hormone (Auxinone, standard rate).
- Canopy pruning.
- Releasing tree.
- Double lift onto prime mover.
- Securing load and further canopy manipulation.

With the tree successfully lifted and packed onto the 75-tonne trailer, Shirley Purdie and another five elders performed a smoking ceremony to allow the tree to leave the Kimberley for a safe journey to Perth. The ceremony was a great way to end the project phase at Telegraph Creek.

Figure 3. Excavating root system (A), Pruning root system (B), seed collection (C), lift stage 1 (D), lift stage 2 (E), and group photo — tree prepared for travel July 2008 (F).

TRANSPORT

On the road we soon discovered that the "Boab story" had spread. People waved and photographed the scene as they stopped to allow the convoy to pass by, which was wider than the two lanes.

This phenomenon followed the tree all the way to Perth with all the towns and residents on the way coming out to see the mighty tree pass.

Six days later in Perth, a convoy followed a complicated route through the metropolitan area, which involved a pre-approved series of roads and many power line lifts. Pre-planned works including tree pruning and the removal of road/bus signs and traffic signals, made the journey through the city much easier.

The procession, involving a 75-tonne rated truck, 2 police escorts, 3 pilot vehicles, power line lifters, various media vehicles and helicopters, finally arrived in Kings Park and Botanic Garden to a great reception.

Figure 4. Gija Jumulu travels down the Great Northern Highway (Photograph by P. Stain).

TRANSPLANTING AND TECHNIQUES

The following day the Gija Jumulu was successfully transplanted at the Two Rivers Lookout (Fig. 5), and a welcoming and smoking ceremony was performed by local Nyoongar people to receive the gift from the Giga people and to commemorate the day.

Although every transplant has its own specific requirements, the general technique for *Adansonia gregorii* and most likely other Adansonia species are:

- Transplant when dormant.
- Minimise the diameter of cut roots.
- Try rooting hormone.
- Early preparation to develop a fibrous root system around base could be beneficial (we never had the time to do this due to salvage activities).

Figure 5. Planting the Gija Jumulu in the Two Rivers Lookout, Kings Park and Botanic Garden, Perth, July 2008.

- Do not change the soil level of the tree when transplanting.
- Some people say to keep the same alignment, i.e., north, south, etc.
- Avoid crown damage.
- Do not mulch with organic mulches.
- Try to mimic the condition of the original environment.
- Be careful of watering regimes in the first couple of years (risk of rotting).
- Use wide slings to lift the trees, double lifts for big trees.
- Protect the trunk when moving as scars take a long time to go (if ever).
- Use very coarse river sand to transplant into and provide excellent drainage.
- Where cold wet winters occur try exclusion of winter rains.
- Consider use of a fungicide drench for very valuable specimens.

PROGRESS

Two years on and the Gija Jumulu has made excellent progress towards full establishment, although it will be a decade before this can be fully confirmed. Indications of the trees good health have included shooting and canopy extension in the correct season and most importantly the ancient roots (which had developed in the East Kimberley for over 700 years) have formed new growth and extended a new root system. The tree has flowered both years but no fruit has set — probably due to the lack of a correct pollinator.

These important signs of life indicate that the tree has stabilized after its dramatic upheaval and is acclimatising to its new environment. Recent root examinations have also revealed that cut root surfaces are healing, with important callusing starting to take effect. Where pressure wounds occurred on the trunk during lifting, callusing from secondary xylem (a reported feature of this genera; Fisher, 1981) appears to be occurring due to proliferation of cells in the parenchyma of the pith and the secondary xylem (Fig. 7).

Figure 6. Gija Jumulu at the Two Rivers Lookout, showing full leaf, 2010 season (Photograph by D. Blumer).

Figure 7. Healing signs — callus formation arising from secondary xylem on trunk wounding (left). New root formation off cut end of original root, May 2010 (right).

EXTENSION

Finally the story of the Gija Jumulu comes full circle. Over 200 seedlings from the Boab that were successfully grown by Kings Park and Botanic Garden have journeyed back to the East Kimberly and were planted at the Warmun Community and surrounding areas. *Adansonia* is an important resource to traditional peoples wherever the genera is found. Like *A. digitata* in Africa (Gebauer, 2002), *A. gregorii* is an important food and resource for the Traditional People of the East Kimberley. This was the first urban planting of a native "bush tucker species" at the Warmun Community.

Kings Park and Botanic Garden staff continues to monitor the progress of the tree and provide the very best in cultural care. At this point the Gija Jumulu has responded remarkably to the conditions in Perth and will hopefully continue on its path to its long-term success.

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Propagation of Jarrah Forest Plants for Mine Restoration: Alcoa's Marrinup Nursery©

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INTRODUCTION

Plant propagation has a useful role to play in disturbed land restoration. Alcoa of Australia (Alcoa) operates a nursery and tissue culture laboratory to produce plants for restoration following mining. This paper provides an overview of a 16-year program to develop ex situ propagation and large-scale production methods for plants absent from mine restoration. In Western Australia Alcoa operates two bauxite mines and Marrinup Nursery in the Darling Range south of Perth, and has three alumina refineries on the coastal plain. The principal vegetation of the Darling Range is Jarrah Forest. This forest has at least 784 plant species (Bell and Heddle, 1989) and is part of one of the world's top 25 biodiversity hotspots (Myers et al., 2000). Alcoa aims to establish a self-sustaining jarrah forest ecosystem on its bauxite mine-sites (see Koch 2007a and 2007b for details on the general mining and restoration processes).

With a large area to restore each year (over 550 ha) and such a large number of plant species in the pre-mining forest, any propagation and restoration work is complex. Southwest Australia has a dry Mediterranean-type climate (Beard, 1990), and this further challenges plant propagation for mine restoration. The nursery's entire annual production has to be held onsite throughout the year, then planted in the first 2 months of the short winter wet season. Many of the Jarrah Forest plant species had not been propagated at a commercial scale prior to Marrinup Nursery's production, so considerable propagation research and development has been undertaken since 1990. Propagation supplied 1% of the restored mine pit biodiversity in 1992, and we had less species in our restored forest than occurred in the unmined forest. The opening of a tissue culture laboratory in 1992 allowed research and development to focus on a wider range of species. A concurrent effort occurred in cuttings and seedling propagation.

Mined lands restored in 2000 had a similar number of species as unmined forest (Gardner, 2001) yet still lacked several plants; Alcoa calls these "recalcitrant" species. While most of the plant species in the restored forest were successfully reestablished from the direct return topsoil seedbank, or from the Nursery-supplied broadcast seedmix, over 20% of species were still establishing poorly or were absent. A focus of Marrinup Nursery's research has been on studying the interactions between each species wild biology, propagation, and revegetation survival. Alcoa's mining department is both the propagator and the primary customer for the plants, so the nursery's products need to have proven field performance before large-scale operational production can be justified. The propagation methods chosen have to deliver the highest field survival but at the lowest cost per plant leaving the nursery.

Each year since 2000 Marrinup Nursery has supplied up to 20% of the species found in restored Jarrah Forest by propagating and planting "recalcitrant" species.

Figure 1. Small legumes seed orchard (top), *Chorizema dicksonii* orchard plant (bottom).

Figure 2. Dryland rush, *Loxocarya cinerea*: post-fire re-sprouting (left); tissue culture (centre); nursery crop acclimatization (right).

Four examples are presented demonstrating the different propagation research and plant production approaches we have used to enhance Alcoa's bauxite mine restoration, as an overview of how propagation can be applied to add value to disturbed land restoration.

CASE STUDY 1: RE-SPROUTING SHRUBS

Re-sprouting shrubs are an important element in the forest's ability to cope with frequent forest fires — they rapidly resprout and spread vegetatively after fires. Two shrub species of interest to Alcoa have low seed production so seldom recruit from the topsoil seedbank. This makes them ideal for cuttings propagation, but we are currently reliant on forest fires to provide source material. *Leschenaultia biloba* and *Dampiera linearis* cuttings have a high strike rate and vigorous root production at Marrinup Nursery. We do benefit though from our low summer humidity for propagation success; during rare humid conditions we can get fungal rots.

CASE STUDY 2: SMALL LEGUMES

We must establish nitrogen-fixing plants in the restored mined areas to assist with sustainable nutrient cycling in the restored ecosystem. Many of the small legumes prevalent in unmined forest have difficult-to-collect seed. The plants are often far apart in the wild, plus the seed ripens and is released in 1 or 2 days, often explosively. We have set up seed-orchards-in-pots to make seed collecting at the correct time easier. As a bonus we also get higher seed production. For several small legume species all seed in the broadcast seed mix comes from these orchards.

CASE STUDY 3: FOREST DISEASE

A team from the Department of Environment and Conservation, Murdoch University, Edith Cowan University, and Alcoa identified Jarrah (*Eucalyptus marginata*) individuals with enhanced resistance to *Phytophthora cinnamomi*. These disease-resistant individuals were tissue cultured but the plants proved to be too expensive for broad-scale planting. Enough plants were produced at Marrinup Nursery for establishing large seed orchards. Seed has been collected for the last 2 years and low-cost seedlings have been produced. These seedlings were given to community conservation groups for field testing. We will collect and share the results from these tests as the plants mature.

CASE STUDY 4: GEOPHYTES

What was the problem? Plants with tubers, rhizomes, corms, or bulbs (geophytes) are often absent from disturbed land restoration. The prolonged annual dry season during summer in the southwest of Australia has favoured the evolution of a large number of geophytes in the Jarrah Forest flora. Geophytes are significant for ecosystem resilience (Pate and Dixon, 1982). They rapidly re-sprout from their underground storage organs following fire or drought, which particularly benefits grazing marsupials and minimizes soil erosion. Many of the plant species absent from Alcoa's bauxite mine restoration in 1992 were geophytes.

Large-scale propagation and restoration methods have been developed for 24 species of Jarrah Forest geophytes including *Clematis pubescens*, *Pteridium aquilinum* (syn. *Esculentum*) (Austral bracken fern), two species of tuberous *Drosera* and eight species of dryland rushes and sedges. This latter group will be discussed further as it provided a good demonstration of the key findings.

Dryland Rushes and Sedges. Why did Marrinup Nursery need a large tissue culture laboratory? The first reason was for producing the dryland rush and sedge species of the Jarrah Forest. Most of these species were highly recalcitrant, having very low production of viable seed, so we couldn't establish them from the returned topsoil seed-bank nor from broadcast seed. This left ex situ vegetative propagation and planting as the only viable restoration methods. Cuttings propagation was not possible with these rhizatomous monocots. Division of mature plants did work but growth rates were very slow, producing enough plants each year was unreliable, dividing the plants was very tiring, and the plants were too expensive. Tissue culture was the last realistic option.

Identifying the optimal time for wild seed collection was critical to improving tissue culture initiation success. Embryos were extracted from the few seed collected and placed on filter-paper bridges with half-strength Murashige and Skoog (MS) liquid culture medium using a modification of Meney's method (Meney and Dixon, 1995). When these embryos germinated they were used to establish shoot cultures.

The rushes and sedges were healthy and reliable in tissue culture, but the growth rates were below the commercial minimum of ×3 multiplication each month. These are naturally slow growing species in the forest. This made them expensive to produce compared to other tissue cultured species.

I thought we could produce all plants by in vivo division and remove the species from tissue culture. I'd previously done this at Marrinup Nursery with wetland rushes. The result wasn't as good though, due to the slower growth rates of the dryland rushes and sedges. I developed a comprise method for production where we produce waves of tissue cultured plants, divide them in vivo once or twice, and then plant them all during the wet season. We then start again, with new waves of tissue cultures.

The tissue cultures rooted well on average, but were variable batch to batch. This made production scheduling more difficult. Accommodating and reducing this variation has been an important development area.

It has been critical to acclimatize plants to the field planting conditions. If you produce your plants well away from the restoration sites then they need to be transferred to a nearby irrigated holding site several weeks prior to planting, to adjust to the planting site environment. Unlike the frost-free coastal plain, due to its 260-m altitude Marrinup Nursery experiences hard frosts, the same as the mine restoration planting sites, so our plants are toughened for field conditions.

MAIN FINDINGS

1) Plant propagation has a useful role to play in mine restoration.
2) Production propagation methods were developed for all the Jarrah Forest plant species investigated, but different propagation methods were needed for each species, even within genera. We have to use a very wide range of propagation methods as a response to the complex biology and life histories of the Jarrah Forest plant species.
3) Wild plant biology studies are crucial before commencing propagation. Collecting seed or spore at the optimum time greatly assisted the germination studies.

4) Re-sprouter spreading shrubs typically propagate well by cuttings. Wild shoots collected within 6 months after forest fires produced the highest percent rooting.
5) To get small legumes seed (for broadcast restoration seed-mixes) requires on-site orchards and close attention to collection time.
6) Dieback-resistant Jarrah tissue cultured plants were expensive. Off-site seed orchards provide seed for low-cost seedlings.
7) To improve field survival it is important to acclimatize nursery-produced plants for several weeks prior to planting in the same environment as the planting sites.
8) Tissue culture can be a valuable first stepping stone when developing production propagation methods for species new to commercial horticulture.
9) Tissue culture production can increase the growth rate of species that are naturally slow growing in the forest.
10) To lower the cost of spreading species tissue cultures, we produce waves of tissue cultures throughout the year, then divide each batch several times in vivo prior to field planting. If left in vivo too long plant growth gradually reverts to the slower wild growth rate.
11) Long-term plant spread and seed production in the field are good restoration sustainability measures. For post-fire re-sprouter species high spread rates of surviving plants in the field can "make-up" for any early losses.
12) In restoration projects the "cost-per-surviving-plant" 2 years after planting is more relevant than the nursery plant price.
13) Larger plants had higher restoration survival and spread; they cope better with the first dry season.
14) The adoption of research and development methods into operational plant production is a key research success measure.
15) By working closely with the mine restoration research team over 10 species have been removed from propagation either by developing seed germination treatments allowing use of broadcast seed, or by increased natural recruitment once we started using direct return fresh topsoil on all mine restoration.
16) Integrated study of each plant species adaptive biology, propagation, and revegetation offers considerable potential for increasing the number of species that can be successfully propagated and established in disturbed land restoration.

SUMMARY

- Propagation now supplies 20% of the species richness of the restored mine area. We routinely have more species in our restored forest than occur in any one patch of unmined forest.
- Seventy-nine recalcitrant (difficult) Jarrah Forest plant species (26 families) have been propagated at Marrinup Nursery since 1992.

- We have propagated 1.94 million recalcitrant plants to date and planted them in 6,537 ha of Jarrah Forest Restoration.
- Thirteen external Marrinup Nursery-based research papers have been published to date and seven internal publications as well as two TAFE diplomas and seven university degrees. Marrinup Nursery's internal publications are available for download on Alcoa's Mine Environmental Department webpage: <http://www.alcoa.com/australia/en/info_page/mining_research.asp>.
- Alcoa runs regular weekly mine restoration and mining tours and Marrinup Nursery tours by arrangement.

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If Walt Disney Had Been a Propagator: A Look Outside the Box at How Propagators Can Develop Their Business©

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When I started my career as a propagator in the late 1960s the emphasis was on how to get plants to root. We did not consider the eventual consumer and marketing was something we left to those further up the supply chain.

It is now 2010 and we live in a different world. The propagator who does not understand the consumer or how to market could be left with a batch of rooted cuttings and no customers.

Walt Disney started his business career with a vision. He was an entrepreneur who understood the market and knew how to create the excitement with the product he was dealing with.

Today's propagator has to have the same mentality. The first critical question that should be asked is "How am I going to add value to my customer's life?" According to research that key consumer today is a 35-year-old woman. To get your plant to your consumer may mean that the plant has to travel through a number of agencies in the supply chain before it reaches your consumer.

This is a challenge you have to create a Unique Value Proposition. That means creating something unique that your customer wants to enable you to build your business and then ensuring the various agents in the supply chain can communicate the message to the next person in the chain.

To be successful you have to promote:

- Yourself as the propagator.
- Your business.
- The plant.
- The value the plant offers the consumer.
- Why they should buy this plant now.

This is something that is not unique to you or your business. All successful business operators face the same challenge. The challenge is how you tackle them as a propagator.

Walt Disney's approach would be as follows:

1) **The Propagator Is the Hero in the Chain.** You should promote yourself as the instigator in the process. Farmers are starting to do this and you can now see their faces being promoted in supermarkets. Dutch plant raisers are starting to do the same on their plant labels.
2) **Promote the Business.** It's not the product at this stage in the process that is important — it is your business. Promote its uniqueness, its history, and how it relates to the consumer.

3) **Promote the Product.** Allen Armitage, one of the U.S.A.'s plant guru's understands what marketing is all about. His latest book is "Legends in the Garden, Who in the World was Nellie Stevens?" He understands that the customer buys stories. He provides the stories behind the product. This is where the propagator has a huge opportunity. One group of growers in the U.S.A. has started "The Graceland's Collection" celebrating Elvis Presley, "The Kennedy Collection," and "Survival Elm" based on the elm in Oklahoma that survived the bomb terrorism in that city. Why not start the "Steve Irwin" collection or even the "Dame Edna" collection. (If you're wondering, Nellie Stevens is an American holly named after a plants woman.)
4) **The Value.** We have recently seen the discount wars across the world as retailers have tried to generate sales. This has been a challenge when prices generally this last decade have increased by 30%. Discounting does work, especially when selling a newspaper, petrol, rice (in some countries), and Coca Cola. These are what are called Known Value products. The consumer believes they know the exact price of the product. When it comes to plants, they are non-known value products. Our job is to sell the benefits if we want to increase sales.
5) **Why Buy Now.** "The best time to buy a tree was 10 years ago; the next best time is now." I love this saying as it creates urgency. We need to create these "WOW" urgency messages to get people to buy now.

SO WHAT WOULD WALT DISNEY DO?

If Walt was alive today and giving this paper, I believe he would be giving us four simple messages:

- Become a hero in the consumer's mind
- Put the story together for the consumer
- Sell the value of the offer
- Create the urgency

Remember, the grower and retailer are "vehicles" to get to your end consumer. They are not your customer. You have to please a 35-year-old woman.

The Benefits of Early Summer Grafting of Japanese Maples©

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In the nursery trade there is a fine line between what makes a plant profitable or a liability for a business. Just because a plant sells and is popular does not necessarily make it a profitable product. With the production and sale of a living product there are a multitude of factors that can affect a plant's profitability. As a production nursery an important role for us is to manipulate and control these factors and use them to our benefit, and in effect produce a profitable product using sustainable practices.

My study explores the limiting factors of growing Japanese maples and shows how small changes in the propagation and growing methods can improve the efficiency of growing this popular group of plants and increase the profit margins.

Firstly, let's look at what we define as a Japanese maple. The term Japanese maple is used to describe all 23 species of plants in the genus *Acer* that are endemic to the islands of Japan. In the nursery industry and in the case of this study it is accepted that the term only includes the most popular and most ornamental species of *A. palmatum* and *A. japonicum* and all of their cultivars; this is due to their relevance in commerce and general garden popularity. Japanese maples are deciduous trees and shrubs that are at their best in a cool temperate climate where they are valued for their beautiful foliage and outstanding autumn colour. There are currently hundreds if not thousands of cultivars available in western horticulture with J.D. Vertrees book *Japanese Maples* (2001) listing over 300 cultivars of significance to gardens and to the horticulture industry. Currently Jubilee Nursery has 113 different Japanese maple cultivars in their stock gardens. A core selection of around 50 is grown each year, with a selection of the remaining cultivars grown in alternate years.

The most common method of propagation of Japanese maple cultivars is by grafting. Although cuttings can take root, they generally do not survive the first winter and those that do tend to be weak on their own roots. The current practice at Jubilee Nursery is a side graft on to 2nd year *A. palmatum* seedlings that have been potted into a 140-mm pot. This takes place from mid-January until the end of February. After a successful union between the scion and rootstock has occurred (about 2 weeks) the rootstock is cut back by about half to expose the scion to more light and to increase air circulation. The scion remains dormant until the following spring. In spring when the scion breaks dormancy the rootstock is cut back completely and the plants are potted into 200-mm pots for growing on. The faster growing cultivars (i.e., 'Sango-kaku', 'Seiryu') are usually ready for sale in January with the slower-growing cultivars around March or in some cases the following spring. The average growing time from grafting to being ready for sale is 12 to 14 months.

There are several problems associated with the current method used, some that I have identified are:

- Large rates of losses over winter. Up to 30% of scions that have successfully made a graft union with the rootstock can be lost due to the scion not hardening off before winter.

- Timing of plants ready for sale not coinciding with peak spring sales period. Although plants are ready for sale 12 to 14 months after grafting the majority of plants are not sold until 20 months after grafting when sales are at the highest. At Jubilee Nursery our records show that the peak sales period for Japanese maples is spring, between the months of September and November.
- Large amounts of time on the ground requiring maintenance. This includes watering, weeding, and fertilizing.

Over the past 2 years I have conducted preliminary trials where I have found that by grafting plants in the 2nd week of December it is possible to force plants into growth before the onset of winter. This is achieved by the following changes to the current practice:

- Earlier timing of grafting (up to 1 month earlier).
- Placing the grafts in a poly tunnel or glasshouse. This provides larger levels of humidity and higher temperatures.
- Cutting back rootstocks completely as soon as the graft union has taken place.
- Potting plants into 200-mm pots at the same time of cutting back of rootstocks.

This practice encourages the plants to begin growing actively at the time of potting, with development of new growth of the scion and new growth of roots. It also leaves enough time for the young plants to harden off before winter. The results of this practice have significant benefits to the profitability of this crop and address problems associated with the current practices by:

- A reduced rate of losses over winter. The small plants harden off more successfully than a dormant scion and have more buds to grow from in the spring. The benefits include a greater degree of accuracy from propagation planning. This means not having to graft many more plants than the desired number just to compensate for expected losses. This reduces costs of both products and labor.
- Reduced growing period before plants are ready for sale. These plants seem to come into leaf earlier and an already established root system sees faster-growing cultivars ready for sale that spring. This sees faster-growing cultivars such as 'Sango-kaku' and 'Seiryu' ready for sale only 10 months after the grafting process and ready for peak sales periods of Japanese maples in their first spring compared to their second spring. Ultimately this means less maintenance, less fertilizer, and less water. An overall reduction in product and labor costs.

Over the past 2 years my trials included grafting 1 of each of 20 different Japanese maple cultivars in each year. Due to the large number of cultivars that Jubilee Nursery grows I felt it important that the initial trials include a cross section of our Japanese maple inventory. By including cultivars with different growing habits I was able to assess the potential for the future application of the proposed changes. In the first year 18 out of 20 grafts were successful. In the second year the process was repeated using another 20 different cultivars with 17 out of 20 grafts being successful. All the grafts that were successful grew away before the onset of winter. All of these plants survived through winter and broke dormancy in the following spring.

The successful propagation of a large number of cultivars over a small number of plants propagated is encouraging. This year larger trials will be carried out and will include 200 grafts of the most popular cultivars of Japanese maple. Ten different cultivars have been selected and twenty of each will be grafted. The results of this trial will be indicative of how the new process will perform under commercial application.

It is my belief that these trials will be successful and assist in further refining this process. The potential benefits in reducing costs and improving the efficiency of growing this crop will increase profit margins considerably. It is my hope that these changes will be implemented in the yearly propagation plan at Jubilee Nursery.

Gidday!©

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As the Southern African IPPS Exchange Student, I was asked by the Southern African Region of the IPPS to speak to you about my involvement in horticulture thus far. I completed my studies in horticulture last year obtaining my bachelor of technology which is a degree in most countries terms but the equivalent of honours in our terms. I will take you briefly through some sights of Cape Town and images of my work experience to date.

I'm not sure if anyone here realises how important this opportunity is for me. As you heard last night, I have never left South African shores and to have been invited by people far away from my home, to attend a conference dealing with something I am deeply passionate about as well as being welcomed and befriended by such warm, kind people is an absolute honour! As it is, while travelling from Johannesburg to Perth, without even blinking, Australia gave me 6 h of my life that I previously never had! I understand, of course, that I have to give it back when I leave but thank you for that so long. I have been in Australia for 4 days now and every one of you has made me feel completely at home.

I recently travelled through some southern African countries, namely Namibia, Botswana, Zimbabwe, and Zambia with some friends. While we were travelling I read a book on Australia called "Down Under" by the literary master Bill Bryson to try and get some inkling of what I was in for. In the opening pages he speaks of Australia as (and I quote) "the driest, flattest, hottest, most infertile and climatically aggressive of all the inhabited continents and still it teems with life — a large portion of which is quite deadly." He goes on to say, "in fact, Australia has more things that can kill you in a very nasty way than anywhere else." What followed these opening pages was a wonderfully humorous description of the people, cuisine, culture, and history of the last 250 years of civilised development. He also speaks about the wonder of horticultural development on this continent of which most of you and, of course, a handful of generations before you are responsible for.

These opening words really struck me and through my travel, especially through the more politically war-torn countries, is how completely immersed Africa is in natural resources. We have huge horticultural potential that could really boost the economies and well being of our people but what we really require is the interest and guidance of more advanced systems and the educated support of our neighbouring countries. South Africa, I feel, has the potential and infrastructure to make huge contributions to the more northern territories but the correct guidance needs to be supported by shared knowledge. What the Australian IPPS is doing to enhance this potential for South Africa cannot be more important for us. You are creating an invaluable window for us to learn, seek, and share information in possibly the most important industry for our current times. It is my opinion that Africa will be called upon to support the world in future times and it is our duty to mankind to have valuable systems in place for the nourishment of our world.

I know that my time here is short. I will however make sure that it is well spent and I plan, in every way, to make the most of this opportunity and hopefully be able to take back a wealth of knowledge and insights to my country. I need to thank so many people for the fact that I am standing here in front of you and I hope to do that through action rather than words in doing what the IPPS has set out to do for the past 60 years. To Seek and Share.

Thank you.

2009 Australia / South Africa Exchange IPPS Paper

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INTRODUCTION

My name is Dan Austin, I work for TAFESA at the Urrbrae Education Centre in horticultural facilities and more recently as a lecturer. In 2009 I was the IPPS Southern African Exchange participant. I was lucky enough to split my time on the exchange in S.A. staying in two very different climatic zones. After a quick stop at Johannesburg I was on to Durban, Pietermaritzburg, and Umpholozi for a week. This area has wet summers and dry winters and I found, has a much stronger African feel than Capetown where I spent the second leg of my journey. Finally, the conference was held an hour or so out of Capetown at a whale-watching town called Hermanus. I got to study many nurseries and sites of horticultural significance and the photographs have already been put to use as teaching resources for classes. During the trip I was given exposure to:

- Nine production nurseries, three forestry nurseries.
- One succulent nursery, four retail garden centers.
- Two advanced tree nurseries, one nursery tradeshow.
- Two forestry trial sites, two tissue culture labs.
- One roof-top garden, three game reserves.
- Three botanic gardens, one edible and medicinal plants tour at Kwazulu Natal University.
- One meeting with hydroponics students at a technicon.
- And much more.

On the journey I also was able to study the native flora. Some of the most noteworthy included the:

Flat top acacia (*Acacia abyssinica*) and flat crown (*Albizia adianthifolia*). The flat tops of Africa are fantastic. I got off the plane in Durban and they were everywhere. I naively thought they'd be in Capetown too but I was wrong so I missed out on photos.

Sausage tree (*Kigelia africana*). This is a strange one, the oil is sold as a remedy for skin cancer and the woody fruit can be several kilos.

Fever tree (*Acacia xanthophloea*). This tree is almost luminescent green in the right light; it got its name because settlers sleeping under it often caught malaria as its canopy creates a nice humid microclimate that mosquitoes seem to enjoy.

Ghaap (*Hoodia gordonii*). *Hoodia gordonii* is an unusual little succulent. It has been used by native people as an emergency food and as a thirst and hunger suppressant and there must be some truth to is because pharmaceutical companies are now processing it for weight-loss pills.

Natal plum (*Carissa macrocarpa*). This one is common in Australia but I've included it because I had always wondered why it was called a Natal plum. I had to go to South Africa to realize its pronounced Naataal plum after its native province Kwazulu Natal.

Capetowns fynbos was also in flower while I was there, and seeing this showy plant kingdom really was worthwhile. There were absolutely stunning fields of hundreds of species all in bloom.

Other than studying plants I also gained an insight into the South African nursery industry. Some comparisons I drew include the workforce — much is done by hand with very little mechanization. There was a lot of road repair happening in preparing for the World Cup when I was there, It was happening mainly without machinery just teams of around ten with hand tools to dig up old bitumen. I saw the same thing in a massive trenching project for a high speed broadband cable across Durban. It was interesting to see something as modern as broadband being made possible through labour-intensive methods now uncommon in Australia.

One initiative that I thought was a great idea was at Shadowlands Nursery where a trainer comes to the nursery and teaches formal lessons to workers on site and I believe the training is recognised similarly to what we call accredited training.

The other difference in nurseries I noticed were the innovations nursery managers had come up with. From a nursery next door to an ostrich farm where someone had incorporated broken ostrich eggs and plants into a novel new product, to another utilizing the nutrient-rich wash water from a nearby chicken farm for irrigation.

Mike Kruger has to be the king of innovative thinking. The innovations at "Top Crop Nursery" could fill a book. How do you maintain plugs of turf? Keep them on the ground and mow them with a lawnmower. Mike doesn't actually sell much turf as plugs; he has a machine that cleans and cuts them into pieces that are bagged and sold to be spread like seed. The leftovers in the machine are then spread onto new trays to start the process again. Other S.A. innovations included using toilet roles as tubes, eliminating moving parts in misting sensors and using a conductivity sensor to gauge moisture instead.

I'm involved particularly in the hydroponics program at home at the Urrbrae Education Centre, so it was great to visit hydroponics students at a South African Technicon and was interesting to see how many nurseries were incorporating hydroponics principles. From an Airoponic method of producing eucalypt cuttings using no media only fertigation to a Brazilian gravel bed system the SAPPI Forestry Nursery was using to grow their eucalypt stock. Because of the availability of coconut coir I saw many nurseries producing cells or saleable products using only coir and fertigation, basic hydroponics! I also work closely with rooftop gardens and the vertical farming concept, so it was fantastic to visit a very successful example of a rooftop garden on top of the multi-storeyed environment ministers building in Capetown.

Another highlight was the time I got to spend learning about tissue culture from mixing agar solutions to sterile environment plant division and growing on. I also learnt hardening off methods for tissue culture plants, methods for exportation, and methods for lengthening daylight.

The final contrast worth mentioning was our countries weed exchange. I found it interesting that while Australia has adopted many of South Africa's smaller often herbaceous or bulbous plant species now considered weeds, South Africa seems to be facing a similar problem with our larger tree species with *Eucalyptus*, *Melaleuca*, *Allocasuarina*, and *Acacia* species all causing significant problems as weeds.

All in all the trip was an unbelievably rewarding experience I won't forget. I sincerely thank all those within The International Plant Propagators Society that contributed directly or indirectly to my exchange. I hope to have the opportunity to return the favour in some way in the future.

South African Exchange 2010©

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INTRODUCTION

From 1 May to 21 May 2010 I visited South Africa as part of the IPPS exchange program. I had some idea of what I was in for before I left Australia, however I was still amazed at some of the things I saw and did.

South Africa has an official population of around 50 million; however I was told unofficially it would be closer to 70 million. The extra 20 million unaccounted comes from illegal immigrants coming over the border to find work. When I first arrived in Johannesburg I saw many wonderful housing developments, shopping centres, and other life style developments. At this point I thought this is a good sign; however I was then told that the global financial crisis (GFC) had hit the country quite hard. Many of these housing developments had come to a halt and very few people shopped at the new shopping centres.

MAJOR DIFFERENCES IN THE INDUSTRY

While touring around many of the nurseries I visited (close to 20) I was able to obtain a good idea on how different the Australian and South African nursery industries are. The major difference was the labour usage. Since the labour is so cheap in South Africa nurseries aren't concerned in hiring more staff to keep production moving. In some cases they don't even interview there staff before hiring them.

There is an increased number of staff used because the nurseries in South Africa aren't mechanised like some nurseries are in Australia. In South Africa they would use 10 (or more) people to do what 3–4 people and a potting machine would do in Australia. One staff member told me that they hope nurseries don't start using machines because it will put many people out of a job.

The main question each owner would ask each other when they would meet was "how is the new potting mix formula/pre-mixed bags going." The reason why they would ask this is they don't have access to potting mix like Australia does. Most would mix their own using various ingredients including: Fresh saw dust, pine bark shavings, quarry dust, compost, soil, and the list could go on. Many nurseries have tried to use composed pine bark, however the grade and quality is too inconsistent. Coir is starting to be used quite heavily in many mixes; again quality is an issue (salt levels).

Access to material in general was an issue for all nurseries I visited, in Australia we can call our nearest supplier and have the product at our door step in 24 h. In South Africa many products come from overseas and require many months notice before the product is needed. Cheap, Cheap, Cheap. I think this would be what most nursery owners would be thinking, however in South Africa the term "cheap" can sacrifice the "quality" of the plant. The term quality is at a different level to what it is in Australia. Some nurseries I visited just want to mass produce their product quickly and cheaply and still sell their product. I would be guessing that the customer wants a cheap product and isn't too worried what it looks like.

LIGHT AT THE END OF THE TUNNEL

After attending the IPPS conference in South Africa I realise there was so much enthusiasm surrounding this industry. Many of the delegates were talking about what improvements they would be making to their businesses once the economy improved. Some mentioned they might even start to look at mechanising parts of the nurseries. Others said it would be good to put some money back into their businesses for general improvements (clean up, weed control).

Labour control and knowledge of what tasks were being undertaken was lacking, however Sittig Nursery was one of the leaders in this area. Hans Sittig was one of the only owners I met that had an idea on what was going on in his nursery. Before Hans would implement any new processes he would see if it needed to be changed or if the new process was more efficient.

Arnelia Nursery also was like a well oiled machine, Hans Hettich and his team run a tight ship. The main reason I was so impressed with Arnelia was the innovations which Hans introduced to his nursery. Hans knew exactly what he wanted, however South Africa couldn't supply everything for him. So instead of giving up he would work out a way of doing it himself.

RETAIL

I didn't just visit production nurseries while in South Africa, I had the opportunity to visit a number of the retail nurseries. The retail nurseries were struggling as much as the production nurseries, one owner said to me he couldn't wait for the bulbs to come into the store then he could start getting some income. Some retail nurseries started to open cafes to bring more customers in; unfortunately most would only come in for a coffee and not buy any plants.

Marketing was lacking in the retail stores, plants would be grouped depending on type. There was very little colourful signage and plants generally looked boring. There needed to be more excitement surrounding the plants.

This trip was such a great opportunity for me to be able to see how another culture tackles what I would consider a tough but exciting industry. There looks like there are so many possibilities in this industry and once the public understands that a plant is more than just a thing in a pot, it could open so many doors for the South African industry.

The Principles of Bio-Dynamics©

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INTRODUCTION

The principles of bio-dynamics were first proposed by Rudolph Steiner in the early 1920s. Steiner is also well known for his philosophy on education — Steiner Schools.

He proposed that soil structure could be improved by placing green cow manure in a cow horn and burying it for a time. This burial takes place between April 21 and June 21 each year. In Western Australia approximately 150,000 cow horns are buried each year. The horns are filled manually with fresh green cow manure collected from the paddock where the cows have been bedded for the night. Each horn is filled to the brim with manure and carefully placed in a well drained pit. The horns do not touch each other and are positioned so that if any moisture were to seep through the ground it passes over the horn and doesn't flow into it. The shape of the horn is such that the opening naturally slopes down. The horns are lifted in September/October. What happens during this time is amazing. The green sloppy cow manure undergoes a complete metamorphosis.

This is stored in a wooden bin encased in moss to insulate it. It should keep for a couple of years providing the location is cool and occasionally may need a sprinkling of rain water over the top of the 500. We then utilise 1.5 oz of 500 mixed in 3.5 gal of water and this is sprayed over 1 acre. The way that it is mixed was also proposed by Steiner. The mixing vessel is cylindrical with a concave bottom and a paddle driven by electricity is rotated with a rounded shoulder. When this is achieved the paddle is reversed creating a chaos and the action is repeated again and again for 1 h. The 500 must be sprayed onto the pasture within 1 h of having been mixed. It is sprayed at a time when there is moisture in the soil and if a pasture like clover, rye grass, legumes, etc. have germinated but soil can still be seen between the plants. We utilise a diaphragm pump at 8 psi to pump the 500 onto the pasture as it is far gentler than a centrifugal pump. The 500 solution is alive contains up to 75% by volume of beneficial bacteria and is known as a concentrated bacterial interforce.

We also believe bio-dynamic compost complements the 500 spray. The compost heap is made on the ground with five bio-dynamic preparations inserted into the heap. The preparations are amazing in the way that they get the heap composting.

The compost is also sparingly spread over the pasture. I must say that before we put out the 500 we deep ripped the entire property in the summer to a depth of 0.6 metres to break up any hard pan caused through years of conventional farming practices. On our property, by putting out a 500 spray each summer/autumn together with compost application the soil structure has changed markedly.

Soil structure is important because we want the roots to go down to access the minerals and nutrients that are already down there. These roots also help the plant to drought proof itself. We also promote minimal tillage and encourage the worms to do our tilling. That gives you a small understanding of bio-dynamics and some of its principles.

NOW WHEN DID WE GET INTO BIO-DYNAMICS?

In a previous life I was a bank manager for some 37 years. I was stationed in a South West country town and loved working on farms on a weekend. It was when I discovered just how much fruit and vegetables were grown utilising Dieldrin as a pesticide. The cattle ate the grass grown on these properties after a vegetable crop and also ingested the Dieldrin. We eat the fruit, vegetables, and meat, and we take up the pesticides. This particular town, I was told, had the highest number of birth defects in Western Australia. Was it due to their farming practices? I believed so, and my wife and I decided to only eat what we could grow in future as we had three small children at the time.

We purchased 6.5 acres in Swan View and established a bio-dynamic commercial orchard growing some 46 types of fruit as well as our own vegetables and ran six cows and a couple of pigs and our own chooks. I had the head of the local Department of Agriculture Research Station visit me every year, and when he left he told me that they should be following the principles I was utilising as I was growing fruit that they themselves couldn't get to fruit in their Carnarvon Research Station. Bio-dynamics really works.

When I retired from the bank we concentrated on our Muchea property although all the hard work such as power, irrigation, etc. had been completed or so I thought. Muchea some 20,000 years ago was under water and where we live was an inlet with sand dunes to our east. The land is very flat and when we purchased it, it was pure beach sand. No body and no structure but we have plenty of ground water beneath. You cannot dig a hole 1 m in summer without it filling up with water. Great for the vegetables in summer but no good if you want to put in foundations for a shed or a composting toilet etc. One of our major problems is in winter when the ground water rises and this causes a separate set of issues for the vegetables. We have had to shift our main growing area twice. We now mainly grow brassicas during winter as they can withstand waterlogging for a few days. We have heaps of frogs which just prior to rain sound brilliant but with frogs we have snakes. Mainly tiger and dugites and it is not fun picking zucchini in summer and constantly coming across a tiger snake in the bush or wrapped around the lettuce.

We did grow bush beans at one stage but the tiger snakes loved settling in the plants and we had a number of scares and near misses, so we no longer grow bush beans. Another pest was the 28 parrots stripping our plums, apples, apricots, etc. so we trained our cattle dog to flush them out or tell us we had them in the orchard. We eventually netted the orchard with a 6-m high structure. We no longer have a bird problem and harvest all of our fruit. Crows and kangaroos eat melons as do foxes. Again, our dog now keeps the majority at bay.

Ideally we should spray our vegetables with 500 every time we construct a new planting but this is not always practical. It took us 4 years to get Muchea certified and you would not recognise the property. Our pasture is greener than our neighbours earlier and holds on for at least 1 month longer in summer. The soil colour has changed from beach white sand to grey and even rich black. The garden is the most noticeable. The soil has structure to a depth of 0.75 metres and is rich black. The reason being that it has had a lot more applications of 500 as well as our own compost. We utilise a lot of green manuring in the garden and even compost with lucerne which we grow on the property. Once a crop has been harvested it is also turned back into the ground. We also use a natural mineral mix from Western

Minerals that contains all the trace elements but no phosphate. During the past 14 years we have put out 1 ton application of rock phosphate over the entire property.

Over the summer months we collect our own cow manure for our compost heap. We also keep a few pigs to take care of any seconds fruits and vegetables and in turn utilise their manure in our compost. The pigs have their own septic system and everything is pumped back into the compost heap. Thankfully we do not have any problems with mildew, black spot, blossom end rot, etc. As I mentioned earlier our biggest problem is snakes.

We are very conscious and aware that we are exporting our minerals out through the front gate and this is why we rely so heavily on our stock to provide the base essentials for our compost. We have numerous requests and enquiries for our manure but all are turned down. Bio-dynamics works and you can physically see the difference in the soil structure and the plants. We do get a great number of enquiries and have two converts who are also both in conversion in Muchea growing commercial bio-dynamic vegetables.

Why do we do it? Sometimes I ask myself that very question. At first the ridicule was pretty heavy particularly when you are a bank manager talking and meeting with conventional farmers and market gardeners. But now people are starting to realize that conventional methods are not working and there has to be an alternative. Sure you don't grow as much as a conventional grower but you grow quality that you can see and taste. The shelf life of bio-dynamic produce is much longer. I say to all my customers who purchase our lettuce that I will put in writing that my lettuces will last at least 2 weeks in the fridge and look just as good as the day they put it in. We don't encourage it though as we should all eat fresh seasonal food.

Bio-dynamics is a way of life in which you are always striving for perfection. Because it is very labour intensive you cannot afford to waste time and when you do something you do it right the first time without having to repeat the process. We try to work smarter. The way we farm now is totally different to the way in which we started.

One example of this is that we now grow vegetables such as carrots, coriander, radish, parsnips, kohlrabi, horseradish, onions and Mediterranean varieties of garlic in raised beds. These beds are 50 m long, 1.8 m wide and 0.9 m high with a concrete path around each bed. These beds are made of concrete 10 cm thick. The bottom is open to the natural ground level. This method, although expensive to set up, saves a great deal of bending when planting, weeding, and harvesting. My knees are totally shot working in the garden 10–12 h per day, but with these types of vegetables it is very rewarding as my last job of the day is to stand there and weed without any discomfort. We have had to invent new ways of dispensing the 500, but now have this covered and it is working very well. It is our plan to increase the number of beds and in turn be in a position to still grow our own vegetables for the household when we finally retire from the garden.

The knowledge we have gained over the past 25 years cannot be dispensed in 20 min at a session such as this. For anyone starting out I would say to them that you need commitment. Water is vital to any farming venture so choose your location wisely. Don't be so concerned about the soil as you can make and improve any soil utilizing bio-dynamic principles. Do make sure, however, that the soil isn't contaminated with nasty pesticides or chemicals. The first thing to do is to deep rip the property to the greatest depth possible in summer with the rip marks being no greater than 2 metres apart.

Utilize minimum tillage on your property as much as possible. Do not use a rotary hoe in heavy or clay soils as you will polish the bottom and not allow water to flow down and encourage deep rooting by your plants. Do not be in a hurry to put in fence lines. Talk to the previous owners and neighbours about floods, droughts, prevailing winds, etc. Do fence water courses. Select what you intend growing very carefully. Perhaps plant a trial plot of a number of vegetables to ascertain what grows best. Contact the Bio-dynamic Research Institute in Powell Town, Victoria, to put you in touch with your closest mentor. Learn from experience and don't make additional work for yourself. Once you have a satisfactory product seek out your market.

Farmers markets are excellent as each customer has the ability to give you feed back. Actively seek this communication and adjust accordingly. Stay focused and you will reap your rewards.

Integrated Pest Management in Western Australia©

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INTRODUCTION

Integrated Pest Management (IPM) is a method used to control insects and diseases in horticultural crops throughout the world.

Manchil IPM Services Pty Ltd (Manchil) is a Western Australian company that produces three types of beneficial bugs and mites that are distributed to growers around Australia. The use of beneficial insects is significantly increasing as pest insects are becoming more resistant to older chemistry and safety issues related to the use of toxic chemicals gain greater public awareness.

Manchil also runs a crop monitoring service checking grower's farms for pest insects.

Manchil is a member of the Australasian Biological Control Association (ABC), which seeks to encourage growers to gain accreditation that enables them to exhibit the IPM logo on their fruit and vegetable produce.

BENEFICIAL INSECTS (PREDATORS)

Orius armatus.

Orius armatus is a predator of various species of thrips (larvae and adults) especially Western flower thrips (WFT). In the absence of thrips *Orius armatus* can survive on aphids, spider mites, butterfly/moth eggs, and pollen. *Orius* is a native to Western Australia. Manchil has recently developed a technique for the mass rearing of the bug under laboratory conditions at its insectary facility at Muchea, Western Australian (WA).

Crops Suitable. Worldwide, *O. armatus* is used to specifically control thrips in capsicum crops. Strawberries, gerberas, and eggplant are also suitable. Crops that produce flowers with pollen and that are not immediately harvested are best suited for *O. armatus* use. Roses for example, whereby the heads open and are cut regularly, are not suitable for *O. armatus* use — with the exception of potted roses that are allowed to go to open bloom.

Description. *Orius armatus* has seven developmental stages. The female lays its eggs in the plant tissue of the stem, fruit, petiole, and major veins on the underside of the leaves. The development time from egg to adult is about 16–18 days at 25 °C and 12 days at 30 °C. At a temperature of 20 °C, *O. armatus* can kill about two thrips a day. When the pest population is high, it will kill more thrips than is required for its nutritional needs. Adult *Orius* have good flying capabilities and move quickly, which helps considerably in finding new prey and in dispersing within the habitat.

How to Use. *Orius armatus* is supplied to growers in units of 1,000 adults and nymphs, contained in a 500-ml plastic bottle of mixed vermiculite and buckwheat husks.

Monitoring. *Orius armatus* is light sensitive, therefore during the cooler darker periods of the day *Orius* will hide more in leaf tips and stems. They are more active in the middle of the day as indicated by the red staining that it secretes onto the white petals of capsicum flowers when feeding in the flower.

Once *O. armatus* has been released for 3–5 weeks, juvenile *O. armatus* will appear and will have a red dot on their backs during the early stages of their growth. After 3 months it should be found throughout the greenhouse.

Phytoseiulus persimilis.

Persimilis is a predator of all spider mites, in particular two-spotted mites (*Tetranychus urticae*) (TSM), also referred to as spider mites and bean spider mite (*T. ludeni*).

How to Use. Persimilis is now supplied in a pure form in 500-ml plastic bottles of mixed vermiculite. Previously, the mites were bred on bean leaves and transported with the leaves in paper bags together with the food source of TSM. This new method has the advantages of being free from any contaminants, more easily applied and cheaper to transport. The vermiculite is sprinkled at random over the plants and released at higher rates in spider mite hot-spots. Manchil can still produce persimilis in leaf form at a grower's request.

Neoseiulus cucumeris.

Cucumeris is a predator of thrips, particularly WFT (*Frankliniella occidentalis*), and broad mite (*Polyphagotarsonemus latus*).

Crops Suitable. Cucumeris does well in humidities above 65% and in crops with heavy foliage. It is used successfully in many protected crops, including tomatoes, capsicum, greenhouse vegetables, cut flowers, ornamentals, and strawberries. In capsicums *Orius* should be used in conjunction with cucumeris to gain total control of thrips.

Description. This predatory mite has been produced commercially for many years in Europe and for over 5 years in Australia. It feeds on the larval stages of thrips and some mites. It is part of a large group of predatory mites called phytoseids.

The adult predatory mite is cream colored, while the younger stages are clear. Both forms are pear-shaped and fast-moving. Predator eggs are clear and slightly oval and about 1.5 times the size of a two-spotted mite egg. Cucumeris feed on 1st and 2nd instar thrips larvae.

HANDY TIPS

For thrips, only the tiny, first-stage larvae are eaten, so it is important to release predators early, and to control adult thrips by trapping them with sticky traps and/or by screening vents and doorways to prevent swarms from entering the greenhouse. In cucumbers, different thrips species prefer different plant strata. Release mostly on lower leaves for onion thrips and upper to middle leaves for thrips. For broad mite, release in growing tips. Go for overkill of pests by releasing often. For thrips, use with Hypoaspis-S and nematodes applied at ground level.

MONITORING

Manchil provides an insect and disease monitoring service for most horticultural crops. Depending on their location, farms can be monitored on a weekly, fortnightly, or monthly basis. Manchil technicians monitor crops by checking leaves, fruits, flowers, and stems for beneficial insects and pests. On the day of inspection the grower is handed a printed report showing details of pest and beneficial numbers present, along with comments and recommended control actions — which may include soft chemical selections or biological control options.

Manchil monitors a range of horticultural crops which include; strawberry crops with cultivars such as Camarosa, Gaviotta, Albion, Calmino Real, Selva, and Aromas. The monitoring season ranges from May to October in Perth and until December in southern regions of WA. Greenhouse strawberry crops are monitored throughout the year especially with growers using heating in winter. Cut flowers such as roses, gerberas, carnations and greenhouse vegetables such as cucumbers, capsicums, tomatoes, and egg fruit are also monitored throughout the year. Field crops such as sweet corn, tomatoes, lettuce, capsicums, and nursery roses are monitored mainly from September through to April.

AUSTRALASIAN BIOLOGICAL CONTROL ASSOCIATION

Manchil became a member of the Australasian Biological Control Association (ABC) during 2004. This organisation was established in 1992 for the purpose of facilitating co-operation and information exchange between professional horticulturists and the companies producing beneficial arthropods for horticultural use. There are currently eleven members from Australia and two from New Zealand.

IPM ACCREDITATION

The ABC is currently implementing an IPM accreditation scheme.

- Crop consultants are assessed by experienced members of the ABC and, if proven suitable, are then able to nominate selected growers for accreditation.
- A grower must meet a set of criteria that demonstrates that they are making a significant effort to incorporate biological methods and minimise disruptive chemical controls in their pest management programs.
- Accreditation by ABC enables the grower to use the IPM logo on their product. This logo is a measure of a high level of commitment to IPM and the need to reduce chemical inputs and minimise environmental and human health impacts.

TECHNICAL SESSIONS
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NEW ZEALAND REGION

Thirty-Ninth Annual Meeting

May 27–30, 2010

BLENHEIM, NEW ZEALAND

Twenty Years Watching Rootstocks©

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INTRODUCTION

Many things in gardening and the nursery industry are done by tradition, but many of these practices are also based on availability of raw materials or local conditions. The available choice and use of rootstocks for *Magnolia* grafting is no different. In this article I plan to discuss the extended observations originally developed in a paper I published in 1990 as well as current practices in *Magnolia* grafting. The results of course are based on our conditions, but by extrapolation in plants exported from New Zealand, it has international implications.

REFINING THE ROOTSTOCK CHOICE

In 1987 I joined the New Developments Department at Duncan and Davies Nurseries in New Plymouth. At this time *Magnolia* taxa were undergoing a resurgence in popularity with the importation of new taxa as well as the locally produced hybrids. Many of these hybrids have a degree of *M. campbellii* type parentage, which means they have a tendency to outgrow the stem diameter of their rootstocks. Observing how the wide range of hybrids had different caliper growth rates due to their parentage, trials were undertaken to determine if it was possible to develop a set of recommended rootstocks to best suit the various hybrids. Duncan and Davies was at the time producing a wide range of *Magnolia* taxa from cuttings, and this meant there was an opportunity to trial several of these for rootstocks. The export market was a significant part of the overall production, so the preference that some customers have for the use of *M. kobus* as a rootstock had to be considered. To address this part of the equation we were able to trial *M.* ×*loebnerii* hybrids as a substitute, which worked well as most of the hardy hybrids had a similar caliper growth rate. An added advantage of using *M.* 'Merrill' was that it did not suffer from root disease as much as *M. kobus* seedlings tended to in our soils. At the other end of the scale the heavy wooded hybrids like *M.* 'Mark Jury' and *M.* 'Caerhays Belle' were trialed on *M.* 'San Jose', which has many features that suggest it is in fact a *M.* ×veitchii type hybrid. When grafted with *M.* ×veitchii the union was seamless, and as a stock for *Magnolia* (syn. *Michelia*) *doltsopa* 'Silver Cloud' it proved ideal.

Being conscious of the variation in caliper lead to the accidental discovery of a wildcard clone in *M.* 'Iolanthe'. When 'Iolanthe' was budded on clonal rootstocks, some scions overgrew, and some did not. On close inspection it was found there were two clones being grown as 'Iolanthe'. The wildcard was traced back to the original stockplant, which had developed a strong secondary stem that was in fact rootstock. This imposter was multiplied by cutting collectors doing trials on 'Iolanthe', but who were unaware of the problem. The cutting results meant the imposter proliferated and the resulting plants were planted as stock plants. However, the positive side of this situation meant we had a heavy callipered clonal rootstock that was easy to produce. The plants that were sold as 'Iolanthe' raised a few questions, but 'Eleanor May' appears to take precedence as the name for this clone. The rootstock designation was *M.* 'Rootstock A', and the flowers and foliage habit suggest the parentages is *M.* 'Rustica' × *M.* 'Lanarth'.

The final recommendations that were made for clonal rootstocks were:

- *Magnolia ×loebnerii* 'Merrill' for *M. ×brooklynensis* and *M. acuminata* hybrids that were destined for cold climates.
- *Magnolia ×soulangeana* 'Etienne Soulange-Bodin' for middle range hybrids.
- *Magnolia* 'San Jose' for lighter *M. campbellii* hybrids such as 'Charles Raffill' or 'Kew's Surprise'.
- *Magnolia* 'Rootstock A' for the heavier hybrids such as *M.* 'Mark Jury' and *M. doltsopa* 'Silver Cloud'.

For one reason or another *M.* 'Rootstock A' became the default rootstock for anything and everything. Although *M. stellata* types are cutting grown, *M.* 'Rootstock A' has a strong dwarfing effect on *M. stellata* 'Waterlily'.

To propagate *M. ×wieseneri* and *M. obovata* (due to the unavailability of seed) a cutting-grown clone of *M. sieboldii* was recommended as a rootstock, since seedlings tend to be prone to soil diseases in a similar way to *M. kobus*.

While it was a relatively quick process to address the caliper variation, only time could reveal the other traits that would be modified or moderated by the use of clonal rootstocks.

COMBINATIONS SUCCESSFUL AND OTHERWISE

In the 30 odd years I have been handling grafted *Magnolias*, I have only seen maybe 6 or 8 cases of outright physical incompatibility where the graft union failed. This is probably something like an incidence rate of 1 in 5,000 — so minor it is effectively non-existent. In any case, these have all been in the first year of growth in the nursery. For this to happen in garden trees would be extremely rare.

Often the difference in caliper between rootstock is viewed as incompatibility but these trees will often grow for many years and flourish with no problem as can be seen by the trees grafted by Felix Jury when originally planting his garden in the 1950s and 1960s. Felix would often graft an insurance tree as soon as he could to avoid the disappointment of losing a treasured plant such as *M.* 'Lanarth' which he successfully introduced to New Zealand after several attempts (Fig. 1). He often used *M. kobus* when it was available but sometimes he had to use *M. ×soulangeana*, which has tended to produce more rootstock suckers than *M. kobus*. The accompanying photographs show some of these trees and the variable rootstock/scion growth rates. In the case of *M. sargentiana* var. *robusta*, the crown growth in these trees was as healthy as trees of a similar stature observed growing on their own roots in Cornish gardens (Figs. 2 and 3).

One of the heaviest caliper scion cultivars is *M. campbellii* ssp. *mollicomata* 'Bernie Hollard'. In my original 1990 IPPS article on rootstocks this clone had a scion stem thickness of 108% of the rootstock based on the first year's growth from a summer-budded plant. When budded onto *M. ×soulangeana* seedlings it often appears to be twice as thick as the rootstock.

Magnolia campbellii subsp. *mollicomata* has been recorded as difficult in warm climates, and as being heat sensitive. This tendency has been observed with 'Bernie Hollard' plants on their own roots grown in the old Duncan and Davies layering beds. The symptoms were a gradual reduction in vigour and leaf size followed by dieback,

Figure 1. *Magnolia campbellii* subsp. *mollicomata* 'Lanarth' grafted on *M. kobus* at 40 years plus.

Figure 2. *Magnolia sargentiana* var. *robusta* grafted onto *M. kobus* by Felix Jury. Tree is 40 years plus old, and the rootstock is about 60 cm (2 ft) thick. The tree canopy appears healthy despite the caliper difference.

Figure 3. Same tree showing old pipe used to support the tree at some point in the past.

Figure 4. A 2-year plant of *Magnolia campbellii* subsp. *mollicomata* 'Bernie Hollard' on *M.* 'Rootstock A'.

Figure 5. A 6-year-old plant of *Magnolia doltsopa* 'Silver Cloud' grafted onto *M.* ×*soulangeana* seedling showing large difference in caliper size.

and a periodic revival of the plant with water shoots from the base. Similar symptoms can be observed on plants grafted onto *M.* ×*soulangeana* seedlings. With this in mind I specifically budded several plants of 'Bernie Hollard' onto the *M.* 'Rootstock A' clonal rootstock to get a reliable plant for the New Zealand Raised Magnolia Collection we are establishing. The plant was planted out last year and has made the best growth I have observed on budded plants of 'Bernie Hollard' (Fig. 4).

One of the fastest caliper-growing scions we graft regularly is *M. doltsopa* 'Silver Cloud', and years ago I grafted it onto a *M. kobus* to see what would happen. After 3 years the scion was twice the diameter of the rootstock so I drilled a wire directly through the stem and attached it to a post for support. Unfortunately I moved and was unable to follow the progress. *Magnolia* 'Silver Cloud' is often budded onto *M.* ×*soulangeana* seedlings and forms, but without such a marked difference of the scion / rootstock calipers. This has been done for at least 20 years with no record of problems. I have been able to keep track of one of the original plants of 'Silver Cloud' budded onto *M.* ×*soulangeana* and recently was granted permission to dig around the tree to prove that the scion had in fact rooted down above the graft union. For comparison we have a 6-year-old plant budded on *M.* ×*soulangeana* in the garden and it is illustrated with the same pen for comparison. I have not seen magnolias root above the graft very often, but once a tree is planted and growing happily, you don't give it a second thought (Figs. 5 and 6).

Since 'Rootstock A' stock was selected as a stock for heavier wooded *M. campbellii* types, I grafted two seedling selections of *M. campbellii* from the "Cook Block" at Pukeiti Gardens in 1999. The first flowered in 2007 at 8 years from grafting, the second 2 years later. This is a relative reflection of age at first flowering for the original seedlings (Fig. 7).

Figure 6. A 20-year-old plant of *Magnolia doltsopa* 'Silver Cloud' grafted on *M.* ×*soulangeana* 'Etienne Soulange-Bodin' that has developed strong roots above the graft union.

As illustrated on the "Cook Block" selection the union is seamless and the time frames to flowering suggest that the selected *M.* 'Rootstock A' is practically the same as having the clone on its own roots, but with not quite the same juvenile phase as a seedling.

Using 'Rootstock A' as a rootstock for the likes of *M.* 'Early Rose' and *M.* 'Caerhays Belle' resulted in overall larger plants and delayed onset of flowering compared to grafting onto *M.* ×*soulangeana* 'Rustica Rubra' seedlings, which were smaller plants over the same time frame.

With the wide range of rootstock experiments I have done over the years, one of the most fascinating and practical combinations are the ability to put evergreen species on deciduous rootstocks. Much of the practical experimentation with evergreen species has been done with *M. doltsopa* (Fig. 8). Using *M. doltsopa* as a rootstock, it is much more difficult to handle when lifting field-grown plants into containers for sale. The biggest lesson from the experiments using deciduous rootstocks was that the evergreen / deciduous combination is that it really only works well by grafting evergreen scions onto deciduous rootstock. There have been reports from Australia where *M. doltsopa* was used as a rootstock for *M.* 'Vulcan', with very unsatisfactory results. In my experience, deciduous scions on evergreen rootstocks appeared to deteriorate over a couple of years and the roots literally starved to death because there was no foliage to feed the roots in winter.

Magnolia maudiae is performing well on *M.* 'Rustica' seedlings and the plants are setting flowers well in the first year from budding (Fig. 8). These rootstocks also respond well with a fibrous rootball when root pruned for lifting and container-

Figure 7. A 10-year-old plant of *Magnolia campbellii* on *M.* 'Rootstock A'.

Figure 8. Graft union on tree at Tikitere.

Figure 9. Three plants of *Magnolia* 'Freeman' budded onto *Magnolia* 'Rustica' seedlings. The variations show it is not reliable.

izing for sale. There are limits as *Magnolia* 'Freeman' illustrates an inconsistent growth rate, whereas *M. virginiana* 'Autumn Queen' grows well (Fig. 9).

Up to this point the discussion has covered a range of combinations, but these observations have been based on limited numbers of each combination. With the release in New Zealand of *Magnolia* 'Genie' came the opportunity to observe large numbers of the same combinations. For the first 2 years 'Genie' was budded onto *M. kobus* and *M. ×soulangeana* seedlings. The results have to be averaged to allow for seedling variation in the rootstocks, but overall there are definite trends in each species used as seedling rootstock crops. The plants budded on *M. kobus* grew stronger than those on *M. ×soulangeana* and appeared to have an increased degree of juvenility. They began to set summer flowers about a month later or the equivalent of an average of 30 cm (12 in.), which allowed them to grow taller. The lateral branches also set fewer axillary flower buds, which made the budwood from the plants budded on *M. kobus* more desirable. To look at the overall performance as a group, the plants budded on *M. kobus* appeared to be intermediate between *M.* 'Genie' on their own roots, and *'Genie'* on *M. ×soulangeana.*

Our main production in the nursery uses *M.* 'Rustica' seedlings as rootstock since this is a fairly even and dependable strain and seed tends to set itself. I have used *M.* 'Lennei Alba' seedlings that set reasonably well, but this strain tends to have a shorter growing season and the seedlings are slower to develop. Once grafted however, the scions tend toward their own normal growing habits, but in a moderated way associated with *M.* 'Rustica' rootstocks.

Figure 10. *M. campbellii* 'Mount Pirongia' graft union onto *M. kobus* rootstock.

The variability of individual seedling rootstocks within a group still needs to be kept in mind. A white-flowered clone of *M. campbellii* called 'Mount Pirongia' also illustrates the influence of *M.* 'Rustica Rubra' rootstock compared to *M. kobus* (Fig. 10). The original plant on *M. kobus* shows no sign of flowering at 5 or 6 years whereas a 2-year-old budded on *M.* ×*soulangeana* has set four flower buds the year after being shifted. The importance of soil fertility and adequate direct sunlight must not be overlooked either.

CONCLUSIONS

It is not often that you have the chance to follow a project through for 20 odd years. I have been able to keep track of trees planted in previous gardens and other combinations by keeping some trees in the collection by moving them around the country. Others I have re-grafted to build on earlier experience.

The tendency for *M.* 'Rustica' seedlings to be somewhat chlorotic in spring does not appear to come through in the scion taxa. The dwarfing effect that encourages more flowering is useful for smaller sized modern gardens. Another observation is that free-flowering seedling strains can tend to encourage scion taxa to flower sooner.

Although watching these rootstocks over this time has not been a truly scientific trial, time and again with individual trees and crops of several thousand trees you see the same or similar growth trends.

Magnolia 'Eleanor May' or 'Rootstock A' has proven itself as a useful option as a rootstock for the large species like *M. campbellii* and similar forms, as well as *M. doltsopa*.

I am sure there is much more to learn such as how soil fertility can affect and enhance these combinations. In the meantime it is interesting to build on the trends observed and enjoy the heavier flowering displayed by grafted *Magnolia*.

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Current Nursery Practice With Regard to Mycorrhizas and the Propagation of New Zealand's Native Plants©

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Mycorrhizal fungi have great potential for use within plant nurseries as they can increase plant growth by increasing plant uptake of soil nutrients. This paper reports the findings of a survey of New Zealand native nurseries to determine whether nurserymen consider mycorrhizal fungi to be important for plant growth and whether they actively incorporate them into their propagation setups. It also explores in more detail the current means by which nurseries inoculate plants with mycorrhizal fungi. The majority of nurseries do consider mycorrhizal fungi to be important for plant growth and expend time and resources on their collection and use (82%). However, the methods currently employed by nurserymen lack efficiency and do not maximise the potential benefits of utilising mycorrhizal fungi. This can be addressed with a better understanding of the basic biology of the different types of fungi and how they interact with their plant hosts.

INTRODUCTION

The vast majority of New Zealand's indigenous flora is mycorrhizal, meaning most species form symbiotic associations with mycorrhizal fungi. The type of mycorrhizal association is dependent on the plant species in question. The great bulk of species form associations with the arbuscular mycorrhizal fungi (AMF), including the iconic podocarps, the myriad species of *Coprosma*, as well as the tussock grasses and ferns (Baylis et al., 1963; Baylis, 1967; Crush, 1973; Cooper, 1976; Johnson, 1977). *Nothofagus* form purely ectomycorrhizal (EMF) associations while *Kunzea ericoides* and *Leptospermum scoparium* are unusual amongst the flora by forming associations with both the AMF and EMF (Orlovich and Cairney, 2004). The biology of the different types of mycorrhizal fungi are very different; for example the AMF sporulate within the soil or even within plant roots while the EMF typically produce wind-dispersed spores from distinctive above-ground fruiting bodies (Smith and Read, 1997).

It is well established that plants inoculated with mycorrhizal fungi can enjoy improved growth rates compared with non-mycorrhizal equivalents, due mostly to increased uptake of soil phosphorous (Baylis, 1959; Gerdemann, 1964; Daft and Nicholson, 1966; Baylis, 1967). However, while early research focussed simply on presence versus absence of mycorrhiza, with presence almost invariably resulting in enhanced plant growth, more recent studies have revealed that the association is not always a mutualism; the association is found to lie on a mutualism-parasitism continuum depending on the specific plant-fungus combination (Johnson et al., 1997; Klironomos, 2003).

As a consequence of the enhanced growth rates possible, interest in the use of mycorrhizal fungi for industrial plant propagation is increasing and numerous mycorrhizal inoculants are now commercially available. However, these are typically based on easy-to-culture species from a particular location within a single country. When sold on a non-local scale, e.g., internationally, these products form novel mycorrhizal associations with the indigenous flora being propagated (Mummey et al., 2009; Schwartz et al., 2006). It has been demonstrated that the use of exotic mycorrhizal species does not always result in increased growth of native plants (Requena et al., 2001; Richter and Stutz, 2002), and that non-native mycorrhizal fungi are not always able to survive in environments dissimilar to their native habitat (Gianinazzi and Vosátka, 2004). As a result, interest in the collection and propagation of indigenous cultures of mycorrhizal fungi for native plant production has been increasing, both within New Zealand (e.g., Williams, 2009, 2010) and internationally (e.g., Corkidi et al., 2008).

In light of the potential that specific mycorrhizal fungi have to either improve or reduce plant growth rates, the differences in the biology of the different types of mycorrhizal fungi, and the availability of off-the-shelf inoculants, it seems timely to conduct a short survey of native nursery practices with regard to the podocarps and mycorrhizas. The podocarps are of particular interest due to their typically slow growth rates, iconic nature and the high price seedlings carry for the consumer. The podocarps also specifically form AMF associations; therefore the survey is oriented towards the use of AMF. The purpose of the survey is to ascertain the following:

1) Are mycorrhizal fungi utilised in native plant propagation?
2) If so, are off-the-shelf products used or indigenous fungi?
3) If indigenous fungi are used, what material is collected?
4) When is the inoculum incorporated into the propagation setup?
5) Are fungicides used as part of common practice?
6) How important do nurserymen consider mycorrhizal fungi to be for plant growth and health?

METHODS

A total of 22 native nurseries were contacted covering both the North and South Islands. These were identified from a database of nurseries developed by Davis et al. (2009). The questions developed for the survey are shown in Table 1. The questions were designed to provide information on nursery practice, the state of knowledge of mycorrhizal fungi, and how, if at all, mycorrhizal fungi are applied to the system. Within New Zealand, the leaf litter and top surface of the soil (highly decomposed organic matter) is often referred to as "duff." In the questionnaire, "soil" refers to the top soil — up to 20 cm depth, including but not limited to duff. Each questionnaire was emailed to the individual nursery.

RESULTS

A total of 11 questionnaires were returned, giving a return rate of 50%; five were from North Island and six from South Island. Not all questions were always answered, or were answered in a format not allowing formal analysis, for example, giving a non-numerical answer to question seven (Table 1).

A high proportion of nurseries surveyed actively incorporate mycorrhizal fungi into their setups (82%), whether consistently or occasionally, depending on the species in question (Fig. 1A). Very few nurseries invest in off-the-shelf mycorrhizal fungi products (9%) with the majority opting to collect their own fungi (55%) (Fig. 1B), which typically comes in the form of duff or top soil (27% each) (Fig. 1C). Most nurseries incorporate the mycorrhizal inoculum during the pricking out stage (45%) (Fig. 1D), when seedlings are lifted from seed trays and placed within individual containers. The majority of nurseries use a range of fungicides to control both root and foliar pathogens (45%) (Fig. 1E).

Of the 11 questionnaires returned, seven provided a numeric response to question seven (Table 1). The average response was 9.14 ± 0.42 (1 s.e.), showing that most nurserymen consider mycorrhizal fungi to be extremely important for plant growth and health. Of those not giving a numeric response, one felt that mycorrhizal fungi are not important within the nursery environment but carried a value of 8–10 for specimens post-planting, another thought they were only important for *Nothofagus*, while another felt more research was needed in order to better understand their importance.

Table 1. The questions included in the survey questionnaire.

1) What is the primary form of propagation – from seed or from cuttings? Please provide approximate proportions if both are used.
2) What is the approximate length of time to produce a plantable specimen, whether from seed or cutting (approximately 15–30 cm shoot height)?
3) What is the retail price for a plantable specimen (15–30 cm shoot height)?
4) Are you familiar with the term mycorrhiza, and what they do?
5) The use of mycorrhiza:
   a. Are mycorrhiza incorporated into the propagating medium at any stage?
   b. If yes, at what stage (e.g., at initial sowing of seed/insertion of cuttings, or when plants are 'upgraded' to larger containers.)?
   c. Are commercially available mycorrhiza products used or is material collected from forests?
   d. If commercially available products are used, which ones?
   e. If material is collected from forests, what is collected? Leaf litter, soil (what depth)?
   f. How are the mycorrhiza incorporated into the propagating medium (e.g., 50 : 50 mix with propagating medium)?
6) Are fungicides used? If so, at what frequencies and what type (e.g., once a year, foliar applied, systemic action)?
7) How would you rate the overall importance of mycorrhiza to plant growth (speed of growth, health of plant), where 0 indicates "of no importance," and 10 indicates "extremely important"?

DISCUSSION

The results show that the majority of native nurseries are aware of the value of mycorrhizal fungi and actively attempt to incorporate them into their propagation setups. In addition, native nurseries are expending time and resources into collecting indigenous mycorrhizal fungi rather than relying on exotic commercial products. This is encouraging, particularly because many of the plants sold are used in ecological restoration projects. Furthermore, pre-inoculation of plants with exotic

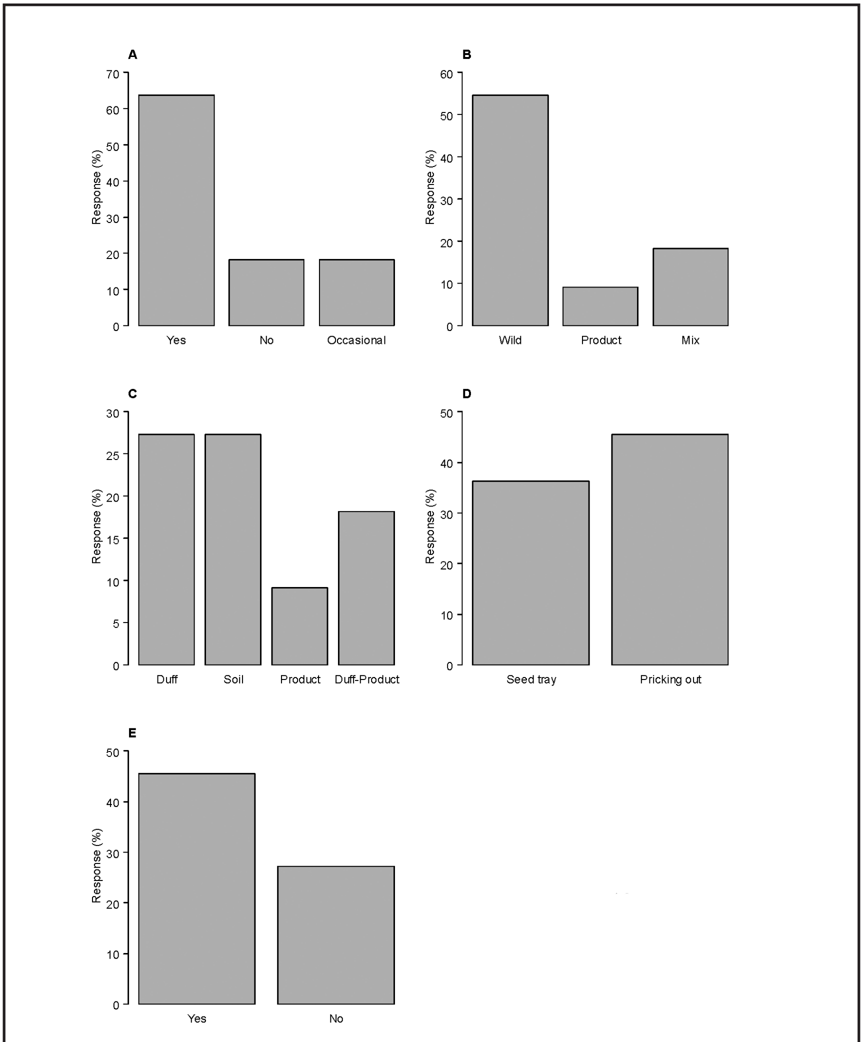

Figure 1. Questionnaire responses to the following questions: A: Do nurseries actively incorporate mycorrhizal fungi into their propagation setups? B: Where are mycorrhizal fungi sourced from? C: What type of inoculant is used? D: When is the inoculants incorporated into the propagation setup? E: Is fungicide used during plant propagation?

mycorrhizal fungi can have negative effects on realising the diversity of mycorrhizal fungi found within a natural ecosystem (Mummey et al., 2009), which can have subsequent negative effects for realising potential plant species diversity (Maherali and Klironomos, 2007). Indigenous mycorrhizal fungi can also drastically improve the growth of indigenous plants compared with nonmycorrhizal plants or those treated with exotic mycorrhizal fungi (Fig. 2).

Figure 2. Growth of *Podocarpus hallii* (mountain totara) cuttings with different AMF inoculants. From left to right, exotic AMF, mix of indigenous and exotic AMF, non-inoculated control, indigenous AMF.

However, despite this initial optimism it appears that the efforts invested in collecting indigenous mycorrhizal fungi may be being squandered. The two primary sources of inoculum used are either duff or top soil. As described earlier, duff is a term describing the leaf litter and highly decomposed organic matter found on the soil surface. This material is unlikely to contain suitable quantities of the infective AMF material necessary to initiate ecologically representative mycorrhizal associations. The podocarps, like the majority of New Zealand's native flora, form AMF associations (see Introduction). The hyphae of AMF proliferate within the soil rather than in the organic matter layer because they acquire nutrients from inorganic rather than organic sources (Abbott and Robson, 1991; Smith and Read, 1997). Furthermore, duff will consist mainly of spores rather than hyphae and will therefore only reflect the diversity of AMF species sporulating at the time of collection; this is not necessarily an accurate representation of the true diversity of the AMF community (Clapp et al., 1995). In order to collect large quantities of diverse AMF material, including hyphae, which are the primary method of AMF colonisation, the top soil down to a depth of 10–20 cm is required. This represents the rooting zone of most plants and thus ensures the rhizosphere, which contains the infective root, and hyphal and spore material, is adequately sampled (Corkidi et al., 2008). It is important to bear in mind that despite duff being a poor source of inoculum for AMF, it is the most important source of EMF material. Duff is therefore vital to ensure mycorrhizal colonisation of *Nothofagus, K. ericoides*, and *L. scoparium*.

Current nursery practice also appears to invest unnecessary time and effort in attempting mycorrhizal colonisation. The majority of respondents indicated that they add inoculum when transferring plants from seed beds or cutting trays to individual containers. In order to maximise mycorrhizal benefit the inoculum should be incorporated into the propagation setup as early as possible, i.e., within seed beds or cutting trays (Gianinazzi and Vosátka, 2004). In addition to maximising benefit this method reduces both the quantity of mycorrhizal material necessary as well as the investment in time needed to inoculate a given number of plants.

The majority of nurseries regularly apply fungicide to their plants and propagation beds. This is an understandable practice given the loss that can occur if a pathogen were to proliferate. However, the use of such chemicals, particularly soil and systemic fungicides, is likely to detrimentally impact the mycorrhizal population. Research also indicates that the inoculation of plants with the appropriate mycorrhizal fungi can reduce the occurrence of fungal pathogens (Borowicz, 2001; Newsham et al., 1995; Whipps, 2004), meaning the use of mycorrhizal fungi could potentially reduce fungicide usage within nurseries.

In summary, it appears that the native nurseries of New Zealand appreciate the importance of mycorrhizal fungi for successful plant propagation and subsequent survival after sale. However, the full benefits of utilising indigenous mycorrhizal fungi could be optimised by a greater appreciation of both the associations that the different plant species form and the biology of the different types of mycorrhizal fungi.

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Nomenclature, Names, and Pronunciation©

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NOMENCLATURE

The botanical naming of plants was established by Carolus Linnaeus around 1745, a Swedish scientist who invented a binomial system, published in his *Species Plantarium*, for the naming and classification of all organisms. This system was intended to cover animals, bacteria, and insects, as well as plants, but over time Linnaeus has become most closely associated with the plant kingdom. Linnaeus did not work alone in the classification of species but is credited with establishing the basis of today's botanical nomenclature. Prior to the Linnaeus system, some botanical names had up to 10 words and were complicated, in effect mini descriptions of that plant. The system Linnaeus established has now been in use for over 250 years and to date, nothing better has arisen to replace it. The success of the system can be attributed in part to its simplicity and use of few conventions. A binomial system comprises two main parts, and for plant naming this is the genus and species. The genus can be seen as the family name and the species the first name as in the examples below:

Genus:	*Malus*	*Cordyline*	*Camellia*
Species:	*domestica*	*australis*	*sinensis*

When the genus and species are written in full, additional letters at the end are often included. These letters at the end are known as the authority, the person or persons who named and identified the species for the first time. A common example is L. for Linnaeus., e.g., *Malus domestica* L., the common apple. The authority can consist of more than one letter or letter set indicating that the species was jointly named or at some point reclassified. For reclassification the first letter set is in brackets. An example is *Hebe elliptica* (Forst. f.) Pennel, where Forster first named the species, then later it was reclassified by Pennell.

The system has continued to develop and adapt over the centuries and a plant may be classified into more than just two parts, with greater naming detail than just genus and species. A full classification comprises a hierarchy of groups with common base characters:

Kingdom
Division
Class
Subclass
Family
Subfamily
Tribe
Genus
Subgenus
Section
Subsection
Species
Subspecies
Botanical Variety
Form
Cultivar

This multi level classification can be applied to all species, but is most commonly applied to very large genera such as *Rhododendron*, *Eucalyptus*, or *Brassica*. The additional classification is not a departure from the Linnaeus binomial system but a refinement, with the original principle forming the basis of the classification.

During the 18th Century, the time of Linnaeus, Latin was the language of scholarship and science. In addition, Latin provided the possibility for Europeans or any others speaking different languages to communicate more effectively, encouraging cross language botanical understanding. For this reason it is not surprising that botanical nomenclature and the Linnaeus system is Latin based. To this day, Latin remains the international botanical language. The plant names we use today are still mostly Latin based, but there have been other language influences, the most significant being Greek.

The use of the system continues with active botanical classification and reclassification continuing throughout the world. Reclassification of well known genera or species to horticulture and agriculture can cause confusion and irritation and some reclassifications are never really accepted by plant users. One example where plant users did not accept a reclassification and even opposed it was that of the florists' chrysanthemum, *Chrysanthemum* ×*morifolium* Ramat. Plant users in the cut flower and pot plant industries considered it created too many problems. This species was moved from *Chrysanthemum* to the new genus *Dendranthema*, and eventually returned back to *Chrysanthemum*.

Other horticultural and agricultural examples include:

1) The species comprising the genus *Michelia* have now been moved into *Magnolia*. This change is still under debate by *Magnolia* botanists and experts.
2) The species comprising *Dipladenia* have now been moved into *Mandevilla*.
3) Some *Helichrysum* species now comprise the new genus *Bracteantha*.
4) The tomato, formerly *Lycopersicon esculentum*, is now *Solanum lycopersicon*.
5) The species *Myrtus ugni* has been reclassified as *Ugni molinae*.

Reclassification is carried out to correct errors and rectify mistakes, recognise new information such as molecular data, and to ensure that all classifications and names closely follow botanical naming conventions. These conventions are internationally drafted and agreed to under a formal system that governs all plant classification and naming, the International Code of Botanical Nomenclature (ICBN).

NAMES

All plant names follow Latin grammatical rules with a noun (the genus), an adjective (the species), and the corresponding gender. The name can often be a mini description such as:

- *Leucodendron*; leuco, without colour, and dendron, tree like. The original plant of the genus was first discovered as a silvery tree-like shrub.
- *Rhododendron*; rhodo, red or rose like, and dendron, tree like.
- *Leptospermum*; lepto, slender or thin, and spermum, seed. The genus with thin seeds.

An example of the use of simple descriptive terms to name the species is *Coprosma repens* A. Rich. The use of repens identifies this plant as a prostate or low growing *Coprosma*. Repens or reptans are Latin for creeping or trailing.

The name may also tell us who first discovered the plant, where it was discovered, and perhaps something of that period of history. Many genera and species refer to historical figures, to commemorate someone or honour persons of significance to the plant discoverer. Some examples are australis, often used as a species to indicate the Southern Hemisphere or the southern version of a Northern species already known, such as *Nothofagus antarctica* (G. Forst.) Oerst discovered in Southern Chile with proximity to Antarctica and *Dahlia* Cav. named to commemorate Dahl, a Swedish botanist who worked with Linnaeus.

An understanding of Latin can not only assist overall knowledge of botanical nomenclature but in some cases provide a literal translation of a plant name. Wheat and bean have botanical names *Triticum* and *Phaseolus*, respectively, which are Latin for wheat and bean. Plant names provide information about that plant which are often not obvious but on closer examination reveal something of the character of the plant and of the discovery; who, where, and the period of history.

The formal botanical name provides international consistency where the use of common names is not consistent and generally unreliable, dependent on language, and usage. In some cases the same common name refers to a certain plant in one place or country and that same name could mean an entirely different plant somewhere else. Common names can also be misleading, for example there are many plants known as lilies but not all would be botanically classified as belonging to the lily family.

PRONUNCIATION

Latin itself is not entirely in agreement regarding its own pronunciation and variation exists caused by the influence of the native language of the speaker. In general botanical names are pronounced as they would be according to the conventions of the native language spoken. Broadly speaking Latin itself lacks emphasis or stress on the syllables. Taking into consideration how English speakers pronounce Latin and the broad principle of not stressing syllables, the following are some examples of two commonly heard pronunciations. The first one would be the author's preference:

Pittos-porum	vs.	Pit-tosporum
Clematis	vs.	Clem-ate-is
Dahlia (Daylea)	vs.	Darhlea
Clivia (Cliveia)	vs.	Cliv-ia
Gerbera (soft g)	vs.	Gerbera (hard g)

CONCLUSION

Botanical nomenclature and the naming of plants have a long and fascinating history which does include rules and conventions. The day to day pronunciation of plant names has fewer rules, having a much greater level of interpretation by the speaker. The speaker's pronunciation of Latin-based plant names will be significantly influenced by the language usually spoken. A pronunciation of a plant name may be acceptable in one region or country but may not be in another place.

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Light-Emitting Diode Lights: The Future of Plant Lighting©

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INTRODUCTION

Higher plants require light for growth. Sunlight, or solar radiation, arriving at the earth's surface is electromagnetic radiation energy given off by the sun, and filtered through the earth's atmosphere. It comprises visible light, as well as near infrared radiant heat and short wavelength ultraviolet (UV) radiation. The spectral characteristics of the sun coupled with selective absorption of different wavelengths in the atmosphere means there are unequal amounts of each wavelength reaching the earth's surface. Light is characterised by its quality (i.e., wavelength) and its intensity.

The human eye is sensitive to visible light (i.e., what we see) in the spectrum of wavelengths from 380 nm (blue light) to 760 nm (red light) but is most sensitive to light in the green and yellow regions, peaking at 555 nm (Fig. 1). Plants perceive light differently from humans, wherein they use both visible and nonvisible solar radiation. Plants use photoreceptors to sense changes in light intensity, quality (wavelength), duration, and direction. They adapt their growth and development according to the light sensed. For instance, chlorophyll is a photoreceptor capturing the energy in light to convert carbon dioxide (CO_2) and water into carbohydrates through photosynthesis. Carbohydrates are the building blocks for the amino acids, proteins, fats, and vitamins required by living organisms. Carbohydrates with oxygen are necessary for plant and animal respiration, with CO_2 and water produced as by-products. Other photoreceptors control plant photomorphogenesis, shading resulting in etiolation or lengthening of internodes.

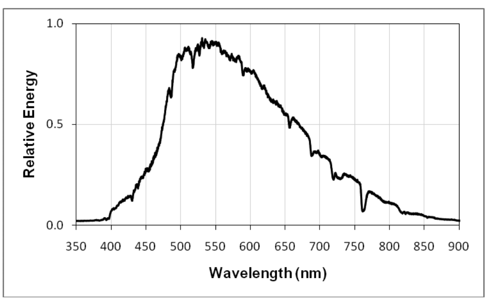

Figure 1. Spectral distribution of sunlight in the 350–900 nm range, which includes emmissions in the nonvisble near infared region (>750 nm).

Understanding the spectral distribution characteristics of artificial light sources enables growers to match lamps to a desired plant response. To be commercially useful, plant lights need to be efficient converters of electrical energy to the wavelengths absorbed by the relevant plant photoreceptors. Traditional horticultural lighting produces a broad spectrum of light with some spectral enhancements in the regions required by plants for growth. This lighting has changed little over the past 20 years. However, new technologies involving combinations of light-emitting diodes (LED) lights, with defined spectral distributions, offer alternative and more efficient light sources for targeting individual, or multiple, photoreceptor-types. With the current rapid development of LED technology, it is possible they will become the major supplementary lighting source for plant production, replacing current broad-spectrum plant light sources.

MEASURING LIGHT

Solar radiation levels at the earth's surface can vary not only with season and time of day, but also with factors such as atmospheric water vapour content and CO_2 concentration. Meters such as the Licor LI-250A Light Meter (Li-Cor, Lincoln, Nebraska), can be used in conjunction with different sensors to measure total solar radiation or its components. Total global solar radiation is measured in units of kW/m^2 using a pyranometer and light brightness (i.e., intensity) as experienced by the human eye is measured with a photometric sensor, which detects the number of lumens falling on a square metre (expressed as lux).

The wavelengths of light that drive photosynthesis occur between 400 and 700 nm, which we call photosynthetically active radiation (PAR). The PAR comprises less than half of the total solar radiation (about 47%), so it is important to use the correct sensor to measure "light" intensities. Quantum sensors simulate the photosynthetic response of plants, expressing PAR in units of micromoles per second per square metre ($\mu mol \cdot m^{-2} \cdot s^{-1}$).

On a clear mid-summer day, PAR peaks in early afternoon at around 2000 $\mu mol \cdot m^{-2} \cdot s^{-1}$. In the early morning, and evening, light intensity falls to the point where photosynthesis equals respiration (the CO_2 compensation point). The CO_2 compensation point varies among species. Knowledge of CO_2 compensation point is important for growers, as it marks the light intensity at which adding supplementary lighting would further enhance the rate of photosynthesis. For a commercial operation, a light intensity of at least 90 $\mu mol \cdot m^{-2} \cdot s^{-1}$ is generally required for significant photosynthetic activity, although it is also dependent on factors such as plant genotype, growing temperature, and water and nutritional status.

In addition to photosynthesis, plants use light to trigger other growth and development processes. Classic examples of this include plants responding to changing ratios in the amounts of red and far-red light they perceive, triggering flowering, vegetative growth, or even seed germination (i.e., photomorphogenetic response). Thus it can also be important to use a spectrometer to measure the full spectral distribution of light. The Ocean Optics UBS2000 Spectrometer (Ocean Optics, Dunedin, Florida) can continuously capture data, graphically presenting the distribution data on a personal computer. This makes it a valuable tool for comparing the spectral distribution of different artificial light sources for PAR.

THE ROLE OF LIGHT IN PLANT GROWTH AND DEVELOPMENT

Photosynthesis. Photosynthesis involves PAR being absorbed by chlorophyll and converted into chemical energy. There are two types of chlorophyll, a and b, each absorbing light in slightly different wavebands. Absorption is principally in the red and blue-violet spectral regions. Most green light is not absorbed, but reflected or transmitted, to be seen by our eyes as the green colour of leaves. Other plant pigments such as carotenoids, flavonoids, and xanthophylls are also found in the leaves, and depending on their concentrations and relative proportions give rise to yellow, orange, pink, red, and purple colours. Under conditions of adequate temperature and CO_2 concentration, photosynthesis increases with increasing light intensity (PAR) in a linear manner to the point where light saturation and factors such as tissue age and genotype limit further increases.

Photomorphogensis. Plants have evolved highly complex mechanisms to monitor their surroundings and adapt their growth and development to the prevailing environmental conditions. Light quality is sensed by different light receptors for specific wavelengths. In higher plants there are three groups of photoreceptors involved in photomorphogenesis: the red / far-red light-absorbing phytochromes, and the blue UV-A light-absorbing phototropins, and cryptochromes (Franklin and Whitelam, 2004).

The phytochromes with photo-reversing properties, exist as red (665 nm) and far-red (730 nm) absorbing forms. The red form converts to the far-red form following the absorption of red light and, conversely, following the absorption of far-red light, the far-red form converts to the red form. While leaves absorb most of the visible light, far-red light is transmitted or reflected. Plants use the ratio of red to far-red energy (R:FR) to sense shade, with higher proportions of far-red indicating shade, causing plants to activate shade avoidance measures. This includes removing an inhibitor of stem elongation, resulting in taller (etiolated) shoots with less branching and smaller leaves. Growth returns to normal once the shade conditions have been overcome, i.e., a lower proportion of far-red. Plants are able to differentiate between light on an overcast day and shade cast by other plant organs on the basis of R:FR ratios. Natural light, whether on a clear or cloudy day, has a relatively constant R:FR of about 1.1 : 1. Phytochromes also regulate chlorophyll and chloroplast development, leaf senescence, and leaf abscission. Phytochromes are also the principal energy receptors for photoperiodism. The signal for a plant to flower is often under photoperiodic control, whereby plants sense seasonal changes in day-length. Plants can be divided into short-day plants (e.g., strawberry, carnation, or chrysanthemum), long-day plants (e.g., lettuce or lily), or day-neutral plants (e.g., rose or tomato). By altering day length, either with blackout curtains, or supplementary photoperiodic lighting, flower initiation can be manipulated to promote out-of-season flowering.

Phototropins are blue light receptors that help to maximize photosynthetic activity by stimulating phototropism, stomatal opening, and chlorophyll synthesis. They are important for the early stages of seedling growth and establishment. Since they grow towards light, shoots are positively phototropic. This occurs when light alters cell auxin concentrations in cells on the side of shoots away from the light source, resulting in cell stretching, causing the shoot to curve towards the light source.

Cryptochromes absorb light in the blue to UV-A wavelengths. They work in conjunction with the phytochromes in the regulation of cell elongation and photoperiodic responses.

ARTIFICIAL LIGHT FOR PLANT GROWTH

Various sources of supplemental light have been used to enhance plant growth, usually by supplementing lower levels of natural light during the duller winter months or on overcast days. A major limiting factor is the efficiency of lights in converting electrical energy into light rather than heat. For example, an incandescent bulb radiates about 12% of the input wattage as light, mainly in the red spectral region, and 80% as radiant infrared heat; a typical fluorescent light radiates about 22% of the input wattage as light and 36% as infrared heat (Bickford and Dunn, 1972). In recent years, compact fluorescent lights (CFL) have become widely available. They are more energy efficient than standard fluorescent tubes, as they require lower wattages and generate less heat, but have similar spectral outputs, making them suitable for small-scale propagation applications, e.g., supplementary lighting at de-flasking of tissue culture plantlets.

High intensity discharge (HID) lamps, such as high pressure sodium (HPS) or metal halide (MH), convert 30% to 40% of the input electrical energy to light. The HPS lamps are, therefore, a popular source of supplementary greenhouse lighting, since they produce more PAR per watt of electrical energy. However, they are slightly biased towards the red end of the electromagnetic spectrum, which is more favourable for promotion of flowering. The heat they generate prevents use of them close to plants. In contrast, MH lamps have greater flexibility in their spectral output since their spectral properties can be manipulated through using different combinations of metal halides in their construction (Bickford and Dunn, 1972). Their ability to produce an abundance of blue light (Fig. 2) makes them more suitable for enhancing vegetative growth than HPS lamps. As with most lamps currently used in plant growth applications, reflectors are necessary to focus the emitted light towards the plants.

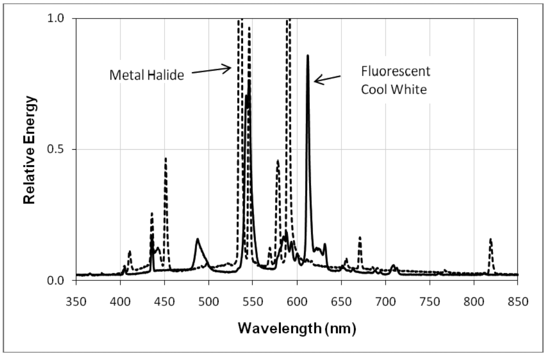

Figure 2. Metal halide lamps, a popular source of supplementary lighting in horticultural applications, emit radiation in the lower wavelength blue bands (400–470 nm) and a lesser amount in the red regions (620–700 nm) compared with fluorescent lamps (solid line). However, both produce a large portion of their energy in the region that has minimal roles in vegetative plant growth but to which humans are sensitive (around 550 nm). For direct comparison, the energy levels have been scaled to to show the relative energy from each light source.

Many lamps are deficient in far-red (700–800 nm), resulting in high R:FR (up to 7 : 1 for HPS) compared with sunlight, which has a ratio of 1.1 : 1 (Cummings et al., 2007). Under these lamps flowering would be delayed in long-day plants, and internode extension inhibited. An exception is incandescent lamps, which have a R:FR of 0.6 : 1. To achieve a R:FR close to natural light, MH lamps need to be used in combination with incandescent lamps.

LIGHT-EMITTING DIODES

Light-emitting diodes produce light by the movement of electrons in a solid-state semiconductor material. Since they do not warm up and "burn" like traditional light bulbs, they have a significantly longer life. Additionally they can be turned rapidly on and off for pulse lighting. The LEDs emit radiation in a relatively narrow wavelength band (Fig. 3), but combinations of LEDs do cover the PAR spectrum (van Leperen and Trouwborst, 2008) with over 75 different wavelengths from UV (210 nm) to near infrared (910 nm) now available (Stutte, 2009). Many are based on chemicals such as gallium, arsenic, and phosphor. As no semiconductor material emits pure white light, most white light-emitting LEDs are based on a blue light-emitting chip coated with phosphor, which causes yellow light to be emitted. This mixture of blue and yellow light is perceived as white light by the human eye, even though these "white" LEDs have spectral distribution peaks in both the blue and yellow regions (Figs. 3 and 4). White light can also be produced by combining the primary colours: red, green and blue (RGB) into a single LED.

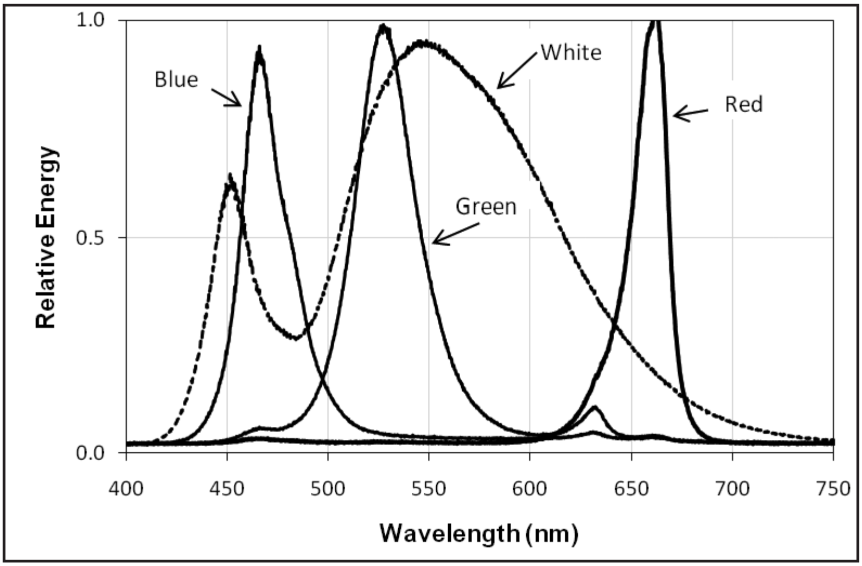

Figure 3. The spectral distributions of LEDs. Coloured LEDs (red, blue, and green) emit defined, relatively narrow, spectra of light energy. The LEDs perceived as white to the human eye are blue LEDs modified with phosphor to produce a wider spectrum peaking in the yellow wavelength band (550 nm). For direct comparison, the energy levels have been scaled to to show the relative distribution of each light source.

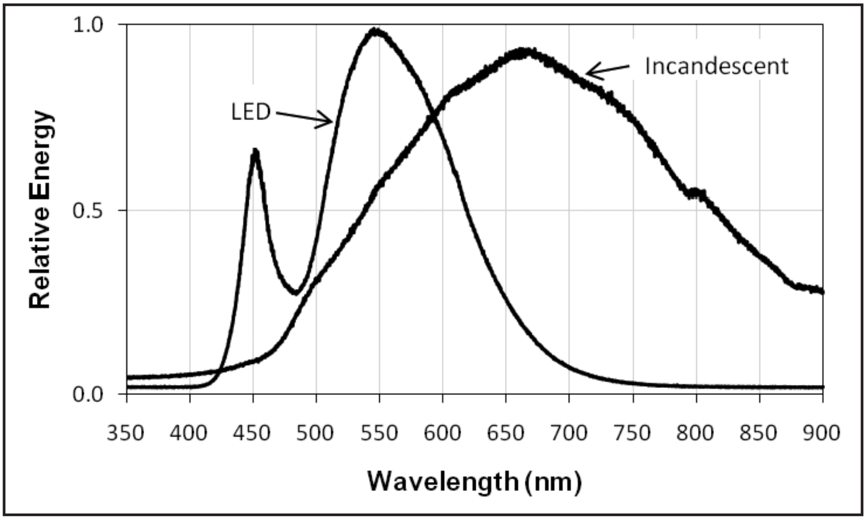

Figure 4. Spectral distributions for two white light sources. In contrast to the white LED, the incandescent lamp has a much wider spectrum, emitting a significant portion as non visible, infrared (>750 nm), radiation, which is experienced as heat. For direct comparison, the energy levels have been scaled to to show the relative distribution of each light source.

The LED technology is developing rapidly, with newer versions producing higher light intensities. This is now making them attractive as lighting sources in a wide range of nonhorticultural applications, including general street lighting, automotive signalling and television back-lighting. A consequence of this development and uptake of the technology is that production costs are steadily falling. Until recently the high cost of LED lighting restricted its use in horticulture primarily to research and controlled environment applications. Much of the early LED work with plants was associated with NASA's research into growing crops such as radish, spinach, and lettuce in space (Yorio et al., 2001). There is a rapidly developing scientific literature on applications for LEDs. For example, different ratios of red and blue LEDs can be used to manipulate lettuce seedling stem extension (Yanagi et al., 1996). Green LEDs have been used in the presence of red and blue LEDs to enhance the rate of photosynthesis (Kim et al., 2004). The addition of 1% blue or UV-A LED can reduce the presence and severity of tomato mosaic virus symptoms in peppers (Schuerger and Brown, 1997).

The small size of LEDs makes them amenable to being grouped together so that spectral outputs can be matched to the required plant response, thereby fully utilising the light energy. In addition, LEDs with different spectral outputs can be programmed to switch on to promote specific responses in a plant production system (e.g., photoperiodic response), without energy being wasted on nonproductive wavelengths. The more intense LEDs suitable for plant growth do require more power management, although voltages of individual LEDs are low (2–4 volts of direct current). An array of LEDs can be connected in series and/or parallel, to form a continuous electrical circuit, with the series voltage being the voltage drop of the individual LEDs multiplied by the number of LEDs in the series. Brightness is proportional to the current, which is typically in the 200 to 1000 mA range. Commercial lighting companies are now starting to fabricate complete multi-LED light units for the horticulture industry (for example, <http://www.led-grow-master.com> and <http://www.ledtronics.com/products>.

The LEDs produce little if any radiant heat. Although some of the electrical energy used is converted to heat energy, in contrast to lamps such as HPS lamps, the heat is nonradiant and can be readily dissipated using heat sinks and convective cooling systems. This allows the lights to be positioned close to plants, thus ensuring maximum efficiency of light interception by the plants.

The R:FR can be readily manipulated using combinations of light sources in conjunction with LEDs. For example, red LED light has been used to promote flower bud induction in short-day strawberry plants by altering the R:FR reaching the crown (Takeda and Newell, 2006). Far-red LEDs combined with incandescent lighting can produce deep canopy shade equivalent R:FR ratios without producing excessive radiant heat (Cummings et al., 2007).

In 2007, LED lighting was reported to be less efficient than HPS lamps, although it was noted that LED technology development was rapidly progressing, whereas HPS development was not (van Leperen and Trouwborst, 2008). Recent reviews on the progress of LEDs, as the technology moves to large-scale horticultural applications, have been published by Morrow (2008) and Yeh and Chung (2009).

LEDS AND TISSUE CULTURE

Fluorescent cool-white tubes have been a commonly used light source for tissue culture growth rooms, since they can provide a relatively uniform coverage of light in the visible spectrum (Fig. 2) on the shelves where plants are growing (two tubes 30 cm above a shelf typically provide around 30 to 40 $\mu mol \cdot m^{-2} \cdot s^{-1}$). In contrast to other growing systems, tissue culture plants grow heterotrophically, with their carbohydrate requirements satisfied by sugars in the nutrient media, thereby negating the need for photosynthesis and the required high PAR levels. In some countries, fluorescent lighting can account for 65% of the total electricity use within a tissue culture laboratory, making it the largest nonlabour cost in tissue culture plant production (Yeh and Chung, 2009). While LEDs are yet to be used routinely as a light source in commercial tissue culture laboratories, this is likely to change as the cost of LEDs continues to fall.

There is a range of examples illustrating the potential value of LEDs to the horticultural industry. Strawberry plantlets taken from culture can be grown under 70% red (660 nm) plus 30% blue (450 nm) LED lighting with a light intensity of 60 $\mu mols^{-1} \cdot m^{-2}$ using a rockwool system with a sugar-free medium (Nhut et al., 2003). Such plants are very healthy, with subsequent growth normal following transferral to soil. Fluorescent lights supplemented with red LEDs have been shown to increase chlorophyll and shoot length of in vitro potato plantlets (Miyashita et al., 1995). Applications such as these may provide a useful approach to aid plantlet acclimatisation and assist in reducing costs associated with plant losses at deflasking in vitro propagated plants.

CONCLUSION

Plant growth and development are complex processes, with light being essential for many of the associated physiological and morphological processes. Sunlight satisfies these needs but to maximize the growth of economically important indoor-grown crops, supplementary lighting can be beneficial. As a result of the low amount of energy actually converted to useful light, many conventional supplementary light sources are inefficient and therefore expensive to operate. LEDs offer efficient alternative light sources with defined spectral distributions for targeting specific plant photoreceptors for plant growth (photosynthesis), photomorphogenesis (morphology) or development (e.g., maturation). The rapid development and uptake of LED technology by many industries over the past decade means production costs are declining. As the light intensity of LEDs producing PAR improves with better technologies, LED lighting will become economically feasible for commercial plant production.

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A Hot Bed for a Good Root©

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FIRST ATTEMPTS

I started in the nursery industry when I was 20. My first attempt at propagation was using some old windows I had borrowed from the neighbour, and some 8 ft × 1 in. timber, 2 high framing as a box edge. For medium I had read that sharp sand was required so I used crusher dust with a little peat. I had seen a really nice rhododendron at Ilam. It was a huge plant and yielded 400 cuttings. Also I did black currants and *Chamaecyparis pisifera* 'Boulevard'. I tried to rig up an irrigation system but that was incredibly uneven and all but a waste of time. The cold frame was placed under the Black Doris plum tree and bombarded with leaves and Black Doris plums from up to 6 m above. A couple of windows cracked and all were severely smudged purple.

Four rhododendrons rooted: 1% success. Most of the *C.* 'Boulevard' and all the black currants survived.

- I probably learnt 50% of what I know now then.
- I was in business.

TRY AGAIN FAIL AGAIN FAIL BETTER

The next phase was a propagation unit using my brother's old red-crested parakeet cage. It seemed perfect. I left the chicken netting on it, lifted the roof to make a pitch, and covered it in plastic. I got a few sheets of asbestos, fired clay sewage pipes stuck on their end to use as legs, some more 8 × 1. I had a raised propagation bench in a glasshouse. Well, plastic house. I purchased a mist system from a firm called Northern Electronics that used an electronic leaf, and purchased some pyrotechnic heat cables, laying them on a layer of vermiculite and covered them with sand. In the roost area of the bird cage I set up benches and shelves that became my work station On my work station I hung a poem by Rudyard Kipling that I had found in the attic. I was set up.

If

If you can keep your head when all about you
Are losing theirs and blaming it on you;
If you can trust yourself when all men doubt you,
But make allowance for their doubting too;
If you can wait and not be tired by waiting,
Or, being lied about, don't deal in lies,
Or, being hated, don't give way to hating,
And yet don't look too good, nor talk too wise;

If you can dream — and not make dreams your master;
If you can think — and not make thoughts your aim;
If you can meet with Triumph and Disaster

And treat those two imposters just the same;
If you can bear to hear the truth you've spoken
Twisted by knaves to make a trap for fools,
Or watch the things you gave your life to, broken,
And stoop and build 'em up with worn-out tools;

If you can make one heap of all your winnings
And risk it on one turn of pitch-and-toss,
And lose, and start again at your beginnings,
And never breathe a word about your loss;
If you can force your heart and nerve and sinew
To serve your turn long after they are gone,
And so hold on when there is nothing in you
Except the Will which says to them: "Hold on!"

If you can talk with crowds and keep your virtue,
Or walk with Kings — nor lose the common touch;
If neither foes nor loving friends can hurt you;
If all men count with you, but none too much;
If you can fill the unforgiving minute
With sixty seconds' worth of distance run,
Yours is the Earth and everything that's in it,
And — which is more — you'll be a Man my son!

I made some wooden boxes to fit 50 tubes and used these as my propagation boxes. These were all ground treated and killed everything within an inch of the edge. I used bark as my propagation media and purchased some IBA and made some alcohol based hormone dips.

- I was 21. I had a hot propagation bed; I was ready to root anything I desired.
- And I pretty much did. I was a legend in my own mind.
- The mist worked well, the media and hormones were good, but the heat was all over the place.
- Try again. Fail again. Fail better.

EXPANDING THE NURSERY

I now needed to expand my propagation area as I only had about 2 m^2 and I was propping rhododendrons. I could fill it in a couple of days and then had to wait 4 to 6 months for the thing to root.

I got a friend to make me an electronic leaf as well as a relay so I could have multiple stations and wean my cuttings. I had a 20-kg transformer made, and fencing wire that I connected to it. Bingo, I had the worst hot bed ever but it did work.

- But it was even more all over the place.
- Try again. Fail again. Fail better.

I was getting good — not. But I needed to expand, so I purchased 53 acres and a house, got a loan from the bank, and then changed it to my dad. He gave me a better term so I even paid him above market rates at the time. I set up a new nursery with eight 15 m × 6-m plastic houses, more pyrotechnic cable, more uneven heat.

Now I completely changed course. Hot water was in with me so I got some 5-kw spa pool elements, some water troughs for cows, and a circulating pump. I put this at the end of each house and bingo, I had the most amazing electricity bills. But it was even and consistent. Burnt bases were not from too much heat, they were now confined to too much hormone.

About 10 years ago I bought a Fletcher® duralite house complete with hot water diesel boiler. I now circulate the water at 23 °C. The beds vary by about 2 °C and my heating is perfect at 20–22 °C depending on the type of trays and connection with the bed.

Most of my beds were sand with polystyrene base or sand and alkathene pipe covered with weed mat to keep things tidy. I decided this wasn't tidy enough so I put all the water pipes in concrete to have nice tidy, clean houses.

- Well, that didn't work because all I did was create a huge perched water table in my medium through removing the capillary action of my sand. I was back to rotten bottoms and it was not caused by the hormone or the heat.
- Try again. Fail again. Fail better.

In between times I had put in a high-pressure fog system, grown under lights, tried a wet tent method, plastic cover, moved over to a calorie counter, gone out of fog, ditched the wet tent and plastic. I fiddled around with every conceivable mist nozzle and now I have ditched mist nozzles.

- To solve the perched water table I purchased some marine carpet and put it on the beds. They grow algae well but they also have reinstated the capillary action and the results have improved. I have gone back to weed mat and sand.
- I'm happy with my hot bed but some plants do better without it even if they do take a bit longer. Some plants are better starting without it than getting some.

INTO THE FUTURE

Jill Reader, another IPPS member, sent an email about a glasshouse listed on TradeMe® (a New Zealand online auction website). I bid $1,000 and got it for $550, and about $40,000 later I have it transported and packed ready to build at home. I have a few ideas.

- Try again. Fail again. Fail better.

Biodegradable Pots, the Whys and the Wherefores — A Journey into the Unknown©

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Lyndale Nurseries Auckland Ltd. is a specialist propagation nursery situated in Whenuapai, Auckland. It grows approximately 3 million young plants per annum covering a wide range of (some 900 different cultivars) outdoor trees and shrubs, which are sold to growers all over the country (population 4.3 million).

Lyndale worked in conjunction with a plastic pot manufacturer to produce a biodegradable pot in which to supply its young liner plants.

Young woody plant production in New Zealand is unique in that plants have over the last 40 years been supplied in plastic 4-, 5-, and 7-cm pots, which are charged on invoice but fully refundable on return. With legal restriction placed on the use of methyl bromide there has been no effective practical way to sterilize the used pots.

INTRODUCTION

A yachting trip in the outer Hauraki Gulf of Auckland produced the catalytic moment.

I saw at first hand plastic waste washed up on an otherwise pristine white sandy beach. Waste which was directly linked to our industry.

A plastic plant pot was washed up in amongst the sand dunes and led me to decide that I could do a little better than this. I decided at that point to explore the possibility of not growing in plastic pots but something that was more environmentally friendly.

Working primarily with Ronald Davidson of Interworld Plastics, we set about exploring biodegradable plastics.

We designed a pot incorporating the advantageous side slots we saw in forestry tree handling systems. One of the motivating factors was to have as many openings as possible to enhance air exchange, encourage air pruning of roots, and, last but not least, to have less bio plastic in the structure.

We developed a pot design that worked well but failed to get the unit cost down to a price which we believed would ensure success, i.e., general acceptance of the concept.

CHINESE INPUT

Some 4 years into the project we had unsuccessfully tried a myriad of additives to the biodegradable plastic resins in an attempt to "dilute" the expense of this product.

A chance encounter with a Chinese company producing plant containers out of rice husks led us to offer them our starter pot design for production.

We now had a young plant or propagation growing on line (GOL) pot, which was priced close to its plastic equivalent and was biodegradable.

Trials back in New Zealand with a range of formulations led us to select a formulation, which was expected to degrade in a period of 12–18 months.

Our trailing indicated that this formulation was in fact breaking down slightly faster than this in our nursery situation.

We have subsequently learnt that the matrix of available water, temperature, nutrients, and the presence of soil organisms all play significant roles in determining how quickly or not the biological degradation occurs. Within this matrix the presence of available water is the single most significant factor influencing the planned degradation period.

By way of explanation of this statement, if a biodegrading time period of 12 months is built into the pot and the pot is constantly dry then the pot will take a considerably longer time to degrade.

THE MARK 1 POT — AND A REALITY CHECK

Lyndale Nurseries Auckland Ltd. made the commercial decision to change 100% from plastic to biodegrading "eco pots" in July 2008. This meant that by January 2009 95% of all plants (young plants) in the nursery (approx 2.5 million) were grown and supplied in the Mark 1 formulation biodegradable pot.

We noticed several things; an increased rate of growth, and a decline in the incidence of disease and weed infestation.

While this had not been our original motivation, with hindsight we had broken the disease and weed infestation cycle. This cycle had become a hidden factor in liner production in New Zealand, with its industry wide dependence on recycling pots with no genuine method of sterilization between usages.

Industry acceptance of the change was at first positive but not universal. Growers were initially encouraged to save one whole process in their potting procedure by planting the liner in its biodegradable pot, relying on the extensive side slots to allow root growth into the new substrate in the larger container.

Resistance to this practice came quickly for two reasons.

The Mark 1 pot did not reliably break down in the time it took for the liner to reach a saleable size in its new pot (this was particularly an issue with fast-growing plants such as *Lavandula* and ericaceous plants with weak fibrous roots.

The second issue was visual. The top collar of the biodegradable pot was often visible which led to problems especially at a retail level. Curious shoppers attempting to pull the plant out, or questioning the value in buying a small plant "stuck" into a larger pot.

Faced with negative retail feedback growers resorted to taking the biodegradable pots off and planting as they had always done with liners grown in the industry standard plastic 5-cm pot.

THE MARK 2 POT

The Mark 2 biodegradable pot was in reality about the fourth formulation we trialled.

Propagation nurseries in Australia had embraced the concept and were able to contribute to refining the formulation determining the speed of breakdown. With our combined experience a clear picture was emerging.

It became apparent that soil temperature, water availability, and the level of microbial activity all had a major bearing on the rate of degradation.

Hence a faster rate of breakdown was experienced in summer than was found in winter.

The addition of charcoal to the formulation altered the colour of the pot so that they were less visible.

However it also sped up the rate of breakdown in some environmental circumstances, a factor which had to be taken into account when arriving at a formulation which was a compromise between lasting long enough in the nursery but not too long.

SUMMARY

Our adoption of the Mark 2 "eco pot" (6–9 month breakdown) has met many of the concerns which arose out of the earlier longer breakdown Mark 1 pot.

This has led to a focus on some of the unexpected benefits.

- Increased rate of plant growth.
- Less weed control input required.
- Fewer incidences of pest and disease.
- Potting into new clean pots has made the adoption of mechanization that much easier.

While our original motivation to explore the possibilities of a biodegrading pot came from a wish to see us use less plastic in the supply of young plants, other consideration have emerged which are of more direct benefit.

Breaking the cycle of disease associated with growing in constantly recycled pots which are not sterilized has been the biggest and most immediate benefit, specific to the New Zealand context.

I am sure that the evolution of the biodegradable pot is not complete. However the direction is clear and positive and well worth the journey.

Integrated Pest Management Strategies at Southern Woods Nursery©

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INTRODUCTION

For the past 3 years Southern Woods Nursery has been looking at different ways of controlling pests and diseases in the nursery. As a result we have now moved away from the calendar-based spray programme to a more preventative spraying system with an integrated pest management (IPM) approach.

There were several reasons for moving away from the calendar-based spraying approach, these being:

- To minimise environmental impact
- To be safer for the health of people in the nursery
- To reduce the costs of chemicals being used

HISTORY

The basic concepts of IPM have been practiced since the start of human civilisation. However, what really set the ball rolling was a book by Rachel Carson in 1962, "Silent Spring." She addressed a number of issues related to pesticide use in both agricultural settings and home landscapes. Prior to the publication of her book, the application of pesticides was often the only method used to manage insects, mites, and plant diseases. However, continued reliance on pesticides gave rise to resistant pest populations and undesirable environmental effects (Cloyd et al., 2004). The acceptance of IPM as a philosophy and a technology can be traced back to 1970, to the first symposium of agricultural scientists where the concepts, strategies, and tactics of integrated pest management were synthesized and expressed as a philosophy and a set of technologies. The objectives are to manage pests using methods that are economically rewarding, culturally suitable, and environmentally acceptable (National Science Foundation Center for Integrated Pest Management, 2006).

In the United States of America, IPM was formulated into national policy in February 1972 when President Nixon directed federal agencies to take steps to advance the concept and application of IPM in all the relevant sectors. In 1979 President Carter established an interagency IPM Coordinating Committee to ensure development and implementation practices (Biocontrol Reference Centre, 2006).

WHAT IS INTEGRATED PEST MANAGEMENT?

Integrated pest management aims to manage pest populations at an acceptable level while at the same time significantly reducing or eliminating the use of pesticides. Often eradication of a pest is not only impossible but also costly and can have a detrimental effect on the environment. Instead of relying primarily on chemicals, IPM uses a wide range of strategies. These strategies can be identified in the following four-step approach.

1) **Set Action Thresholds.** The point at which economic damage is likely to occur is often called the action threshold, which can be triggered by environmental conditions or pest populations. The presence of one or two pests does not mean that control is needed; but when they become an economic threat to the crop actions need to be taken. Some controls like pesticides can be used very close to the action threshold, while others such as biological controls must be introduced well before a pest reaches the action threshold. It is important to know these thresholds for all pests.
2) **Monitor and Identify Pests.** Regular monitoring of the crop and environment can assist in determining when a pest is nearing the action threshold. Monitoring generally involves a combination of visual crop inspection, the use of insect traps or crop sampling, and record keeping.

   It is essential to accurately identify all the pest organisms found on a crop. This is especially important when biological control agents are to be used, because biological control agents are often quite specific to the pest(s) they attack. Incorrect identification could result in incorrect actions.

   The order in which control methods are used, their timing in relation to the pest's life cycle, and the pest's lifestyle are all important in effectively controlling a pest.
3) **Prevention.** As a first line of control, IPM programmes work to minimise the pest becoming a threat. Most pests are opportunists. However, by making conditions unfavourable the chance of pest invasion is reduced. Examples of unfavourable conditions include the selection of pest-resistant cultivars, maintenance of suitable environmental conditions, and sound crop practices. In order to successfully adopt these strategies it is important to understand the pest's biology. These control methods can be very effective and cost-efficient and present little to no risk to people or the environment (Biocontrol Reference Centre, 2006).
4) **Control.** Once it has been identified that a pest population is above the set action threshold, and preventative methods are no longer effective, control is required. There are three different types of control available — mechanical, biological, and chemical. Mechanical and biological control are usually employed, with chemical control only used as a last resort.
   a) **Mechanical Control.** This type of control involves directly killing the pests or making the environment unsuitable for them to live in. Using sticky traps or steam sterilising mixes are two good examples.
   b) **Biological Controls.** These can be broadly defined as an activity of one species that reduces the harmful effect of another species. Biological controls agents (BCAs) are usually low cost and can be very effective. Compared to chemical control they have minimal impact on the environment and are relatively safe for human health. Biological controls agents include

pathogens, predators, parasites, antagonists, and competitors. A wide range of BCAs is available in New Zealand.

c) **Chemical Control.** Even though the aim of an IPM programme is to reduce or eliminate chemicals, chemicals can still be an important tool. Some pests can only be controlled by chemicals, whereas with other pests, chemicals need to be used in combination with other management strategies for successful control. In any cases, chemicals are only used when other management strategies are unable to keep the pest below a certain threshold.

Most pests can be controlled by a combination of chemical and nonchemical control methods. For integrated pest management, these control methods must be compatible, i.e., they must not disrupt each other when they are used together. In the long term the combined effect of two or more control measures is often greater than that of a single method. As biological control agents are susceptible to many pesticides, it is essential to determine which chemicals are integrated into an IPM programme.

IPM AT SOUTHERN WOODS NURSERY

Over the past 3 years IPM has slowly been integrated into the pest and disease programmes.

Our spray technician, Stephen Lockett, was in a position to "get the ball rolling" in the nursery as he had seen the vast amount of unnecessary chemicals being applied around the nursery before he had taken the job. Through the following four-step approach we set about making change and implementing IPM strategies. The following is an example of whereby IPM can be integrated into a nursery with significant result.

1) **Set Action Thresholds.** This varies greatly around the nursery and is determined on a case-by-case basis.
2) **Monitor and Identify Pests.** Monitoring is carried out on a weekly basis, and with the nursery increasing in size it was essential to get the staff on board. The staff are a vital part of the monitoring process, reporting back anything of concerns with regard to pests or diseases (PODs).

   Every week Southern Woods staff document the PODs that have been identified and the plants they are affecting. These records have allowed preventative systems to be put in place for more effective control.

   For example, two-spotted spider mites have been a significant problem in a few of our deciduous tree lines and from our records we know which trees are hosts to these mites. Therefore using this information we have put a system in place whereby in late winter/early spring we spray oils over the trees to kill any overwintering mites. This has dramatically reduced the mite populations in the deciduous trees and therefore reduced amounts of chemicals needed during the season when they are active.
3) **Prevention.** When focusing on IPM strategies, cultural controls can often seem less important compared to reducing chemicals and using biological controls. Around Southern Woods I am always looking at ways to change the conditions to favour the plants rather than the pests.

Although we have not eliminated powdery mildew in our *Quercus*, we have modified the cultural conditions to reduce the susceptibility of the trees to disease. In the past, the trees have been spaced very closely together, where they were watered by overhead irrigation. The lack of air flow caused high humidity amongst the crop, creating perfect conditions for powdery mildew. However, now all of our *Quercus* that are susceptible to powdery mildew are held on wires and spaced further apart to allow greater air flow throughout the crop. They are also watered in the morning to give the plants a chance to dry out.

This helps to reduce fungal conditions such as botrytis in the smaller grade plants.

4) **Control.**

Biological Controls. There first became an opportunity to trial the use of biological controls when fungus gnat populations exploded in our tunnel houses. Since then, we have been looking into and trialling other biological controls for aphids and two-spotted spider mites. Next year we plan to investigate biological controls for thrips that cause damage in our *Pinus* spp.

Case Study: Fungus Gnats or Sciarid Flies (*Bradysia* spp.). Fungus gnats have a large economic impact in plant nurseries. The adults have been implicated in the passive transmission of fungal spores from one plant to another, and thus may assist the spread of some plant diseases. Damage caused by fungus gnat larvae feeding on roots can cause direct loss of seedlings, and is likely to promote the development of soil-borne fungal diseases and loss of seedlings and cuttings.

A range of insecticides are claimed to be effective against fungus gnats although few have specific registration claims for use on greenhouse crops. At Southern Woods Nursery, chemicals were applied regularly and were very costly.

A number of natural enemies (predators, parasites, and diseases) have been researched to assist with the management of fungus gnats. The predatory mite *Hypoaspis aculeifer* has been found to have the most effective control.

It is a small pale brown mite with a distinct V-shaped dorsal shield. Adults are 0.5–1.0 mm long and are commonly found in the top few centimetres of potting mix. Females lay their eggs near the soil surface, and these hatch into six-legged larvae. There are two further nymph stages and a life cycle can be completed in 10 days at 25 °C, but can vary from 7 to 30 days depending on temperature. Below 12 °C, the mite becomes inactive, and development stops when temperatures fall below 8 °C. The species does not hibernate and is able to survive for 6 to 8 weeks without prey by feeding on decaying organic matter.

Southern Woods buys the mites in for our tunnel houses and for the areas with our smaller-grade plants. Since using the predatory mite at the nursery the use of chemicals to control the fungus gnats has reduced dramatically.

Chemical Control. The use of chemicals to control pests and diseases has decreased over the past 3 years. Insecticides and fungicides are very costly, not only in down time (re-entry/withholding periods) but also because better quality protective clothing is required. Instead of using general insecticides that only have one use, we started to look at other products. What we found were two products, De-Pact® wetting agent/insecticide and JMS Stylet-Oil®. JMS Stylet-Oil is an organic product which contains 97.1% white mineral oil. It is distributed by Elliott Technologies Ltd. in New Zealand and is a registered trademark of JMS Flower Farms Inc., U.S.A. De-Pact® wetting agent/insecticide contains 10 $g \cdot L^{-1}$ eucalyptus oil and 2.5 $g \cdot L^{-1}$ tea tree oil combined with organic wetting agents. De-Pact is a registered trademark of Barmac Industries Pty Ltd, Queensland, Australia. These products are both used in vineyards around New Zealand for powdery mildew and foliage pests, and the JMS Stylet-Oil label also claims botrytis suppression plus mite and mealy bug control. JMS Stylet-Oil works by smothering the disease and modifying the plant surface, making it inhospitable and unsuitable for disease establishment. It also destroys powdery mildew cell walls in seconds and interferes with attachment to plant surfaces.

As well as working as an insecticide and a fungicide, the spraying oils are better for the environment and safer for the health of people working within Southern Woods nursery, as there is little to no withholding/re-entry period. Compare this to a general insecticide which can be up to 24-h re-entry and 7 days withholding period. De-Pact and JMS Stylet-Oil are also very cost effective. Karate® costs $255 per liter and has one function — to kill insects (Karate contains 250 $g \cdot L^{-1}$ lambdacyhalothrin in the form of a capsule suspension. Karate is a Registered Trademark of a Syngenta Group Company and is distributed by Syngenta Crop Protection). JMS Stylet-Oil, on the other hand, costs $6.30 per liter, approximately one-fortieth the cost of Karate, and not only kills insects but is also a very good fungicide.

Insecticides are still an important part of our spray programme, but we have reduced the use of them and only use them where essential. For example, we have found that woolly aphid on hornbeam (*Carpinus betulus*) in our nursery can only be controlled by a systemic insecticide, due to the aphids living and feeding on the underside of the leaves. In this case it is almost impossible to control them using an oil.

CONCLUSION

Since using IPM strategies at Southern Woods Nursery, not only are we using fewer chemicals but we also have better control of the whole system. This is due to having more knowledge in all areas of the process and therefore we are able to make better decisions.

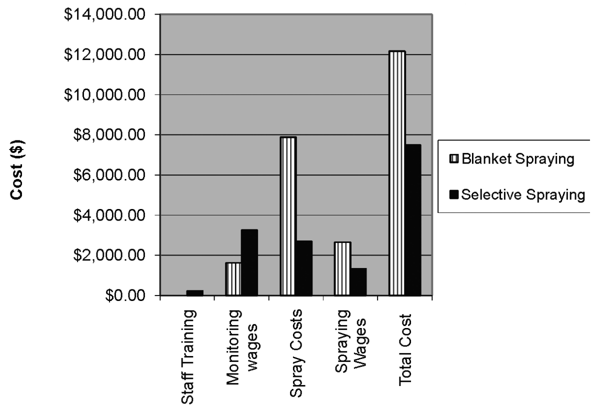

Figure 1. Comparison of costs associated with blanket spraying compared to selective spraying and the total cost of each programme.

The costs associated with staff training and monitoring have increased as a result of introducing IPM strategies. However the cost of sprays and the spraying wages have decreased, and overall we have reduced our total costs by 33% per year (Fig. 1).

The investment in time taken to change our system has been well worth it, and has resulted in a healthier, more environmentally aware workplace, not to mention the money we are saving.

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TECHNICAL SESSIONS

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Variables Involved in Rooting Rhododendron Cuttings©

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INTRODUCTION

The mission of the Rhododendron Species Botanical Garden is to build and maintain a comprehensive collection of species rhododendrons. This requires that we send collectors into the field to acquire plant material from the entire range and distribution of the genus that implies a great deal of plant variety. Rhododendrons grow from the tropical latitudes to the tundra of Siberia and most habitats in between. Much of the plant material that we grow is not in general cultivation and, therefore, not commonly propagated which has led to some difficulty in replicating many of them. As a result of this difficulty I have come to view the general rules of cutting propagation as variables. Looking at these variables individually has helped me develop practices that have increased our success rate with cutting propagation. By viewing each of these variables as something to be manipulated either individually or in combination and by keeping close records we have done pretty well with new plant material coming from lands far away. This is of course nothing more than a review of how to use standard propagation practices but I find that review of things such as this are often helpful and seldom done.

Before looking at some of the variables of cutting propagation for rhododendrons let me list a few things I will call "constants."

CONSTANTS

Observation. Attention to details involving the plants in question, cultural conditions, and details of every step of the process involved with replicating the plants desired.

Cleanliness. With each step of the process the propagator should be concerned with keeping the plant material and the work spaces involved as clean as possible.

Record Keeping. It nearly goes without saying that clear and concise records should be kept of propagation. Especially with plant material that has no propagation history, it is important that records be kept with as much detail as one can manage if anything is to be learned and successes repeated and failures remembered. Many rhododendrons have a narrow window of opportunity for rootability and record keeping is the only way to close in on the requirements that will achieve success.

Really Sharp Tools. Dull tools cause damaged tissue that, in turn, feed microorganisms that will move into the damaged tissue and then opportunistically move on to the rest of the tissue of the cutting, often causing it to rot. Dull tools also lead to sloppy methods. Notice that once a tool is determined to be extremely sharp, its use becomes far more precise than a tool that is dull. All propagators should know how to sharpen the tools of their trade!

Heirarchy of Rootability.

- Difficult to root = More attention to detail.
- Easy to root = Less detail required.

VARIABLES INVOLVED IN ROOTING CUTTINGS AT CUTTING TIME

Time of Year. Many rhododendrons have a very narrow window of opportunity when it comes to their ability to form adventitious roots. This is also an easy variable to manipulate if the window is unknown. With intuitive knowledge of timing of cuttings and record keeping the best time of year for taking cuttings of a particular species can easily be determined.

Time of Day. This is not so variable, but is important to mention. If cuttings are taken from the stock plant late in the day they are under transpirational stress as soon as they are removed from the stock plant. Shifting the time of day when the cuttings are taken to early morning when the rate of transpiration is lower and tissues are turgid will eliminate some of the immediate water loss a cutting suffers thus increasing the chances of rooting. This can be the difference between success and failure on plants that are moderately difficult to root.

Type of Cutting Selected: Lateral, Terminal, Flowering, and Vegetative. The ability of a cutting to form roots is controlled by many factors and among them is the hormonal status of the plant or plant parts in relation to one another. This gives us another interesting and useful set of variables to manipulate in the pursuit of greater rooting success. Some plants produce growth with a flower bud at every terminal which, as nursery stock is very good, but from a propagation standpoint is not necessarily so good. Many plants will form roots on flowering wood, but the hormonal changes that initiate flowering act to inhibit root formation so if a plant is difficult to root one might consider taking only cuttings that do not have flower buds. The question always arises: can the flower buds be removed from the cuttings? Well, yes they can, but for difficult-to-root plants this is not necessarily productive as the change that has taken place in the tissues of the plant to cause flowering cannot be reversed by removing the flower bud, so, it is no more likely to root. This also adds an injury to the cutting that makes it more susceptible to decline by fungal infection in the cutting bed.

Likewise, there is a hierarchy of rootability between vegetative terminal growth and lateral growth of plants that can be a useful variable to manipulate in pursuit of rooting success. Apical dominance of a terminal cutting can reduce the capacity to form roots, so it may be productive to select nonterminal or lateral cuttings.

Location of Cutting Selection — Sun and Shade. It is often useful before taking cuttings from a stock plant to walk around the entire plant and closely observe the condition of the possible cuttings that can be taken from all sides of the plant. This is useful for taking cuttings grown in different light levels from the same plant. In this way the propagator can determine an optimal level of sunlight by recording the situations of batches of cuttings; for instance, collected from the north side or the south side of the plant. It is also important to notice subtle clues the plant will express if it is exposed to too much sun which can be a stress possibly diminishing the plants capacity to initialize roots.

Juvenility. It has been shown that many plants in their juvenile stage, that is, before flowering maturity, are much easier to root than those that are mature.

This has occasionally been true of rhododendrons I have worked with and those collections that are known to be difficult to propagate vegetatively are often easily grown from seed. I have had occasion to grow a crop of seedlings and take cuttings from them as soon as they are large enough and most of the time they root quite easily. Of course, if clones of a particular selection are required then this variable will be of little use, but for increasing your numbers of species plants this can be an effective method.

Some rhododendrons can be induced to partial juvenility through severe pruning especially those rhododendrons with a tendency for rapid growth stimulated by pruning. In this manner clonal propagation of some selected material may be accomplished.

Physiological Condition of Stock Plants. Disease pressure, cultural conditions, and water relations of the stock plants in question are important variables that can come into all manner of manipulation. A plant that is diseased or growing under poor cultural conditions should be grown back to health before attempting to root cuttings from it. However, the eternal optimists we are, we often try anyway, usually to find out that cuttings taken from these poor plants don't do so well.

Water relations are of high importance as well. Plants should be well-watered prior to cutting removal, preferably the night before so that the material taken is turgid and will not dehydrate prior to being prepared for the growth chamber. On the other hand, cuttings taken from a plant that is growing in too much water will be less likely to root and should be moved to more suitable cultural conditions before attempting to root cuttings from it.

Fertility Level of the Stock Plant. Plant tissues must have moderate levels of nitrogen and other nutrients in them to root. Also, plant tissues that have too much nitrogen seem to rot very quickly in the warm and wet conditions of a rooting chamber owing to the fact that nearly every pathological organism in their environment is also looking for nitrogen. Nutritional levels in stock plants can be an important variable to manipulate and can be done with relative ease with close observation and good record keeping.

Carbohydrate versus Nitrogen Level in Cutting Stems. This variable relates to both the fertility level of the stock plant and the time of year in which the cuttings from a particular plant are taken. I mentioned earlier that many rhododendrons have a narrow window of opportunity when cuttings will root. This has to do with the "ripening" or stage of lignification of the cutting material in relation to the level of nitrogen contained in the stem. This can be useful as a variable in timing cutting removal from stock plants by developing an intuitive skill in the propagator of taking "snap tests" of cuttings throughout the possible cutting season as an indication of readiness of the cuttings. I have seen many propagators remove a cutting from a plant and bend it in half, maybe more than once along the length of the stem, to get a feel for the texture of the stem breaking. When the ratio of carbohydrate to nitrogen approximates the optimal rooting time the stem will have a good snap feel to it and can give an idea if the general timing for taking cuttings is correct. I know it sounds a bit folkloric, but it seems to be a pretty good rule of thumb when working in the field.

VARIABLES INVOLVED IN ROOTING CUTTINGS AT CUTTING PREPARATION TIME

Cutting Length. Attention should be paid to the length of the cutting stem and where the final cut is made. Often it is helpful to cut near or even through a latent bud or node, thus stimulating a meristematic site. Stem length must also be long enough to support the cutting in the medium, but short enough not to have the leaf material waving around in the atmosphere high above the medium supporting it; again, another detail that can be manipulated in the quest for better results.

Leaf Removal. Reduction in leaf surface area and hence transpirational water loss can be an excellent variable. A death commonly suffered by cuttings is caused by dessication. This can be easily moderated by leaf removal. With record keeping, a good balance between transpirational surface and photosynthetic capacity can be found for any particular plant being propagated. This can increase your chances of rooting difficult rhododendrons.

Wounding and Rooting Substances (Hormone Analogs). With difficult-to-root rhododendrons I pay careful attention to wounding and end cuts. Wounding is a nice variable to work with as wounds can be larger or smaller, more or less aggressive or any number of different styles. One thing they should not be is sloppy, i.e., leaving thin tissue flaps and crushed or bruised tissue. This is where very sharp tools become important. With plants that are difficult I do not use pruners for end cuts as they cut with one side and crush with the other. This leaves bruised and damaged tissue which will die, feeding fungal and bacterial organisms and causing the whole cutting to rot because of the tissue damaged in the preparation. We use knives for preparing cuttings and sharpen them to a keen edge to prevent tissue damage and to keep the propagator from becoming lackadaisical.

In conjunction with end cuts and wounding there are many rooting hormones or analogs of plant hormones that promote rooting and can be varied in strength, application, and type.

Indumented Leaves and Stems. An interesting, but sometimes problematic, feature of many species rhododendrons is indumentum. This often densely furry material can be quite attractive on the plants, but on cuttings it can sometimes interfere with physical contact with the rooting medium thus creating an airspace that can inhibit rooting. On most indumented species this material can be rubbed off to improve contact if labor time is not an issue or it is a very valuable plant which needs to be replicated. Likewise, indumentum on the tops of leaves (known as tomentum) will often stay too wet in mist beds and quickly form a dark layer of algae that shuts off the photosynthetic surface of the leaf and certainly will inhibit rooting. Again, with most rhododendrons this material is easily rubbed or washed off which can be most helpful.

VARIABLES ON THE CUTTING BENCH

Water Relations. The optimal atmosphere for rhododendron cuttings is generally fairly consistent, but for plants that seem to rot too quickly or suffer from botrytis or other fungal infection even after disinfection it is possible to experiment with varying levels of mist and humidity. Another variable related to this is rooting medium temperature. It is important to pay close attention to the physical interaction between these bench conditions as changing one of them affects the others. It is easy to lower the misting interval, but doing so can cause drying of the flats from bottom heat so hand watering may be required to replace the water in the medium which was previously supplied by the mist. Attention to details is important.

Rooting Medium. The three things important to a rooting medium are support of the cuttings, water holding capacity, and airspace. All three of these items can be changed and manipulated to supply a specific need for any particular plant.

Light. Again, three variables to be worked with are light quality, intensity, and day length. There are any number of ways these variables can be changed to produce results. An example of this in rhododendrons is the North American group of deciduous azaleas. They generally root quite easily and can be potted on and they look fine, but if they do not get extended day length (at least at our latitude) they will go dormant and then never grow again. The terminal buds will still be green and the cambial tissue alive and they can remain that way for 2 or more years and still not grow. Given extended day length immediately after they are rooted, until they push new growth then taken away from intensive growth and allowed to go dormant and overwinter outdoors or in a cold frame, these plants will grow the following spring in their normal fashion.

The overview of the variables I have listed is brief and certainly not comprehensive, but they have been instrumental in helping me achieve some success in rooting many species rhododendrons that are thought to be very difficult. In my experience with new and often unknown plant material I have found that careful observation and detail-oriented practices plus simple thought of variables involved with the physiology of forming adventitious roots can go a long way in the success or failure of rooting species rhododendrons.

Fern Propagation 101©

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INTRODUCTION

What follows is an outline of how to propagate ferns.

Prerequisite: Basic math, powder/liquid measurements, and common sense growing.

Background:

- Spore germination — Gametophyte (heart shaped and sometimes mossy looking)
- Sperm cells to eggs
- Male structures (antheridia / sperm cells) female structures (archegonia / eggs)
- Sporophyte emerges from gametophyte
- Sporophyte matures into parent fern and produces spore.

Step 1: Collect your spore

- Spore matures at different rates
- Many types of spore
- Green spore should be refrigerated (short life span)
- Most spore keeps 1 to 2 years / even longer

Step 2: Sow your spore

- Mix 1 teaspoon of spore / 1 cup of fine vermiculite, this mixture will sow 10 flats.
  - Variables include how old spore is, how difficult to germinate, etc.
- Soil: peat based, well drained, slightly acid (pH 6.0 to 6.5).
  - Always exceptions to the rule: i.e., sow *Osmunda* spp. on straight peat.
- Wet (soak) your propagation mix down with clear water
  - Evenly disperse thin layer of spore / vermiculite mixture
  - Heavy spray (sprench) with Chipco 26019 (wettable powder only) at 1 tablespoon/gal
  - Cover with clear plastic or put into clear plastic bag

Step 3: Germinate your spore

- Temperature of 65–70 °F works well (take into account heat coming from lights)
- Under lights — long days recommended, 24/7 works well
- Do not bake in direct sunlight
- Remove plastic cover at first sign of greening (3 to 12 weeks depending on fern species)
- Water (carefully) only with clear water and keep moist

Step 4: Care for your gametophytes

- Do not bake in direct sunlight!, 60% to 70% shade needed
- Temperature of 55–75 °F

- Sperm cells migration to eggs requires misting / watering
- Use clear water with no fertilizers
- Warm sunny days: mist heavily 3 to 6 times depending on day length
- Warm cloudy days: mist heavily 3 times depending on day length
- Always allow enough time for gametophytes to dry off by nightfall
- Sporophyte development time varies with specie:
  - *Athyrium* — 10 to 16 weeks
  - *Osmunda* — 10 to 36 weeks
  - *Dryopteris* — 12 to 24 weeks
  - *Polystichum* — 12 to 24 weeks
- Always exceptions to the rules
- Chipco 26019 (powder only) at 1 teaspoon/gal
- Enstar for fungus gnats no good
- Orthene WP for severe gnat infestation cases

Step 5: Transplanting your sporophytes

- Crowd them and transplant them several times
- 200 to 300 per 10-in. × 20-in. flat (1st transplant)
- 70 to 100 per flat on 2nd transplant. Plug tray fine at this step.
- Plant small clumps to a 4-in. pot
- Usually best to go with a well drained, peat light mix while plants are small
- pH should be 6 to 6.5 for your soil mix
- Begin fertilizer at 100 ppm N every other watering
- Ferns hate salt build up and require very little fertilization
- Continue with 60% to 70% shade and 55–80 °F degrees for growing on.

Step 6: Finish your fern to maturity, market your fern, and sell your fern

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QUESTIONS AND ANSWERS

Corey Barnes: I'm working with a species of *Lepisorus* spp. from the Sichuan Province. I planted the spores 9 months ago and they're still sitting and staring at me. I have gametophytes and I'm wondering how long they can survive before sporophytes are formed?

Terry Berger: Congratulations. You can hear the frustration in the man's question. You can't give up. You watch for fungus problems and you keep your seatbelt on. Don't get frustrated; be patient. It will pay off.

Corey Barnes: Have you ever seen gametophytes not produce sporophytes?

Terry Berger: Only if they rot. No, they'll just keep on going until conditions are perfect.

Corey Barnes: Can fertilizer be added?

Terry Berger: You can feed them and bulk them up as long as it's low amounts of fertilizer (50–100 ppm). I don't ever recommend it, though. Most people will burn them right up.

Patrick Peterson: How do you go about cleaning the spores before planting?

Terry Berger: After we bag them we put them through really fine sieves. Many ferns have lots of chaff or hair that can be separated from the spores with sieves.

Angela Anderson: Have you tried using slow-release fertilizers added to the soil medium before planting the spores?

Terry Berger: We never have. We don't add fertilizer until we see sporophyte formation.

Angela Anderson: We saw too much yellowing.

Terry Berger: I know you can get away with low amounts, but I also know you can burn them easily.

Organics and Biological Control in Propagation©

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Even the most conventionally trained professional growers are learning now how to manage biologically active materials, and living organisms in their greenhouse growing systems. Materials for consideration by nursery operators would include: biologically active container media, the addition of microbial-based products (both bacterial and fungal), biostimulants, beneficial insects, and nematodes.

INTRODUCTION

Growers are discovering a wide range of benefits as they begin to build biodiversity into their operations. We are essentially learning how to stack "environmental services" into otherwise sterile growing systems. Some of the many benefits include increased worker safety, decreased use of pesticides, enhanced root growth and nutrient utilization, heightened flower color, and marketability. As scientific data continues to accumulate regarding the multiple benefits of increasing biodiversity on farms with food crops, there are correlations between growing sectors worth noting. These data support what organic farmers already recognize about the self-regulating effects of their operational models. These concepts are to some degree transferable to our largely conventional models of growing container plants for market. The presentation at IPPS in Bellingham attempted to give an overview of how we might achieve these goals of enhanced biocontrol and fertility through the use of some accessible tools, like beneficial insects and compost teas.

UNDERSTAND YOUR MOTIVES AND GET SUPPORT

Growers please consider the following:

- It is important to have clear and specific goals. Approach the problem all or nothing, or area by area.
- Make sure your goals are realistic. Will the management and staff agree on what is envisioned?
- Create a budget based on these goals. Keep it reasonable and affordable.
- Implement a simple program in propagation. Note and track your small successes, and if there is a glitch, make note and get support.
- Note your improvements in plant quality. Point these things out to team members that might not notice your efforts, or how it might affect them as that plant material move from propagation to the next growing stage.
- Build trust amongst your staff members, so there is an understanding if they communicate well with you, you will be responsive to them, and that you can create a track record of successes as you learn how to use these new tools.

- Document your small victories and share experiences with the rest of your team.
- Distinguish your product and capitalize on your investments and good intentions.

CONSIDERATIONS BEFORE BEGINNING WITH BIOCONTROLS

Adopting the use of beneficial insects and/or nematodes in your operation is a good place to begin, but will take a good, full year to gain experience and confidence in using these new tools. As growers we know there are certain issues that begin at specific times in the crop cycle. Good planning is essential to your success. Planning in the summer and fall for the new cycle of cuttings and seedlings in your propagation makes the most sense for starters. Schedule time or enlist someone in your ranks to help you do the planning. Begin early and give yourself adequate time to do so.

Assess the major problems/pests that you see most important to address. Consider what both the risks and benefits of reducing or eliminating pesticides in a given growing area might be. Maybe the risk of eliminating a certain systemic pesticide in a hanging basket crop is too great an economic risk to take. Consult a knowledgeable supplier that you trust to help you assess the best place to begin. Do plenty of research, reach out, and talk to other growers that have been successful. If you find growers to talk to that have not been successful, try to gain an understanding as to what might have gone wrong for them. It is good to recognize that every growing system is different, even in identical greenhouses with similar crops. There are also seasonal differences in how beneficial insects might work. For example, the aphid predator, *Aphidoletes aphidimyza*, is daylength sensitive and diapause could be a factor in its effectiveness in midwinter without some supplemental light.

Additional factors can affect your biological control program and are important to consider. These include: freshness of product, quality of product, inconsistencies in application methods, and the quality of the monitoring system. All these aspects need to be managed, as they can impact the success of a grower beginning to use biocontrols. Feeling supported and having a backup plan is always important. Learning from people that have made mistakes. Learning from those mistakes can be one the most invaluable components of your planning process, accelerating the learning curve and creating a short cut to success.

After you have set your realistic first-season goals, make sure you have a game plan for handling spots of pest insects that are bound to occur. These may require a small chemical application.

- What is in your current chemical arsenal?
- Are those materials compatible with insects that you would wish to use in those areas?
- Do you need to have a few "softer" pesticides or perhaps different fungicides on hand?
- Are you committed to stopping all routine spray programs in the treatment area?

A plan "B" is always in order.

You can get some idea of chemical side effects on a web site like this one: <http://side-effects.koppert.nl/>. Please consider all off-target innocent bystanders such as bees that will be attracted to pollen in flowers. Consider all impacts. There will be caveats to using information sources like this, but they can be very useful tools.

Develop a pest monitoring system that works for you. If you are not currently using yellow sticky cards, get into the habit of reading and recording fungus gnat, western flower thrips, shore flies, and other basic pests that can be easily monitored by these weekly counts. Some operations make sure that the person who does the counts is different than the pest manager, who may get too busy or take shortcuts. Training someone to take more time to look at the foliage of the crops, digging deep for aphid colonies, watching for early signs of mite damage, or other irregularities out of the norm of the healthy patterns we see in good plant growth is critical. Some data is easy to record and some growers are beginning to take advantage of different computer logging systems for this information, so they can easily reference and note patterns from year to year, crop to crop, area to area. There is a free beta version of a monitoring system you can download created over the last year or so by Krishna Reddy at Blooming Nursery in Oregon. It can be accessed at: <http://www.ipmsuite.com/> and login using the following credentials:

- Email Address: krishna@bloomingnursery.com
- Password: demo

You can configure as you like, adding the pests that you wish to track. For someone starting new, they can sign up and create an account. Then setup:

- **Scouts** and **Locations** being monitored
- **Pests** being monitored
- **Monitoring tools** being using (sticky cards, tape, etc.)
- **Record pest data** by location

Add new locations as needed. For those who choose to experiment, we would love feedback as to how it works for your operation.

Before beginning to implement your beneficial insect program, it is important to reduce pest pressure in your operations. Biological control is largely preventative in nature and it is important to have a proactive approach, and to start with as clean a crop as possible. One of the biggest problems in biocontrol today is not knowing what your plug or liner supplier might have used on their plant material before shipping to you, the customer.

The importance of cultural sanitation and hygiene in your operation should go without saying, as build up of wet soils or decaying plant material, drip zones, or leaky faucets can all create an environment where pests that feed on algae (and plant roots) can thrive. Keeping the propagation area very clean, even if you have gravel floors is a great goal. Improving this can be as simple as covering well-drained gravel floors with ground cloth that is pinned to the very edge of where your cement walkways begin. This makes for much easier cleaning. Short of that, many growers find creative ways to "take advantage" of these not-so-positive wet pockets and use them to propagate their own biocontrol agents under the benches: for example, the rove beetle, *Atheta coriaria*, can be established in these wet conditions and used to augment a grower's shore fly and fungus gnat control. This complements the use of the predatory mite, *Stratiolaelaps scimitus (*syn. *Hypoaspis miles)*, for fungus gnat control. While the *Stratiolaelaps* predator mite is busy on fungus gnat larvae in the container soil, the rove beetle is patrolling the floor and flying up into the container area as needed. Adding the next dimension, western flower thrips (WFT, *Frankliniella occidentalis*), is often the next consideration. Another voracious predator mite, *Amblyseius cucumeris* (syn. *Neoseiulus cucumeris*), works in the canopy of the plants and searches for young thrips as they hatch out of the foliage. The addition to

A. cucumeris helps complete the control program, increasing efficiency of the other biocontrols. Bases are now covered for fungus gnats, shore fly, and to a good degree the western flower thrips. Western flower thrips are now the key pest in ornamental horticulture. They transmit both tomato spotted wilt virus (TSWV) and impatiens necrotic spot virus (INSV). Feeding directly on leaf and flower tissue, WFT need to be considered at all stages in horticultural plant production. Biocontrol for WFT is indeed possible, but requires proactive planning and monitoring. An adult WFT can lay 300 eggs in her lifetime and larvae can crawl or jump quickly through a plant system. Wherever pollen is present, the WFT can cause extensive damage. For all these reasons it is crucial to reduce pest pressure before beginning your program. Chemical treatments have become largely ineffective because of extensive pest resistance in our industry. Biological control is actually quickly becoming a more effective means for WFT control in North America, Holland, Spain, Denmark, and other places where biocontrol is quickly becoming more the norm.

MICROBIAL APPROACHES TO PLANT HEALTH — COMPOST TEAS

There are many more examples, even in greenhouse ecosystems, where, as we begin to build more diverse, interactive systems between insects, and perhaps the microbial world, there is a natural balance that can be achieved. Biodiversity continues to be the keyword here, yet the challenge of creating that in a plant container is something that most growers are just becoming familiar with. Examples of registered organic fungicides that are based on beneficial microbes would be the Cease™ (*Bacillus subtilis*), Actino-Iron® (*Streptomyces lydicus*), and PlantShield® and RootShield® (*Trichoderma harzrianum* T-22). These materials are most often beneficial bacterial strains that have specific modes of action against common diseases like *Pythium*, *Phytophthora*, *Rhizoctonia*, *Verticillium*, and others. They have been used on a wide range of crops at this time and much info is available online.

Just coming into the spotlight is the use of aerated compost teas, which although they are not registered biological fungicide products, they are enjoying popular acceptance. Compost teas can and will vary from grower to grower, depending on their production methods. Those who make them consider this a positive, not a negative. How a grower brews their compost tea extraction, what composts are chosen, temperatures, foods, air level in the tank, extraction devices, can all affect the outcome. Custom tea recipes are available for specific target problems. Organic and conventional farmers around the world have been fine-tuning these methods for some time and now professional horticulturalists are doing the same. The downside of the compost teas in comparison to the aforementioned "bugs in a jug" approach is that they do not contain the exact concentration of specific lab-reared microbes that the registered products must meet. Another downside could be that they do take equipment to brew on site and take a little time to set up and clean up. The upside is that they can indeed be tailor-made for a grower's needs and contain a huge array of beneficial bacteria and fungi. This diversity is where we find a growing body of scientific knowledge every day, as we determine that there are so many microbial modes and mechanisms of activity in both the soil system (rhizosphere), as well as above ground in the plant canopy.

LITERATURE AVAILABLE TO YOU ON REQUEST

- Biological control questionnaire to get you started.
- Tech sheets for specific beneficial insects and compost-tea production guidelines.
- Biocontrol quality assurance standards and checklists.
- Becker Underwood nematode/chemical compatibility charts.
- Illustrated guide to biocontrol: *Knowing and recognizing the biology of glasshouse pests and their natural enemies*. M.H. Malais and W.J. Ravensberg, published by Koppert Biologicals.

QUESTIONS AND ANSWERS

Anonymous: How can I learn more on this topic? Can you direct me to resources?

Alison Kutz-Troutman: Check out <http://soundhorticulture.com/> and I'd be happy to talk with you individually. I'd also be happy to visit anyone's nursery.

Blooming Nursery System Overview©

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Since constructing the range of five, large, gutter-connected greenhouses, it has averaged an annual consumption of 3,100,000,000 BTUs of natural gas. Air was heated by gas burners and blown into the greenhouse range. A tremendous amount of the heat rose into greenhouse gables and escaped. We were interested in installing a more efficient system of delivery as well as collecting natural heat energy to power the range. Our new system includes an in-ground radiant delivery system which conducts heat to the roots of the plants to put the heat where it can be utilized most efficiently (saving 2,160,000,000 BTUs) as well as a hybrid energy supply system including solar collection panels (saving another 700,000,000 BTUs).

Following is an overview of the major components of the system, followed by a brief summary of how the system functions. The radiant-heat delivery system is comprised of PEX (flexible tubing used in residential and commercial plumbing applications). The PEX is laid on the floor of the greenhouse, over styrofoam, insulating underneath the tubing and crushed rock over it, to produce a "heat bank." Because the heat is delivered near the roots, this improved design significantly reduces the heat needed to keep the plant root zone warm. As mentioned above, this reduces the need for input energy by two-thirds. The second and most visible component is the solar collector array. Over 350 EnerWorks solar thermal energy collector panels are connected through a closed glycol loop which transfers heat energy to a closed water system through a finned stainless-steel heat exchanger. A unique racking system was developed that made it possible to erect the collectors above the existing greenhouses as well as above the storage tank, in order to avoid interference with existing production areas. The 290,000-gal water loop consists of a large four-chambered underground storage tank, numerous pumps, as well as the in-ground delivery system underlying the greenhouse. The size of this very large tank was determined by the heat generation possible through the collectors installed, coupled with the heat storage needs to supply the range through nearly the entire winter season. The fourth component is the heat-pump system, utilized at times of marginal or no output from the solar array. The fifth component is the backup gas heaters. The system has gas-fired unit heaters hanging from the ceiling of the greenhouse that can provide enough heat to prevent freezing conditions during peak design winter conditions. In addition, the system has "on-demand" water heaters that can introduce hot water directly into the radiant heating system in the occasional scenario where weather conditions have been poor for an extended period of time preventing the solar and heat pump system from functioning as designed.

The final and most critical component is the array of sensors and controls. Sensors in the greenhouse monitor temperatures in the radiant heating system, the plant, soil, and the air above the plants. Sensors are also placed outside the greenhouse to monitor outside air temperature, wind speed, and solar radiation. The information from the sensors is used to control the performance of the solar array, the heat pumps, and the backup gas unit heaters.

The sequencing of the system is complex and involves many phases, depending on heating requirements, component temperatures, and environmental conditions. In the summer, heat is transferred to the water in the tanks to be stored for use as needed in the fall and into the winter. As the output from the solar system becomes inadequate to supply the needed heat directly to the radiant heating system for the greenhouse, the system routes warm water from tile storage tanks to the floors, and later still, to the heat pumps. The heat pumps are able to build the temperature in the supply water and deliver the appropriate temperature water to the radiant-heating system loop. In the winter season when radiation levels are at their lowest, the system shifts into another mode. Water is routed directly through the heat exchanger from the floor loop, heat being transferred to the water from one segment of the storage tank, now with water temperatures between 50 and 70 °C. The energy is extracted and the colder water is returned to the "cold tank". This strategy allows the system to continue to run at low temperatures in the winter season, producing significant efficiencies.

We estimate energy savings from the solar and heat pump systems combined at a net 700,000,000 BTUs annually, after allowing for the supplemental load required to power the new equipment.

The combination of the system design changes and the energy supply savings will result in an approximately 95+% reduction in energy usage to heat the range.

QUESTIONS AND ANSWERS

Steve Hottovy: Grace, I salute your forward thinking on this. Who designed and manufactured the system?

Grace Dinsdale: Ra Energy in Portland.

Kristin Yanker-Hansen: I can suggest one other benefit. I bet all your employees want to park underneath the solar panels.

Grace Dinsdale: Actually, we planned to put some herringbone parking, but right now the surface isn't prepared for auto traffic. The 8-in. carbon-steel pipe is buried right below and it has to maintain a particular slope. I'm worried about uneven settling in the soil. We've protected the buried pipe with large telephone poles to keep cars from driving over it.

New Plant Session Western Region©

Steven A. Hottovy
Beyond Green LLC, P.O. Box 1045, Canby, Oregon 97013
Email: beyondgrn@aol.com

***Picea glauca* 'Topper'.** 'Topper' originated as a point mutation on a large mature *Picea glauca* 'Conica'. The terminal bud had mutated into a compact, bushy, cute, 18-in. Christmas tree on top of a large dense Alberta spruce body. Cuttings rooted easily and grew vigorously while maintaining true to type of the new form.

- Selected in 2000 as a sport on *Picea glauca* 'Conica' in Newberg, Oregon
- Propagated by rooted cuttings, vigorous on its own roots
- Compact, full bushy pyramidal habit. Suited to smaller landscapes

Figure 1. *Picea glauca* 'Topper' plant.

Richie Steffen
Elisabeth C. Miller Botanical Garden, P.O. Box 77377, Seattle, Washington 98177
Email: richies@millergarden.org

***Bergenia ciliata* 'Susan Ryley'**

- Hardy to 10 °F (possibly 5 °F?)
- Partial shade and well drained requires some summer watering

- Propagated by stem cuttings
- To be released through the Pacific Horticulture Magazine's Pacific Plant Promotions program late 2012 or early 2013

Ercilla volubilis

- Hardy to 10 °F (untested at lower temperatures)
- Native to Southern Chile and Argentina
- Evergreen vine
- 15–20 ft in 10 years
- Propagated by stem cuttings
- To be released through the Pacific Horticulture Magazine's Pacific Plant Promotions program late 2011

Polystichum* × *dycei

- Hardy to 5 °F (untested at lower temps)
- Vigorous and easy to grow
- Prefers full shade to morning sun
- Propagate by rooting bulbils on end of fronds, tissue cultured plants are grown by Casa Flora Nursery

Matthias Mart

EuroAmerican Propagators, L.L.C., 32149 Aquaduct Rd., Bonsall, California 92003
Email: matt@pweuro.com

***Leucanthemum* 'Daisy May'** USPPAF

- 2010 Proven Winners Introduction
- A dynamite plant
- Day-neutral
- Highly floriferous
- Very fast in production

Gomphrena

- Undeveloped / underdeveloped market
- Some recent introductions by various companies, including *Gomphrena leontopiodes* 'Balboa' USPPAF by EuroAmerican Propagators
- An old genus being reinvented
- Lots of room for improvement on current market types
- Several selections available for trials

Verbena (for the landscape)

- Various trial varieties and colors available
- Cover lots of space in no time

***Mandevilla* Vogue® series**

Dave Adamson

Adamson's Heritage Nursery Ltd., 1832 240 St., Langley, B.C. Canada, V2Z3A5
Email: dave@adamsons.ca

***Sambucus* 'Morden Golden Glow'**
***Rosa rugosa* 'Jaimie'**

Eric Hammond
Heritage Seedlings, Inc., 4194 71st Ave. SE Salem, Oregon 97317
Email: ehammond@heritageseedlings.com

Cornus kousa 'Summer Gold' PPAF

×_Gorlinia floribunda_

Cercidiphyllum magnificum

A selection of evergreen oaks

John Dixon
BooShoot, 17618 Dunbar Rd., Mt. Vernon, Washington 98273
Email: john@booshoot.com

Gaillardia × _grandiflora_ 'Tizzy'

Gaillardia × _grandiflora_ 'Frenzy'

Coming soon: _Gaillardia_ × _grandiflora_ 'Moxie'

Crocosmia 'Severn Sunrise'

Lynne Caton
Briggs Nursery, Inc., P.O. Box 658 Elms, Washington 98541
Email: lynnecaton@briggsnursery.com

Rhododendron maximum

Hydrangea quercifolia 'Ruby Slippers'

Hydrangea quercifolia 'Munchkin'

Daphne odora 'Mae-jima'

Hebe ochracea 'James Stirling'

Raspberry Propagation and the Washington State University Breeding Program©

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The Washington State University red raspberry (*Rubus idaeus* L.) breeding program develops new cultivars that are suited to the needs of local growers. In the process of developing new cultivars the program has to deal with various propagation issues including: controlled pollinations, seed germination, micropropagation, and traditional raspberry propagation from root cuttings. The breeding program will describe the flow of plant material through the process of developing new cultivars.

The Washington State University (WSU) raspberry breeding program began in 1928 with the first crosses made in 1929. The program has released 11 raspberry cultivars since then. Dr. C.D. Schwartze released six cultivars, including 'Meeker', in 1967. Over 40 years since release, 'Meeker' is still the most widely planted raspberry in the Pacific Northwest, with over 50% of the commercial plant sales. Recent releases from the program include 'Cascade Delight' and 'Cascade Bounty'. 'Cascade Delight' is a large-fruited, root-rot tolerant, fresh-market cultivar that is finding acceptance in the Pacific Northwest for fresh market as well as worldwide interest. 'Cascade Bounty' is a very productive, machine-harvestable raspberry with excellent root-rot tolerance. Plant sales of 'Cascade Bounty' in the Pacific Northwest are still increasing.

In 2009, Washington produced 65,700,000 pounds of red raspberries, leading the U.S.A. in raspberry production (NASS, 2010). Only 700,000 pounds of this were sold fresh with 98.9% of the production being used for processing uses. All processed berries are machine harvested. Only a very small segment of the Washington raspberry industry would benefit from a new cultivar suited only to the fresh market. Therefore, developing machine harvestable raspberry cultivars is an extremely high priority of the WSU raspberry breeding program. Other high priorities are breeding for root-rot tolerance and raspberry bushy dwarf virus (rbdv) resistance, two of the major diseases affecting commercial raspberry production in the Pacific Northwest.

Over the past 5 years, the breeding program has averaged 95 raspberry crosses per year. Parents have been selected to combine machine harvestability, root-rot tolerance, and rbdv resistance. The seed from the crosses is cleaned from the fruit by the use of pectinase. The fruit from a cross is placed in a small bottle, covered with water and 1–2 drops of pectinase per 50 ml of water is added. This is incubated overnight at 37 °C. The bottle is shaken and the seeds settle to the bottom of the bottle. The remaining pulp from the fruit is removed by rubbing the seeds in a strainer in water and floating the pulp away. The seeds are air-dried and then stored in a refrigerator until needed. Prior to sowing, the seeds are acid-scarified and then cold-stratified. Dry seed is treated with concentrated sulfuric acid for

15–20 min, washed in running water, and then soaked in 1% calcium hypochlorite with excess calcium hydroxide at room temperature for 6 days with the solution being changed after 3 days. After this treatment the seeds are rinsed and then given 6 weeks of moist, cold (4 °C) stratification.

The goal for each cross is to produce 200 seeds and have those seeds produce 100 seedlings. Over the past 5 years, the program has planted an average of 7,100 raspberry seedlings each year.

Two years after the seedlings are planted in the field, selections are made. Seedlings are evaluated weekly for vigor (especially root-rot tolerance); yield; growth habit; fruit color, size, appearance; fruit firmness and ease of fruit harvest; and flavor. Superior seedlings are propagated for further evaluation. The next year (3rd year after planting) additional seedlings are selected in the same seedling field, independently of the previous year's evaluations. Approximately 1% of the seedlings are selected for further evaluation.

The selections are propagated by micropropagation. Shoot tips (1–4 cm long) are collected from 1st year canes;, expanded leaves are removed and then surface sterilized with 0.5% sodium hypochlorite with Tween 20 as a surfactant for 16 min. The shoots are transferred to 0.05% sodium hypochlorite solution for at least 5 min and then placed on growth medium. The advantage of micropropagation is rapid propagation of small numbers of plants and greatly reducing root-rot contamination of the plants. Each year the program has over 100 different raspberry selections and cultivars in propagation. When a selection is not micropropagated successfully, roots of the selection are dug in early winter; roots are washed and placed in vermiculite in the greenhouse. The shoots that are produced are rooted in pumice on a mist bench. The plants produced this way are grown in the greenhouse and shoots from these plants are then collected for micropropagation.

The next stage of evaluation of a selection is machine-harvest evaluation. Ten plant plots of each selection and standard cultivars are established with a cooperating grower. These plantings are grown using commercial methods. Two and three years after planting these plots are machine harvested with commercial harvesters. The selections are evaluated weekly during the harvest season. Fruit of the selections is evaluated as it passes over the belt on the harvester. Selections are subjectively evaluated for the stage of ripeness of the harvested fruit, fruit size, integrity, firmness, flavor, and yield. The selections that appear to machine harvest well are evaluated further.

The advanced selections are planted in another machine harvesting planting and replicated plots at WSU Puyallup where they are hand harvested and data is collected. The advanced selections may be evaluated for root-rot tolerance in a field naturally infested with *Phytophthora rubi*. The selections may also be evaluated for resistance to rbdv by graft inoculations.

If selections appear promising after these evaluations, they are commercially propagated and planted in grower trials with intellectual property protection. Finally, a selection may be named and released as a new cultivar or discarded. The average amount of time from when the cross was made to when the 11 cultivars were released from the WSU program is 14 years.

LITERATURE CITED

National Agricultural Statistics Service. 2010. Non-citrus fruits and nuts 2009 Summary. <http://www.nass.usda.gov/Publications/Todays_Reports/reports/ncit0710.pdf>. Accessed 8 September 2010.

QUESTIONS AND ANSWERS

Gayle Suttle: How are the selections evaluated for resistance to root rot and is the field test selective enough for the correct disease.

Patrick Moore: A few years ago, we did a study comparing the field response to root rot to the response of the same raspberries in the greenhouse. The plants in the greenhouse were inoculated with *P. rubi*. There was a significant correlation of about 0.7 between the field response and the greenhouse response. So the field response was similar to the response of plants inoculated with *P. rubi*, even though the greenhouse study used small tissue cultured plants and the reaction occurred in just 3 weeks and the field response was a slow decline over the course of several years, with relatively woody plants. We also collected samples from the field site that we use for screening and DNA tests indicated that *P. rubi* was present in that field. A researcher in British Columbia has identified several different fungi that are pathogenic on raspberry. The last I heard about his work was that *P. rubi* appears to be the major disease-causing fungus for raspberry root rot. Additionally, selections and cultivars that have performed well on our root-rot site at the Goss Farm, have generally survived well on most sites in the Pacific Northwest.

Kristen Yanker-Hansen: What kind of taste testing are you conducting?

Patrick Moore: I taste many of them. My goal is to have the best tasting one in the whole field. What I do when testing for flavor is to throw out those that taste bad and as the testing process continues more people will taste them so that it's more than just my opinion.

Dharam Sharma: Are there viruses affecting raspberry and are you testing for all of them?

Patrick Moore: No. The big one is bushy dwarf requiring some growers to replant every 5–6 years instead of the normal 10–12 years. It's a high priority for those growing the high-end fruit. There are many other viruses. Before we release a selection we send it to a U.S.D.A. lab in Corvallis, Oregon, for virus testing to be sure we have clean planting stock. Most other viruses are vectored by something you can get around. If you control aphids you can control viruses spread by aphids. The same goes for those spread by nematodes. Those spread through the pollen are difficult to control so we need to develop selections that are resistant.

Plant Propagation of *Solanum tuberosum* Using Tissue Culture©

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INTRODUCTION

A rapid technique to rapidly increase the number of potato plants is by using the tissue culture method. The first step is getting clean plantlets. Mother plants may be purchased from universities or private tissue culture "banks." These are virus-free and ready to multiply. This is the fastest and easiest way to begin. Unfortunately, many of the new selections in field trials get viruses and have to be cleaned up before clean seed stock is available for multiplication. This is time consuming and may take more than a year.

MATERIALS AND METHODS

Before starting with a potato plantlet you will need to make medium. This may be purchased from various labs in ready-made packages and all you do is add deionized water and agar. Alternatively, it may be made from scratch (Table 1). After cooking the medium until the agar dissolves, you pour 1/4 in. into Magenta® vessels or baby food jars and cap them. They are then autoclaved and, once cooled, ready for new plantlets.

The tissue culture technique is performed in a laminar air-flow hood. Using forceps, remove the plantlet from its container. Cut the plant with a small pointed scissors between the leaf nodes leaving a small stem on each to place into the new medium, making sure the leaf node rests on the top of the agar in the new vessel. Each vessel can hold 15–20 new nodes to grow into plantlets. Sterilize the tools in a glass bead sterilizer or ceramic sterilizer for 15 sec. Place under fluorescent grow room lights giving them a 16/8-h light/dark photoperiod. In a few days the nodes will callus and new shoots between the leaf and stem segment will begin to grow. In 4–5 weeks you will be ready to repeat the process giving you five to eight times the plant material, depending on the selection.

METHODS AND MATERIALS

Using a Tuber. When starting with a tuber, wash it with soapy water, lightly scrubbing the eyes to remove dirt. Place into a paper bag and let it sprout. This may take up to 2 months if the potato has been freshly dug.

In the laminar flow hood cut the sprouts into a beaker containing a 10% bleach solution and 15 drops of Tween 20 (disinfectant) stirring for 15 min. Place sprouts into a 70% ethanol solution for 1 min and rinse twice in sterile water for 3 and 12 min, respectively. Take out the sprouts and let them dry on a sterile paper towel. Put them into growing medium under the grow-room lights with a 16/8-h light/dark photoperiod, keeping the temperature around 70 °F. Make enough plantlets to have back-ups since the potato will shrivel and die. If these plantlets are tested, the chance of virus is high and the clean-up process will have to be done again.

Table 1. Potato medium recipe for 8 Liters.

Sucrose	240 g
Inositol	800 mg
Sulfate ($CaS0_4$)	2752 mg
Nitrate solution	80 ml
Sulfate solution	80 ml
Halide solution	80 ml
Phosphate solution	80 ml
Iron (Fe) solution	80 ml
Thiamine solution	80 ml
Kinetin solution	80 ml
GA_3 solution	80 ml
Bring to 7500 ml dH_20	
pH to 5.7	
Add 500 ml dH_20 (up to 8 L)	
Agar	56 g
Heat till clear (1 h or so)	
Add 50 ml dH_20 per L for evaporation	
Fill vessels with 1/4 in. medium	
Autoclave filled vessels for 15 min	

Virus Eradication. After making six to eight vessels of plants, keep a couple in the grow room for back-ups and place the others into an incubator. Each day of the week, the incubator is set to 35 °C with the lights off at 2 pm and then to 30 °C with the lights on at 2 am. This makes the plants grow rapidly and also "cooks" out the diseases. After 4 weeks of this heat and light therapy (or until the plant is nearly wilted), remove to the hood. Within 1 h out of the incubator, remove the apical bud from the upper nodes using a microscope and put it into a test tube of therapy medium containing Ribavirin and gibberellic acid (GA_3). Ribavirin is an anti-viral drug. Transfer the small plant tissue every 2 1/2 weeks to new medium. After 5 weeks, GA_3 is deleted and a growth regulator, IBA, is used to promote root development. Transfer again to new medium at 2 1/2 weeks. The next medium at 5 weeks contains no Ribavirin and is renewed after 2 1/2 weeks. Finally, after about 4 months of this process you will hopefully have some plant material to cut and put into regular growing medium.

When a plant grows six to eight nodes, take out that plant and tissue culture the bottom four nodes into one vessel and the top nodes into another. Allow these to grow 4–5 in. and test the bottom nodes for potato viruses and bacteria. Keep the top plant nodes for your own increase. If the test results are clean and free of disease, discard all plant material and back-ups of that clone except what is clean from the top of the tested plant. This is considered the "mother plant" from which the clean plant stock will be made of.

Saving Clones for Future Use. Putting tissue culture nodes into media to create microtuber potatoes instead of plant tissue is the best way to keep selections for future needs and backups. They take up a very small place in the refrigerator and can be kept for up to 3 years. When the selection is needed again, the microtubers are cut in half and placed cut-side down on regular growing media. A plant will emerge out of the eye of that tuber.

SUMMARY

Many different plants can be propagated quickly using tissue culture. Potato is one of many plant species for which this technique is useful. New stock is clean of disease in a sterile environment and takes very little space to keep year after year.

QUESTIONS AND ANSWERS

Steve McCulloch: When you use ribavirin are you filter sterilizing it or autoclaving it?

Marlys Bedlington: It's added to the medium before autoclaving.

Gayle Suttle: Once a commercial grower gets their planting started, how often can they continue to use the stock?

Marlys Bedlington: We have commercial growers who buy our "seed" every year because potato gets infected with viruses quickly. That's why we start fresh every year even though we sell the same cultivar. Commercial growers are primarily focused on cosmetics, not so much disease. We try to keep our fields as disease-free as possible by rouging the summertime.

Kristen Yanker-Hansen: How many varieties of potato do you grow?

Marlys Bedlington: We have 28 in the greenhouse this year. I switched varieties 25 times 2 days ago and 5 times yesterday in the field. We eliminate those that don't work for us and/or are not of interest to our growers.

Anonymous: Have you considered starting them as plantlets rather than mini-tubers?

Marlys Bedlington: We've tried that. I have had to cover our plants with Styrofoam cups because of the weather. They are very fragile at that stage. You can harden them off somewhat, but I would have to have a separate greenhouse.

Educating the Next Generation©

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Every generation has its challenges in education. It's said that our current generation has lost its connection to the natural world because it is plugged into so many electronic diversions. A generation also will not protect something in their lives that they do not know or love.

We have all heard of "no child left behind" in education, but there is now a national movement to "leave no child inside." This is currently a focus of the Obama Administration's "A 21st Century Strategy for America's Great Outdoors," <http://www.doi.gov/americangreatoutdoors/>, also with Capitol Hill hearings, legislation on the state level, and grassroots organizations.

In the book "Last Child in the Woods: Saving Our Children from Nature-Deficit Disorder" by Richard Louv (2006), he brings together the studies showing that direct exposure to nature is essential for a child's healthy physical and emotional development. They have recently linked the lack of nature in children's lives with the rise in obesity, attention disorders, and depression.

New ideas and programs are being developed to address this. One such new program is the California Native Plant Society's (CNPS) development of a curriculum that teaches kids to become observers of nature. They pointed out that if you ask a kindergarten class if they can draw they will all raise their hands. If you ask the same question to a sixth grade class very few will think they can draw and that drawing is for only a gifted few. John Muir Laws, a naturalist, educator, and artist, and Emily Breunig, a teacher for the California Institute for Biodiversity, have developed a curriculum for kids 8 years old and up. The curriculum integrates observation of nature using art, language arts, and science. The curriculum can be downloaded from the education page of the CNPS web site: <http://www.cnps.org/cnps/education/>.

Educators have expressed that the experiences with nature have to be repeated through a child's education to make a long-term impact on them. Reflect back on how you got into the field of horticulture. What childhood experiences could have led you on this path? What can we do in our profession to help pass on the knowledge and love of botany and horticulture?

Here is an example of what can be done on a local level; fast forward to Winthrop, Washington. Winthrop is a small rural town on the northeastern side of the Washington Cascades 30 miles as a crow flies from the Canadian border. It has a mix of agriculture, recreation, and forestry industries. This is a rich shrub-steppe plant community. It is important for the children to know the plants with which they coexist, what are their significant uses for wildlife, and what do they need to germinate and grow. This understanding will help preserve this environment and increase their appreciation of their surroundings.

The plan was to develop a shrub-steppe landscape garden from seed collection to installing the garden. This garden would be used as a teaching garden in the future. The recipe for the plan included a dedicated first-year teacher, Erica Bleke, who graduated from Western Washington University with a degree in

Environmental Education and an energetic sixth-grade class of children. A lesson plan aligning the project with current science standards was needed to proceed. She took a more integrated approach broadening it to cover standards in many subjects including science, communications, math, reading, social studies, writing, and art. The project would span the whole year. Included below are the targets.

Science.

- Mathematics used to ask and answer most scientific questions.
- Science and technology addressing problems in everyday life, whether at home, school, or work.
- Living organisms playing critical roles in shaping the Earth systems that we see today.
- Nonliving factors in ecosystems affecting populations of organisms found in the ecosystems.
- The major source of energy for ecosystems on Earth's surface is sunlight. Plants make their own food, animals obtain food by eating organisms and decomposers use waste, dead organisms for food and recycle nutrients.
- Human use of resources can affect the capacity of ecosystems to support various populations of organisms.
- Communications.
- Research and present a presentation to a group on their findings.

Math.

- Multiplying and dividing non-negative decimals.
- Solve single and multi-step word problems involving operations with fractions and decimals and verify solutions.
- Identify and write ratios as comparisons for part-to-part and part-to-whole relationships.
- Make and test conjectures based on data collected from explorations and experiments.

Reading.

- Apply understanding of printed and electronic text figures to locate information and comprehend text.
- Analyze sources for information appropriate to a specific topic or for a specific purpose.
- Analyze appropriateness of a variety of resources and use them to perform a specific task or investigate a topic.

Social Studies.

- Construct and analyze maps using scale, direction, symbols, legends, and projections to gather information.
- Identify the location of places and regions in the world and understand their physical and cultural characteristics.
- Understand and analyze how the environment has affected people and how people have affected the environment in past or present.
- Understand the characteristics of cultures in the world from the past or present.
- Understand the learning about the geography of the world helping us understand the global issue of sustainability.

Writing.

- Apply more than one strategy for generating and planning writing.
- Produce multiple drafts.
- Revise text.
- Publish in a format that is appropriate for a specific audience and purpose.
- Demonstrate and understand the different purposes for writing.

Art.

- Observe and draw a subject.
- Draw for a specific purpose.
- Integrate the art into a specific project.

With these goals in place the project started in the fall and began with the collection of seed. A plant list for the stratification experiments was determined by what seed was available for collection at the time. This included; blue elderberry [*Sambucus mexicana* (syn. *S. nigra* subsp. caerulea and syn. *S. cerulean*], snowberry (*Symphoricarpos albus*), chokecherry (*Prunus virginiana*), and Wood's rose (*Rosa woodsii*).

The seed was collected and weighed uncleaned then again when cleaned. The *S. mexicana* berries were plucked from the stems then pureed in a food processor, the debris was floated off then the seed was dried and weighed. The *S. albus* and *R. woodsii* seed was placed on racks and stacked onto a food dryer where they dried then were ground on the seed board and the debris was blown off. There were two collections of chokecherry. The tree collection was crushed fresh on the seed board then dried and rubbed again then the debris was blown off. The second was collected from bear scat and was easily separated from the scat.

The students did calculations to determine how many fresh seeds needed to be collected to get the number of cleaned seeds that they needed developing a ratio of unclean to clean seed. They also figured out how many seeds per gram and ounce. The seeds were checked for viability with a cut test to see if the embryos were fully developed.

Each plant had a work sheet for recording the weights and listing the treatments to be done. The experiment was done with 200 seeds for each treatment. The seed bags were labeled for each treatment and labels were made at this time too.

This was a good time to have a discussion about seed germination and seed dormancy including internal dormancy and methods of breaking dormancy ending with a discussion of what nature does and what we could do to mimic that (Tables 1, 2, and 3).

Half of the seed treatments would be stratified using natural means. The seeds were sown in five sections and covered with a screen to keep rodents out and buried outside the classroom in the snow for the winter. The other half was treated, if needed, and stratified in a refrigerator. In March these seeds were sown and the seeds from outside were dug up and brought in to germinate under lights. As the seeds germinated the data was recorded and the percent of germination was calculated.

At this time the students worked on their presentation to the first graders. The children were broken into groups and rotated through stations where they had made information poster boards on their project and a PowerPoint presentation "The Native Plants and Grasses of the Methow Valley."

Rob Crandall from Methow Natives Nursery gave a presentation on the adaptation of plants and discussed the shrub-steppe habitat with the students. They plant-

Table 1. Germination and dormancy information.

Germination	The resumption of active growth of the seeds embryo. It requires moisture, proper temperature, and oxygen. Timing varies per species.
Seed coat dormancy	A seed coat that is impermeable to water and oxygen or has an inhibiting chemical in the epidermis.
Internal dormancy	Physiological conditions delay germination. These seeds need after ripening. This is most likely found in high elevation species. Some seed need a period of dry storage or mountain species may need a period of moist cold period to simulate a cold winter. For desert seeds dry storage over 100 °F stimulates desert heats then the seeds will germinate later when it is cool. Some need treatments with chemicals like gibberellic acid.

Table 2. Methods of breaking dormancy.

Scarification	Scaring seed to let water in with sandpaper, file, pin, or knife
Hot water	180–200 °F and left to cool over 12 to 24 h
Dry heat	180–212 °F heat in an oven
Charate	Charate from a burned plant stems can neutralize germination inhibitors
Fire	For seeds with a hard thick coat. Burn in fall seed swells with rain.
Acid	Thins impermeable seed coats
Mulch	Hastens the microbial breakdown or softening of the seed coat.
Water	Removes water soluble germination inhibiting chemicals
Cold stratification	For internal dormancy simulates cold winter conditions. 1 : 3 ratio of seeds : perlite at 28–32 °F for 10–120 days
Warm stratification	Room temperatures 65 °F for after ripening of the embryos
Photochemical dormancy	Some seeds need light to germinate. Do not cover seed
Germination temperatures	Look at your surroundings where your seeds are from and mimic nature

Table 3. Mimicking nature.

What would nature do	How to mimic nature
Freeze and thaw	Moisten seed and refrigerate to mimic winter conditions
Rub between rocks, gravel	Sand seed coat lightly to make it thinner
Go through animal GI tract	Soak in sulfuric acid
Rub between rocks, gravel	Moisten seed and refrigerate
Chewed on by animal	Hot water to soften the seed coat. Sand seed coat lightly to make it thinner
Fire and charate	Burn needles over planted seeds and water in charate

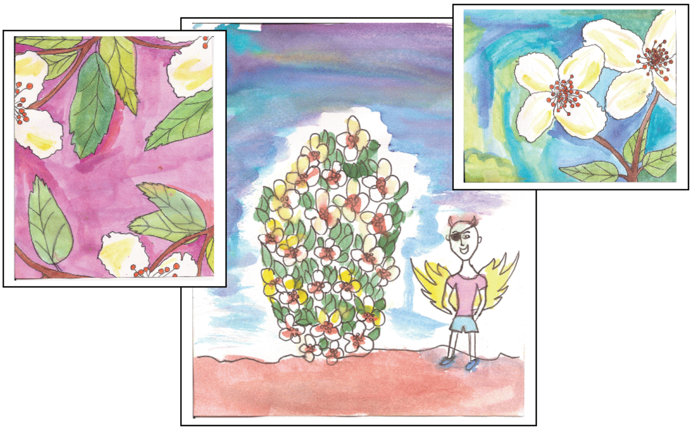
ed three native grasses into plug trays and grew them under lights to be planted in the garden. A list of shrub-steppe plants was made for which plants to be include in the garden. Each child was given a plant to do botanical drawings of and to research in the computer lab to be used to make an information plant card for the garden (Table 4 and Fig. 1).

The garden space was cleared and planted in 2 days with the two classes back to back. The design included a walkway ending with a sitting rock. The purpose of the garden was to be a teaching garden and a place to take classes and the local communities to read, draw, and observe the plants. The garden was irrigated for the first summer and weeded regularly. By the following fall there was a good foundation started for the garden.

Table 4. Plant list for shrub-steppe garden.

Common name	Botanical name
yarrow	*Achillea millefolium*
serviceberry	*Amelanchier alnifolia*
Michaux's mugwort	*Artemisia michauxiana*
big sagebrush	*Artemisia tridentata*
tall Oregon grape	*Berberis aquifolium* (syn. *Mahonia aquifolium*)
rabbitbrush	*Chrysothamnus nauseosus*
Wyeth buckwheat	*Eriogonum heracleoides*
snow buckwheat	*Eriogonum niveum*
shrubby penstemon	*Penstemon fruticosus*
Chelan penstemon	*Penstemon pruinosus*
Richardson's penstemon	*Penstemon richardsonii*
Blue Mountain penstemon	*Penstemon venustus*
mockorange	*Philadelphus lewisii*
ponderosa pine	*Pinus ponderosa*
bitter cherry	*Prunus emarginata*
chokecherry	*Prunus virginiana*
bitterbrush	*Purshia tridentata*
wax currant	*Ribes cereum*
blue elderberry	*Sambucus mexicana* (syn. *S. cerulean*)
grasses	
bluebunch wheatgrass	*Elymus spicatus* (syn. *Agropyron spicatum*)
great basin wildrye	*Elymus cinereus*
Idaho fescue	*Festuca idahoensis*

Mockorange
Philadelphus lewisii



Plant: Mockorange is a shrub. Its height can be 6 to 15 feet tall. It blooms in mid June.

Flower: The flower has 4 petals. They are a creamy white color, usually about 10 to 20 millimeters long. They cover most of the shrub.

Leaves: The leaves on the Mockorange are oval shaped. They usually have smooth edges, but sometimes there can be a few fine teeth near the tip. Their feel is slightly sandpapery.

Habitat: Mockorange is commonly found on steep slopes or rocky ledges. It is found in both riparian and shrub steppe habitats.

Range: It ranges from Canada to Washington, Oregon and Montana.

Figure 1. Example of plant information card. Illustration by Delilah Cupp, 2008.

The sustainability of the garden depends on the school incorporating it into their curriculum and the community using it as a teaching resource, to keep adding to it, and maintaining this resource. Think about what you could do to pass on your knowledge to the next generation of horticulturalists.

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QUESTIONS AND ANSWERS

Kathy Echols: Has the program gone national?

Ann Fisher-Chandler: If you go onto the website you'll see input from teachers and students trying to make this program bigger.

Rita Hummel: How do you approach the teachers? Do you have any suggestions on how to encourage teacher involvement?

Ann Fisher-Chandler: I think I got lucky with the teacher with whom I worked. She didn't know how to say no. In fact, the new teacher taking her place has yet to show as much interest. I think it just takes lots of persistence. Introducing the teachers to the book I mentioned is helpful.

Cutting Propagation of Difficult-to-Root Woody Ornamental Plants©

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Rooting performances of softwood, semi-hardwood, or hardwood cuttings of 45 difficult-to-root deciduous and evergreen plant species or varieties were tested. The result showed that most difficult-to-root deciduous plants were successfully rooted by using softwood or semi-hardwood cuttings with proper sticking method from May to July. For difficult-to-root evergreen plants, hardwood cuttings from February to April or semi-hardwood cuttings from July to August were optimal growth stages for propagation.

INTRODUCTION

Cutting propagation is a simple and efficient way to propagate large numbers of homogenous plants. With the improvement of recent techniques, more and more difficult-to-root woody ornamental plants can now be propagated commercially by cuttings (Drew III and Dirr, 1989; Moon and Yi, 1993; Palzkill and Feldman, 1993; Rosier et al., 2004). However, there are still many difficult-to-root woody ornamental plants currently propagated either by grafting or by seedlings. These plants include Japanese maple, *Hamamelis*, *Quercus*, some *Magnolia* and *Michelia* (see *Magnolia*), *Cercis, Carpinus betulus, Parrotia persica, Cercidiphyllum japonicum, Ginkgo biloba, Daphniphyllum*, and many other plant species. The purpose of this study was to find the possible method that could be used commercially for cutting propagation of difficult-to-root woody ornamental plants.

MATERIALS AND METHODS

Softwood, semi-hardwood, or hardwood cuttings collected at different growth stages from 45 plant species or varieties were made about 10–12 cm long with 0.5–1.0 cm basal slice wounding. These cuttings were first applied STIM-ROOT Liquid plant rooting regulator at IBA concentration of 500–4000 ppm (most time using 2000 ppm unless specified) with quick-dip method, then stuck into 50-plug tray with propagation medium consisting of coarse perlite, fine perlite, and peat moss (1 : 1 : 1, by volume). After sticking, the cuttings were put inside propagation greenhouse under either fogging or mist system with shading.

RESULT AND DISCUSSION

Effect of IBA Concentration on Rooting of Japanese Maples. In order to figure out the effect of IBA concentration on rooting performance, four IBA concentrations and three Japanese maple cultivars were tested (Table 1). The results showed that rooting percentage was significantly improved when IBA concentration increased from 500 to 1000 ppm. However, continually increasing IBA concentration from 1000 to 4000 ppm did not further increase rooting performance.

Table 1. Effect of IBA concentration on rooting performance of Japanese maples.

IBA concentration (ppm)	Rooting (%)		
	Acer palmatum 'Enkan'	*Acer palmatum* 'Sango-kaku'	*Acer shirasawanum* 'Aureum'
500	57.8a*	70.5a	62.5a
1000	89.4b	91.8b	82.8b
2000	90.8b	93.5b	84.2b
4000	89.1b	91.2b	83.8b

*Numbers followed by the same letter within a column are not significantly different (*p<0.05*).

Effect of Cutting Sticking Methods on Rooting Performance. The effect of propagation media on rooting performance of cuttings has been tested extensively (Hartmann et al., 2010). We found that, in addition to propagation media, sticking methods significantly affected rooting performance. Our result showed that cuttings stuck from the center to nearly the bottom of the cell in the plug tray had higher rooting percentage than stuck from the center to the middle of the cell (Fig. 1). The cuttings stuck from the side to nearly the bottom of the cell with pressing to make the medium relatively tight had the highest rooting percentage; conversely cuttings stuck from the side to the bottom hole of the cell with pressing to make the medium relatively tight had the lowest rooting percentage, because cutting base exposed to the air in the hole stimulated callusing rather than rooting.

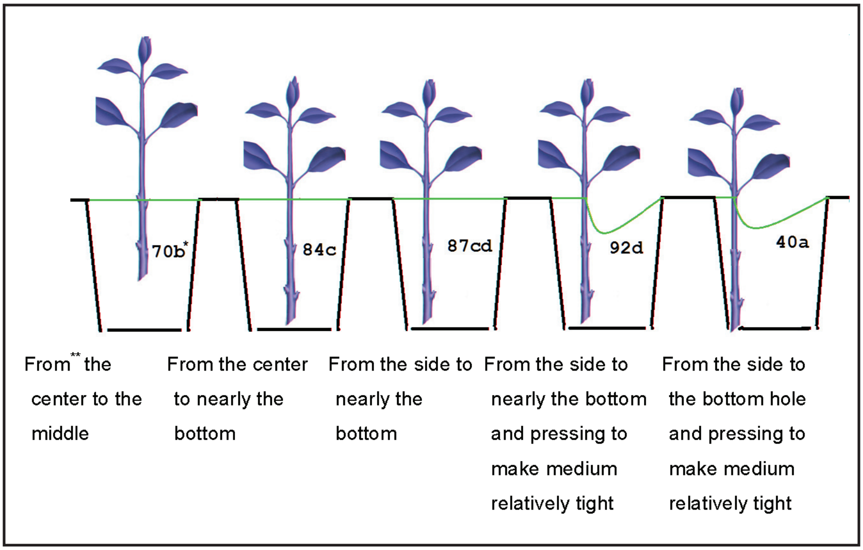

Figure 1. Effect of cutting sticking method on rooting percentage of *Acer palmatum* 'Sango-kaku'. * Numbers followed by the same letter are not significantly different (*p<0.05*), **Cutting sticking method.

Effect of Plant Species and Varieties on Rooting Performance. More and more varieties of *Acer rubrum* and *A. cappadocicum* are propagated by cuttings. However, the Japanese maples (*A. palmatum, A. japonicum,* and *A. shirasawanum*) are, so far, still merely propagated commercially by grafting. This is mainly because Japanese maples are difficult to root. Our results showed that although Japanese maples were more difficult to root than *A. rubrum* and *A. cappadocicum;* the softwood and semi-hardwood cuttings of eight Japanese maple cultivars collected at optimal growth stage were successfully rooted by using proper cutting sticking methods (Table 2). Among the three Japanese maples, the rooting percentages of *A. palmatum* and *A. shirasawanum* were higher than *A. japonicum*. Cutting basal slice wounding is important for Japanese maple root initiation. With basal slice wounding, even hardwood cuttings of Japanese maple taxa were rooted successfully.

Evergreen *Magnolia*, *Michelia* (see *Magnolia),* and *Manglietia* (see *Magnolia)* are usually more difficult to root than most deciduous *Magnolia*. Our results showed that using hardwood (February to April) or semi-hardwood (July to August) cuttings with basal slice wounding, these evergreen plant species could be successfully rooted and some of them even had higher rooting percentages than deciduous *Magnolia* (Table 2). Cutting propagation of other difficult-to-root woody evergreen plants including *Sciadopitys verticillata*, *Berberis aquifolium* 'Compactum', *Arbutus unedo* 'Compacta', *Daphniphyllum glaucescens*, *D. himalense* subsp. *macropodum*, and *Q. myrsinifolia* also showed that hardwood or semi-hardwood cuttings with basal slice wounding successfully stimulated rooting. Among the evergreen plants tested, cutting basal slice wounding for *B. aquifolium* 'Compactum', as an exception, did not increase rooting performance; conversely, cutting basal slice wounding enhanced disease infection and rot. For cutting propagation of *B. aquifolium* 'Compactum', controlling air and keeping medium moisture relatively low was important.

Using softwood or semi-hardwood cuttings from May to July, *Hamamelis, C. betulus*, *Parrotia persica* 'Vanessa', *C. japonicum* 'Red Tint', *Davidia involucrata*, *Styphnolobium* (syn. *Sophora*) *japonica* 'Flavirameus', *Cercis canadensis* and *C. chinensis, G. biloba*, and *Crataegus laevigata* 'Crimson Cloud' were successfully rooted. For most of these plant species, cutting basal wounding improved rooting performance except *C. betulus*, *P. persica* 'Vanessa', and *C. japonicum* because the roots of these plants mainly initiated from lenticels. The rooting percentages of *C. canadensis* 'Forest Pansy' and *Robinia pseudoacacia* 'Frisia' were very low, because the cuttings of both plants rotted easily, plus the leaves of the cuttings fell off readily.

Effect of Callusing on Rooting. Adventitious roots can develop either naturally on the stem cutting or in response to wounding (Koyuncu and Balta, 2004). Adventitious roots may originate from living parenchyma cells, young secondary phloem, vascular rays, cambium, phloem, lenticels, and pith (Hartmann et al., 2010). Callus formation may be favorable for rooting. Our result showed that callusing and rooting were independent of each other and the roots arose directly from lenticels in cuttings of relatively easy-to-root plant species including *C. betulus*, *P. persica*, *C. japonicum* (Figs. 2A and 2B). In most species that are difficult-to-root, initiation of roots occurred from callus. Example plant species were *S. verticillata*, *Arbutus unedo*, *D. glaucescens*, *D. himalense* subsp.

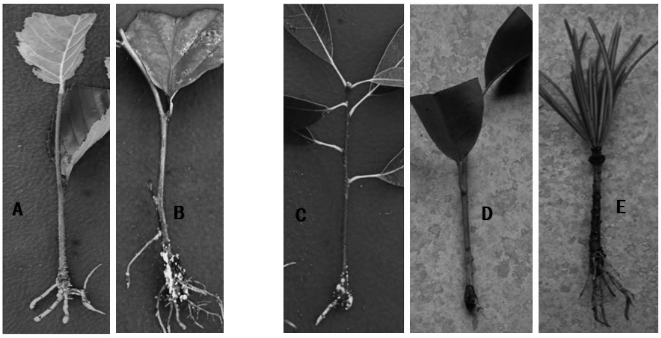

Figure 2. Effect of callusing on rooting: (A) *Carpinus betulus*, (B) *Parrotia persica*, (C) *Quercus myrsinifolia*, (D) *Magnolia* (syn. *Michelia*) *maudiae*, (E) *Sciadopitys verticillata.*

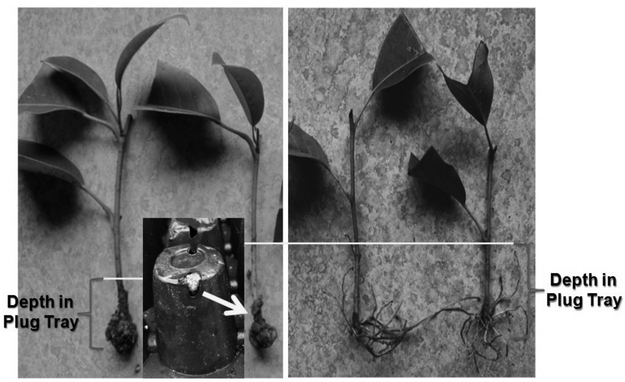

Figure 3. Effect of cutting sticking depth on callusing and rooting of *Magnolia* (syn. *Michelia*) *maudiae.*

macropodum, *Q. myrsinifolia*, *Michelia* and *Manglietia* (see *Magnolia)*, *G. biloba*, *C. laevigata*, etc. (Figs. 2C, 2D and 2E). Some plant species have direct root formation in juvenile cuttings and indirect root formation from callus in cuttings from more mature plants. Example plant species were Japanese maples, deciduous *Magnolia*, *Hamamelis, Nyssa sinensis*, etc.

The initiation of roots from callus of difficult-to-root woody ornamental plants has been found previously in many plant species (Haeman and Owens, 1972; Hartmann et al., 2010). For this kind of plant species, callusing is the first step of rooting. However, we found that excessive callusing inhibiting root initiation became the main problem for cutting propagation of difficult-to-root woody ornamental plants. Our results showed that by increasing the depth of cuttings stuck in the

Table 2. Effect of plant species, variety, and cultivar on rooting performance

Plant name	Rooting (%)	Cutting type
Acer rubrum, A. cappadocicum 'Aureum', and *A. cappadocicum* 'Rubrum'	85–90	Softwood or semi-hardwood (May–July)
Acer palmatum		
A. palmatum 'Shōjō-nomura', 'Enkan', *'Sango-kaku'*, 'Kashima', and var. *dissectum* 'Seiryū'	65–93	Softwood or semi-hardwood (May–July)
Acer japonicum 'Aconitifolium'	50–75	Softwood or semi-hardwood (May–July)
Acer shirasawanum 'Aureum'	75–84	Softwood or semi-hardwood (May–July)
Magnolia (deciduous)		
M. denudata, M. zenii, and *M. kobus*	82–90	Softwood or semi-hardwood (May–July)
M. salicifolia	78–92	Semi-hardwood (July–Aug.)
Magnolia (evergreen)		
M. grandiflora	60–70	Hardwood (Feb.–Apr.)
Magnolia (syn. *Michelia*) (evergreen)		
M. maudiae, M. platypetala, M. figo M. yunnanensis, M. alba, and *M. martinii*	70–85	Hardwood (Feb.–Apr.) Semi-hardwood (July–Aug.)
Magnolia (syn. *Manglietia*) (evergreen)		
M. insignis and *M. chingii*	70–90	Hardwood (Feb.–Apr.) Semi-hardwood (July–Aug.)
Sciadopitys verticillata	40–60	Hardwood (Feb.–May) or semi-hardwood (July–Aug.)
Berberis aquifolium 'Compactum' (syn. *Mahonia aquifolium* 'Compactum')	50–80	Hardwood (Feb.–July), firm semi-hardwood (July–Sept.)
Arbutus unedo 'Compacta'	60–85	Hardwood (Feb.–July), semi-hardwood (July–Sept.)
Daphniphyllum glaucescens and *D. himalense* subsp. *macropodum*	60–85	Hardwood (Feb.–May), Semi-hardwood (July–Sept.)

Quercus myrsinifolia	65–85	Hardwood (Feb.–Apr.) or semi-hardwood (July–Aug.)
Quercus robur	60–80	softwood or semi-hardwood (May–July)
Hamamelis		
H. ×*intermedia* 'Rubin', *H.* ×*intermedia* 'Jelena'		Softwood or semi-hardwood (May–July)
H. ×*intermedia* 'Diane' and *H.* ×*intermedia* 'Arnold Promise'	75–85	
Cercis		
C. canadensis and *C. chinensis*	75–90	
C. canadensis 'Forest Pansy'	20–48	Softwood or semi-hardwood (May–July)
Carpinus betulus	75–92	Softwood or semi-hardwood (May–July)
Parrotia persica 'Vanessa'	80–90	Softwood or semi-hardwood (May–July)
Cercidiphyllum japonicum 'Red Tint'	75–90	
Davidia involucrata	75–90	Softwood or semi-hardwood (May–July)
Davidia involucrata 'China Compact'	60–75	Softwood or semi-hardwood (May–July)
Ginkgo biloba	80–90	Softwood or semi-hardwood (May–July)
Crataegus laevigata 'Crimson Cloud'	60–75	Softwood or semi-hardwood (May–July)
Styphnolobium (syn. *Sophora*) *japonica* 'Flavirameus'	60–80	Softwood or semi-hardwood (May–July)
Robinia pseudoacacia 'Frisia'	30–50	Softwood or semi-hardwood (May–July)
Nyssa sinensis (potted young seedlings)	85–95	Softwood or semi-hardwood (May–July)
Nyssa sinensis (field mature trees)	3–5	Softwood or semi-hardwood (May–July)
Nyssa sinensis (young grafted tree in shade)	70–75	Softwood or semi-hardwood (May–July)

plug tray, the rooting percentage of *M. maudiae* increased while excessive callusing decreased (Fig. 3).

Effect of Rejuvenation on Rooting Performance. The age and maturity of the mother tree from which cuttings are taken has been reported to significantly affect cutting rooting performance (Amissah and Bassuk, 2007; Schaffalitzky de Muckadell, 1959). Our results showed that softwood or semi-hardwood cuttings from *N. sinensis* young seedlings were very easy to root. However, the rooting percentage of cuttings from field mature *N. sinensis* trees was only 3%–5% (Table 2). Rejuvenation has been used in improving rooting performance in many woody plants by severe pruning (Amissah and Bassuk, 2005; Morgan et al., 1980), grafting (Moon and Yi, 1993; Siniscalco and Pavolettoni, 1988; Zaczek and Steiner, 1997), shading (Amissah and Bassuk, 2007) and etiolation (Amissah and Bassuk, 2007). When grafting the scion wood from mature trees onto *Nyssia sinensis* young seedling rootstocks grown inside greenhouses with shading, our results showed that the rooting percentage of rejuvenated softwood cuttings from the grafted tree increased to 70%–75%.

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QUESTIONS AND ANSWERS

Douglas Justice: Have you tried other media like Oasis foam to get the good water-air ratios?

Pinghai Ding: We haven't tried any of the foam products. We have tried coconut fiber and other less expensive media.

Michael Hicks: Can you say a little more about *Berberis acquifolium* 'Compactum'? Did you use bottom heat? How much mist were you using? What was the concentration of the rooting hormone?

Pinghai Ding: We used a 2000-ppm quick-dip. We used bottom heat at 25 °C. The misting frequency changed with time of year.

Nevin Smith: Did you have any problems with transplanting *Davidia* or *Robinia* 'Frisia'? In our experience they often lose their leader after transplanting.

Pinghai Ding: Most of the time they have been okay, but we've also seen some lose their leader.

Rosemary Prufer: Do you do a pre-soak on your *Sciadopitys*? We've found that a 48-h pre-soak increases rooting. We believe the pre-soak reduces the amount of sap that's released from the cuttings.

Pinghai Ding: No, we don't do that. It's a good idea.

Eric Hammond: Do you wound *Daphniphyllum*?

Pinghai Ding: Yes, it's wounded.

NUGGETS OF KNOWLEDGE

The following three papers were part of the Nuggets of Knowledge session

Plug Tray Storage Shelf©

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Classical Farms is a mid-size wholesale bedding plant grower located in Rainier, Washington. It has been owned by Ross Merker and Ann Roggenkamp since 1985.

We do most of our vegetative propagation ourselves, but due to space/facility limitations, leave the majority of the seed propagation and plug growing to others.

Problem: Finding space, space, and more space, especially in the spring when our shipping and planting are really rolling along.

When our plug tray shipments arrive, (usually 512 or 288 size) we need a bench/prime location to store them as we plant up over the week. Our best benches and growing conditions are in our shipping bay, so we used to take up order space with our plugs, defeating the purpose of the shipping benches.

Solution: We have seen shelf ideas in use at other nurseries in the past, so Ross decided to try our own version. He and Keith Koontz, our facilities maintenance guru, came up with the plan and how to put it together.

Each 6 × 13 ft. shelf contains:

Number	Item
1	Roll 2 × 4 in. wire fencing (6 ft),(wrapped around top rail tight)
3	10 ft top rail (chain link fence supply)
4	Chain link fence corners (comes with own hardware)
2	Pipe clamps (used instead of hinges)
2	Turn buckles
	12-ft-high tensile wire
2	Eyelets
1	Hand crank
2	Pulleys (both single and double block)
	30 ft plastic coated cable $^{1}/_{8}$ in.
5	Cable binders (small)

RESULTS

These shelves have been a good temporary staging area for our plug trays. We are able to load our shipping tables for their shipping purpose and keep our plug trays in a well aerated, central location.

Positives: Space savings, central location, cost, easy to monitor plants in the short term. Also, we pick up our plugs at the airport in our own trucks, so it is convenient that we can just back right into the area where they will be stored.

Negatives: Tougher for shorter employees to check trays, sometimes tough to slide on/off. Can't check back trays easily, have to shuffle somewhat to check.

Lights Out©

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During the dark winter months in the Pacific North West, many lights get left on accidentally. Recent advances in motion sensor light controls have made it easy and economical to automatically turn off lights at the nursery. Screw-in motion sensors can change a light bulb into an automatic light.

At Beyond Green LLC, we have found many applications for their use: employee time-clock area, lunch areas, hallways, pump houses, chemical storage area, and remote corners in the warehouse. The motion of a person entering the area triggers the detector and turns on the light automatically which remains on for 10 to 15 min. Many types of sensors are available at your local home improvement store. The sensor costs range from $8 to $14. Check with your local utility company for cost sharing or energy-saving coupons. Additional savings may be found ordering online.

A drawback is most sensors are for indoor use only. Other added benefits include night security and increased safety.

Pond Biocontrol©

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When I moved the nursery to a new location by Canby, Oregon, I acquired an irrigation holding pond that is bowl-shaped with no direct outlet or spillway and the water level is maintained by pumping in or out. It turned out to be a biological nightmare.

The floating weeds and algae mats continually plugged the floating pump intake lines, necessitating a cleaning job about three times a day to keep the pumps running. Dredging with a rake and dipping with a skimmer just provided a lot of physical exercise and not much control. It looked like a movie set for "The Creature from the Black Lagoon." I didn't want to treat with aquatic herbicides since it was a major source for my field irrigation for a diverse crop list.

So my first attempt at control was to stretch a spare piece of heavy shade cloth across the shallow end of the pond to try to shade out the weeds. But the floating weeds moved where the wind and current sent them and it was not very effective. The intakes were still clogging.

So I next attempted to go after the mosquitoes since the new threat of West Nile

Virus. So I went for a biocontrol, gold fish. I visited the local PETCO and purchased 25 little feeder gold fish (12 gold and 13 black, the black ones seemed sturdier) and dumped in the pond at 8 PM. It was like ringing the dinner bell for the local blue heron. By 6 AM big daddy blue heron was seriously fishing in the pond. Neighbor Ed said he hadn't seen a blue heron around here in 20 years. The bird hung around for a few weeks. So I wrote off my goldfish investment, and continued cleaning the pumps and added a few more screens.

So I had spent $7.25 on this adventure.

Winter came the weeds froze and the pond looked normal. In the spring everything starts growing about the time the irrigation season starts. But as the water warmed with the spring days, something was different this year.

One weekend in mid May, the pond looked like it had been thrown into a blender. All the weeds were torn up into tiny pieces. The goldfish were still there and feeding like Holsteins.

25 goldfish, $7.25, the results: priceless

The weeds are gone!

The 25 gold fish had grown and multiplied into about 200 fish that were hungry and growing fast. Of course the blue heron kept coming back, but he went after the frogs and tadpoles. Now they are gone. The mosquitoes are definitely gone. The mud snails are gone. The duck weed, algae mats, and aquatic weeds are gone.

So the gold fish population has grown from 25 in Year 1 to about 200 in Year 2, to about 800 in Year 3, and now about 2,000 by Year 4. They are also a wide range of colors and patterns.

The intakes on the pumps get checked once a month, the pond is clean and the fish are thriving. I give the fish a treat of a couple scoops of dry cat food three times a week during July and August. The blue heron shows up occasionally, but this year an enterprising Osprey had developed a taste for the now 5-in. goldfish, and visits almost daily.

This experience has been a small-scale laboratory on how an ecosystem can be quickly changed by introducing a new species to it. It took about 16 months from weeds to clean.

Caution: I do not recommend introducing a non-native fish into a pond with a free flowing outlet, drain pipe, or spillway. Asian carp were introduced into southern ponds in the U.S.A. for weed control in the 1980s. Disastrous floods accidentally swept the fish into the main waterways and the Mississippi River. They spread. The fish are now far north threatening the Great Lakes ecosystem. So be careful with what you release.

Questions and Answers

Douglas Justice: If you're such a cheapskate why didn't you make the floaties round? Why not just put two of them together and glue them into a circle?

Mike Anderson: It's because I forgot to consult an expert.

Kristin Yanker-Hansen: I think Mike Anderson and Steve Hottovy should get together. Books on basic pond construction and maintenance suggest putting water hyacinths and goldfish in together.

Steve Hottovy: I tried water lettuce, but the goldfish ate it. I also tried a water lily, but they ate it.

Bob Buzzo: What's going to happen to the goldfish? Won't they get too large?

Steve Hottovy: I added some koi to the pond and they are now 17 in. long. They are much less active. The biggest goldfish is 5 in. long and they are dwindling due to an osprey feeding on them.

Sylvia Mosterman: By adding the lettuces in your compost, will you accumulate toxins by doing that?

Mike Anderson: I don't think so. I believe you're trapping the nitrates and phosphorus that may be in the pond. If there are toxins in there, I'm not aware of it.

Mary Fazekas: Would you consider offering tours for bird watchers interested in osprey and blue heron?

Steve Hottovy: There's also an eagle nesting down by the river. He hasn't yet decided to "fish" the pond, but he's there.

A Brief History of Native Plants©

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The term "native plant" seems to have entered the lexicon of horticultural speak in a big way over the past few decades. As a lifelong nurseryman and native plant grower, the question of what is a native plant comes up with great frequency around my office. It seems everyone knows what a native plant is, but we don't all agree on the same definition.

This seemingly straightforward word "native" creates enough controversy to cause some real confusion. A simple web search will quickly demonstrate the problem, and a good place to start is this Wikipedia definition which states: "Native plant is a term to describe plants 'endemic' (indigenous) or 'naturalized' to a given area in geologic time") (Wikipedia).

At first glance this doesn't look too bad to most people; however, as is often the case, one size really doesn't fit all. If we consider geologic time, the fossilized *Ginkgo biloba* forest in eastern Washington provides evidence of what once was a native plant in that region, of interest to a paleontologist, but not very useful for today's native plant propagator or restoration ecologist.

The words endemic and indigenous seem straightforward; however, when the word "naturalized" is added to this definition, things start to get fairly fuzzy. So here's another definition from the Pennsylvania Department of Conservation and Natural Resources that narrows down the description a bit more: "A native plant is one which occurred within the state before settlement by Europeans." This definition sets the starting line, at least in Pennsylvania, at the time of European contact. They also go on to address the issue of "naturalized" with this statement: "An introduced or non-native plant is one that has been brought into the state and become established. At the turn of the 21st century, about 1,300 species of non-native plants existed in Pennsylvania. That is 37% of Pennsylvania's total plant flora (which is about 3,400 species), and more introduced plants are identified every year." (The Pennsylvania Department of Conservation and Natural Resources)

The United States National Arboretum, like Pennsylvania, distinguishes "naturalized" from "native" in this statement: "A native plant is one that occurs naturally in a particular region, ecosystem, or habitat without direct or indirect human intervention. We consider the flora present at the time Europeans arrived in North America as the species native to the eastern United States" (The United States National Arboretum).

These definitions of a native plant are comfortable including everything present before European contact as native. This notion seems to have fairly wide acceptance in North America, though it's not universal. The History of Native Plant Communities in the South references John and William Bartram's 18th-century, historically significant expedition and book which notes the issue of Native American influence on the indigenous flora with this statement: "Native plant communities in the South have been much studied and written about since the Bartram's explored the region in the 18th century. Bartram noted that Native Americans as well as European settlers altered native plant communities by intentional burning, land clearing for agriculture, clear cutting of timber, and introductions of exotic species from Europe and the Caribbean. The plant communities of the South were not pristine in Bartram's time, and they were not pristine when Europeans first arrived on these shores. The southern landscape had already seen 10,000 years of human history" (Owens, 2009).

"The last 400 years, however, have brought more radical changes than any caused by Native Americans. Today's landscape and vegetation are not only the result of a very long history of change; they are also the starting point of tomorrow's vegetation. To better understand the resource at hand, it is valuable to remind ourselves of how we got here so that, perhaps, we can do better in the future. For the purposes of this assessment, a native plant community is defined as a set of populations of plants naturally indigenous to an area that are interacting to the extent and degree that would have been observed prior to European settlement and share critical physiognomic and compositional traits. It is somewhat arbitrary to define what is natural in terms of a pre-European time frame, because it is impossible to separate the influences of native cultures from the historical landscape. However, even at the height of aboriginal culture in the Southeastern United States, Native Americans could not have had the impact on native vegetation to the degree that the Europeans had" (Owens, 2009).

The California Native Plant Society does not address the introduction of plant material from pre-European humans. They do, however, acknowledge the importance that indigenous plants played in sustaining the first Californians in this statement: "Our native plants grew here prior to European contact. California's native plants evolved here over a very long period, and are the plants which the first Californians knew and depended on for their livelihood. These plants have co-evolved with animals, fungi and microbes, to form a complex network of relationships. They are the foundation of our native ecosystems, or natural communities" (California Native Plant Society).

We North Americans might be willing to find one of these descriptions acceptable; however, our British friends would probably take issue with these definitions. The starting line for what is native takes on an even longer viewpoint in this description from the U.K. Woodland Assurance Standards (2008): "A species that has arrived and inhabited an area naturally, without deliberate assistance by man, or would occur had it not been removed through past management [by man]. Trees and shrubs in the U.K. are usually taken to mean those present after post-glacial recolonization and before historic times. Some species are only native in particular regions. Differences in characteristics and adaptation to conditions occur more locally" (United Kingdom Woodland Assurance Standards, 2008).

This gives you an idea of the some of the underlying ambiguity associated with the term "native plant," which might seem purely academic and of little consequence for most people; this lack of consensus, however, is problematic and of significant concern for the restoration community. Acknowledging the differences in characteristics within a single species as a result of local adaptation is important to the work this community does. These ecotypes or subdivisions reflect the biodiversity within an area that have adapted to a particular set of environmental conditions over a long period of time.

Douglas Tallamy (2007) describes the problem quite clearly in his book *Bring Nature Home* — "The broadest definition is also the most commonly employed: a native is any plant that historically grew in North America. Some people recognize that it's a stretch to call a plant adapted to a California desert that's a native of New Jersey, but these same people happily consider all plants grown east of the Mississippi as native to any area in the east. Maps of U.S. Hardiness Zones are often used to justify the "nativeness" of one species or another. By this reasoning, a plant adapted to Zone 6 in Tennessee will serve as a fine native in the areas of Pennsylvania with a Zone 6 climate. The problem with these definitions of "alien"and "native" is that they do not consider the roles plants play within their respective ecosystems. I believe that what is and is not a native plant is best defined by nature herself. Because plants do not grow in isolation from other living things around them and are in fact essential to the lives of neighboring creatures, they interact with residents of their habitats in countless ways" (Tallamy, 2007).

Problems also arise even when the geography is broken down into much smaller areas like Washington State, or Whatcom County, Washington, or even a specific watershed. Because even though a plant like *Potentilla palustris* may have the same botanical name regardless of whether it comes from the wetland down the street or one in Maine or even Russia, the genetics may be completely different.

In my experience, this is where we nurserymen often come up short, and for good reason. The idea that a healthy cloned *Sambucus racemosa* which has been selected because of its tidy smaller stature, resistance to disease, and superior winter hardness, may be completely unacceptable to a restoration customer, is often perplexing. And why not — after all, we nursery growers have had centuries to hone our craft of propagating plant material cheaply, with uniform cookie cutter perfection that our ornamental plant customers have come to expect. While the quickest and cheapest way to produce a healthy vigorous plant may be the objective for ornamental production, it quite likely won't satisfy the needs of an increasingly sophisticated restoration community.

Put as simply as I can, propagating native species for environmental restoration is not just about the plants, it's about the entire habitat linkage. Sophisticated consumers of native plant species understand the importance of these symbiotic relationships and require a much greater attention to genetic origin; propagating to preserving genetic diversity is one of their objectives.

So when you look through a Fourth Corner Nurseries catalog you won't find a USDA Plant Hardiness Zone Map, instead, what you'll see is a reference to origin: we call it SS (for seed source) because 97% of what we grow is propagated from seed.

The sexual propagation of plants, using U.S. Forest Service Standards for seed collection, is how we capture the genetic diversity our customers are looking for. Forest Service collections have us picking seed from many different plants, while at the same time leaving enough behind for wildlife food and the "seed bank." Whereas making plant selections in the wild for eventual ornamental use would probably have us doing the opposite by searching for the nicest looking, smallest grower in a population to eventually clone and name. Propagating plants for U.S. Forest Service installations requires us to use site-specific seed collection with the finish crop harvested and shipped "row run." Rather than grading by size, which in some cases could end up separating the taller males from shorter females, their objective is to obtain the greatest range of diversity possible by taking plants of all sizes.

So when I visit an ornamental nursery grower and they tell me they're supplying native plants for a restoration project and they've given their customer the cultivar

Thuja excela in place of *Thuja plicata* or *Ribes sanguineum* 'King Edward VII' in place of *Ribes sanguineum* because "it grows better" and "no one will know the difference," I cringe a little. Unapproved species substitutions are never a good thing to do even in the ornamental world, but it's completely unacceptable in restoration where the damage these plants can potentially cause is often irreversible.

This attention to provenance is nothing new to the forest industry where seed zones are determined by elevation and genetic makeup. Likewise, the restoration community is also interested in preserving the genetic diversity within a given environ. Unlike an ornamental planting, native plants used for restoration are meant to mix with the surrounding flora and breed. Ecosystems are complex webs of interacting organisms, so when we introduce plants with a different genetic origin we impact the native population in unpredictable ways.

Generally speaking, it's probably fair to say that the scientific community has a long way to go to fully document these symbiotic relationships that have evolved over immense periods of time. So, "when a plant is transported to an area of the world that contains plants, animals, and diseases with which it has never before interacted, the coevolutionary constraints that kept it in check at home are gone, as are the ecological links that made that plant a contributing member of its ecosystem." Tallamy and others "argue that a plant can only function as a true native while it is interacting with the community that historically helped shape it" (Tallamy, 2007).

As naturalized alien plant species replace the native species in an area, the effect over time can be dramatic with the first changes being felt in the insect world. "If our native insect fauna cannot, or will not, use alien plants for food, which is usually the case, then insect populations will be smaller" (Tallamy, 2007).

This may sound wonderful to us growers or to the home gardener, but because so many animals depend on insect protein for food, "a land without insects is a land without most forms of higher life" (Tallamy, 2007). The Xerces Society has determined that one out of every four mouthfuls of food that we consume requires the presence of an insect pollinator; there's no way to overstate the importance of insects to a healthy eco system (Matthew et al., 2003).

More that 40 years have passed since the First Earth Day celebration and our universities have now produced a generation of smart, talented restoration ecologists.

A shift in thinking clearly is underway, with a greater understanding that the loss of genetic diversity is not a good thing. Therefore, when presented with the opportunity to restore habitat using native plants, it's important to remember that not all plants, even those of the same genus and species, are appropriate for a restoration planting.

The need for genetically diverse native plants is going to grow.

There is an international awareness for the need to reverse the destruction of native habitats. In addition, much of the world community has begun to look at our forests and rangeland as repositories for carbon capture in the fight to ease global climate change. Climate change is a non-localized problem, it doesn't matter where we live, greenhouse gases spread evenly throughout the atmosphere. So carbon capture is potentially an equal opportunity employer for plant propagators.

The large cap and trade regimes of the Europe Economic Community, over 20 U.S.A. states and other signatories of the Kyoto Protocol on global climate change have already begun foraging for carbon offset projects. Some of these projects will inevitably require the propagation and installation of plants and most if not all will likely be selected with very intentional genetic origins in mind.

Vattenfall, a Swedish energy firm, has examined the potential for large-scale revegatation of wasteland to sequester carbon. They concluded that "there are approximately 1.86 billon hectares of degraded land in the world. This includes land that was once grassland, forested, or farmed. Of this, they believe that nearly half, 930 million hectares, has the potential to be reclaimed: an area larger than the entire United States (916 million in the U.S.A.)" (Kollmuss, 2007).

In addition to the demands of global climate change, there are also undeniable strains being imposed on the environment through increased population growth. The earth's human population is increasing by an extra Bellingham every 7 h and 39 min, an extra Canada every 163 days, an additional United States every 46 months. The need for careful management and restoration of the natural environment will only become more acute in the years ahead.

The potential for protecting, preserving, and restoring habitats is huge and native plants are going to be part of that. It's an amazing time to be a plant propagator, the needs are great and the demand will be satisfied by those who can supply the genetically diverse plants and seed that the market place will undoubtedly demand in the years ahead.

Acknowledgement. Author would like to thank the Fourth Corner Nursery staff for their insightful counsel, with special thanks to Richard Haard, Julie Whitacre, and Veronica Wisniewski.

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QUESTIONS AND ANSWERS

Anonymous: Do you have a way of getting this information out on a larger scale?

Todd Jones: Our catalog has an article by Douglas Tallamy in it. We try to feature something like that in each of our catalogs.

It's Not All Asphalt: Washington State Department of Transportation's Use of Native Plants©

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The Washington State Department of Transportation (WSDOT) spends most of its time and energy planning for, building, improving, and maintaining highways and other modes of transportation. What most people don't know is that our work also includes planting hundreds of thousands of mostly native plants in a variety of locations in several different kinds of projects.

Transportation impacts to aquatic resources are often unavoidable, since the area we have to work in is so limited and our state has so many wetlands, streams, and rivers. These unavoidable impacts must be mitigated, or compensated for, usually by creating or improving a similar resource nearby. This leads to a lot of native plants being installed in mitigation projects.

As well, our own policy requires us to repair or replace roadside elements disturbed or removed in the course of our work. That's true for sidewalks, lights, or plants. Disturbed vegetation is restored to a self-sustainable plant community that will keep out weeds, hold the soil, block or enhance views, reduce noise levels, and perform a host of other roadside functions, as well as be low maintenance to save money. In most situations this means planting native plants.

The right-of-way along a highway is part of the functional roadway, just like the traveling lanes, and has roles to fill as well. Among these jobs are preserving surface drainage, allowing traffic visibility, control of noxious and invasive weeds, maintaining visibility of signs, and providing erosion control and slope stability. A roadside plant has a tough job — it has to perform in disturbed soil, glaring sun, droughty conditions, where highways are a heat sink in the summer and channel cold winds in the winter, and there is a constant influx of weed seeds to battle.

As important as "Right Plant, Right Place" is in the garden, it's even more so in a mitigation site or on the roadside, where conditions are severe and follow-up care is minimal. Our landscape designers and biologists use nature as their template, taking climate, soil type and structure, water holding capacity, aspect, hydrology, and a host of other environmental factors into account when they choose species to use.

In order to do all that, we buy a lot of native plants. Actually the majority are not purchased directly by WSDOT but by the contractors who install our projects.

I used information on WSDOT's website to estimate the number of native plants bought from January 2005 through about July 2010 (Table 1). Using this system, I calculated that WSDOT has planted approximately 2 million native plants in the last 5 years. I didn't try to count the non-native plants, but they're a small fraction of the total, used mostly in highly urbanized areas or in community gateways. If you would like more detail, the website address is at the bottom of the table.

The USDA Forest Service has created a database of native plant propagation protocols that can be found at <www.Nativeplantnetwork.org>. Information about subscribing to the Native Plants Journal (NPJ) can also be found there. The NPJ is a journal for those interested in the practical aspects of growing and planting-

Table 1. Top 25 species purchased by WSDOT from January 2005 to July 2010.

Species	Common Name	Qty	Form
Gaultheria shallon	salal	160,800	shrub
Symphoricarpos albus	snowberry	118,400	shrub
Salix sitchensis	Sitka willow	100,600	shrub
Cornus sericea	red osier dogwood	96,000	shrub
Rosa nutkana	Nootka rose	74,300	shrub
Carex obnupta	slough sedge	66,000	emergent
Schoenoplectus acutus	hardstem bulrush	65,700	emergent
Rosa pisocarpa	peafruit rose	55,200	shrub
Rubus spectabilis	salmonberry	55,200	shrub
Acer circinatum	vine maple	54,500	shrub
Salix scouleriana	Scouler's willow	52,300	tree/shrub
Thuja plicata	western red cedar	48,100	tree
Mahonia aquifolium	tall Oregon grape	47,800	shrub
Scirpus microcarpus	small-fruited bulrush	47,000	emergent
Lonicera involucrata	black twinberry	43,400	shrub
Pseudotsuga menziesii	Douglas-fir	43,400	tree
Rubus parviflorus	thimbleberry	42,600	shrub
Salix lucida	Pacific willow	39,700	tree
Sambucus racemosa	red elderberry	38,500	shrub
Corylus cornuta	beaked hazelnut	37,400	shrub
Amelanchier alnifolia	western serviceberry	34,800	shrub
Physocarpus capitatus	Pacific ninebark	32,400	shrub
Schoenoplectus taebernaemontanii	softstem bulrush	25,400	emergent
Holodiscus discolor	oceanspray	24,100	shrub

Summarized from: http://www.wsdot.wa.gov/Design/ProjectDev/EngineeringApplications/UnitBidHistory.htm

natives. It comes out three times a year and the summer issue includes a national native plant nursery directory. Links to a variety of other websites concerned with native plants are also available there.

I know that you are all familiar with the American Standards for Nursery Stock (ASNS). Don't rely on these alone; WSDOT has specifications that supersede these standards. Plants can be and have been rejected at the job site for failing to meet WSDOT standards, which focus on plant health and root structure.

The first place to look for plant specifications is in the Standard Specifications, at this link: <http://www.wsdot.wa.gov/Publications/Manuals/M41-10.htm>. Here, you'll find details that don't change from project to project. You won't find species and quantities, since these change. But you will find all the basic details that apply to every project. The plant specifications are in Division 9, Section 9-14.6. Seed specifications are in Section 9-14.2

Check for revisions to the specs by going to this link: <http://www.wsdot.wa.gov/Design/ProjectDev/Specifications.htm>. Look for the latest update package; this will have the amendments to the Standard Specifications. They are organized by Division as well.

The second place to find specifications is on the plan sheets for the individual project. If you are bidding on a project, you'll have the plan sheets with the plant materials tables, or plant schedules. If a contractor sends you a bid request for plants, make sure s/he has included the whole table from the plan sheet, including the scientific name, quantity, size, type or root condition, and remarks. Otherwise, you may deliver to the job site and discover that your plants don't meet specifications and are rejected. The plans will have tables similar to the excerpt below in Table 2.

For more information, please consult the WSDOT Roadside and Site Development webpage at: <http://www.wsdot.wa.gov/Design/Roadside/>

QUESTIONS AND ANSWERS

Bob Buzzo: At what point did DOT change their mission to recognize native plants? When I lived in Olympia 35 years ago they landscaped the highways with plants that have fallen out of favor.

Susan Buis: English ivy fell out of favor when maintenance showed management how much they were spending trying to keep it out of trees. *Rosa rugosa* fell out of favor when all of that long stretch of planting on I-5 through Tumwater and parts of Olympia got a virus and died. We can't afford to try to control diseases in highway plantings. When that happens we have to remove the diseased plants and find replacements. Washington State Department of Transportation has made a huge shift from ornamentals to natives in the past 15–30 years. They've shifted to natives because people started paying more attention to what was succeeding on the roadside and what wasn't. What they found was that non-native ornamentals did fine initially, but they didn't hold up over time. Certain natives do, but not all natives. There's nothing native about roadside. It's a highly disturbed, highly impacted environment so some natives work well and some don't. And, some ornamentals work well. The ones that do are still being used.

Douglas Justice: Susan, you mentioned grasses. Are you talking strictly about native grasses?

Susan Buis: On the east side of the state we have found that it's worthwhile to use native grasses with specific genetic provenance. We found they perform best in the long-run. On the west side of the state we still use standard erosion-control grasses because they perform adequately in the milder westside climate.

Table 2. Plant Materials List.

Botanical Name	Common Name	Qty	Size (in. HT)	Type	Remarks
Carex obnupta	slough sedge	100	8	10 $in.^3$ plug	
Corylus cornuta	beaked hazelnut	55	24–36	#2 container	
Holodiscus discolor	oceanspray	120	12–18	Bareroot	
Mahonia aquifolium	tall Oregon grape	70	24–36	#1 container	
Rubus parviflorus	thimbleberry	95	12–18	Bareroot	2 cane minimum
Symphoricarpos albus	snowberry	165	12–18	Bareroot	
Pseudotsuga menziesii	Douglas-fir	25	12–18	#1 container	No sheared trees

Growing and Energy Conservation©

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INTRODUCTION

As energy costs rise, resistance to it becoming a larger proportion of production cost increase. One option to consider in this battle is altering thermostat settings during initial crop growth stages early in the growing season.

The challenge is to reduce energy requirements in greenhouse crop production while maintaining quality and on-time delivery. Two concepts will be discussed with respect to greenhouse heating set points. These are Q_{10} factors (Q_{10} temperature coefficient is a measure of the rate of change of a biological or chemical system as a consequence of increasing the temperature by 10 °C) during seed germination and DIF (refers to the difference between day and night time temperatures) during active growth.

GROWING AND ENERGY

A plant is packaged energy. Like any organism it consumes energy to grow, protect, maintain, and reproduce itself. In native habitats, plant species evolve to accomplish this within the seasonal time frame utilizing "free" energy supplied by the sun. In nature success is defined as being there.

In the nursery we impose size, time, uniformity, and developmental requirements. Impatience costs money. Supplementary energy input, in the form of light and heat purchased during winter and early spring is what costs. Establishment of uniformity early in a crop cycle is perhaps the most energy intensive. If establishing uniformity at lower temperatures is required, then high-seed vigor is extremely important because it facilitates seed germination at a wider range of temperatures. Multiple sowing (per cell) and thinning may be a viable strategy depending on seed cost and availability. Germinating at low temperatures generally results in reduced uniformity that can be partly or wholly re-established at thinning.

Energy forms critical to photosynthesis and "growing" are light and heat. Light drives the photosynthetic process and heat warms the photosynthetic machinery so it can operate. Heat also encourages convection around plants thereby replenishing CO_2 supplies and "driving" transpiration. Outside, during the natural growing season, these energy forms are abundantly available and in approximately the correct proportions. However, in a greenhouse during the winter they seldom are. The challenge is to supplement and balance them in such a way that "growth" occurs. Optimum settings are growth-stage dependent.

HEAT AND GERMINATION

Respiration of stored seed reserves provides the energy that fuels germination. Respiration rate increases with temperature. The goal is fast, uniform, disease-free germination. Many things affect this but let's concentrate on seed temperature. Given healthy, stratified seed at appropriate moisture content Figure 1 depicts its response to germination temperature. If ~82% germination is the cutoff for

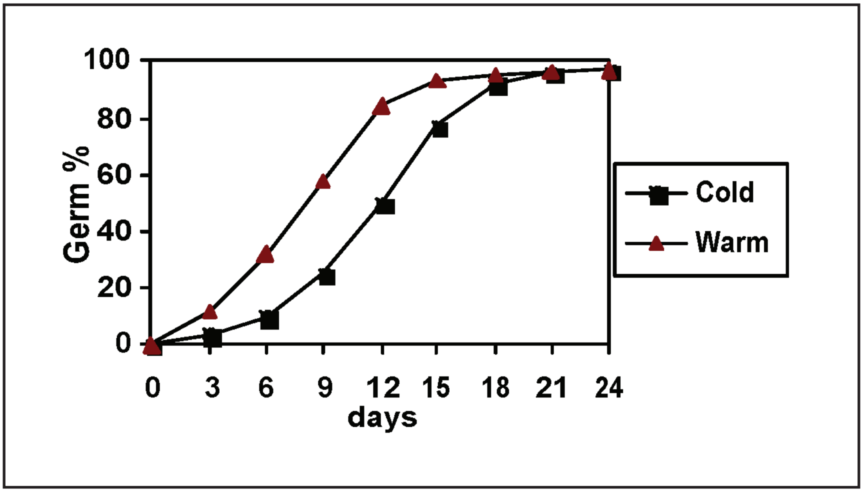

Figure 1. Cumulative germination percentage over time (24 days) at different temperatures.

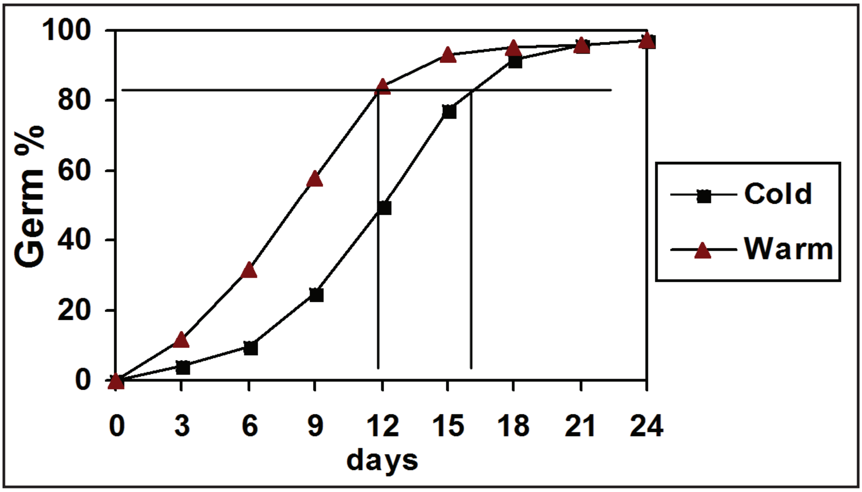

Figure 2. Effect of temperature on time to reach threshold germination percentage (82%).

switching from a "germination" to "growing" environment, then the "warm" regime allows compression of the germination phase by 5 days (Fig. 2).

Shortening the germination phase... does it pay? Figure 3 depicts in general the rate at which energy is supplied to a seedling, and how it accumulates energy over the course of its first growing season. Please realize that no heat energy supplied ends up inside the seedling as stored chemical bond energy. All the energy that constitutes a seedling it has to capture and store itself. We cannot "pump it up." Heat energy supplied only helps facilitate conversion of light to chemical bond energy by warming the production machinery, allowing it to work more quickly and efficiently. A germinating seedling, once showing green, is a small solar panel.

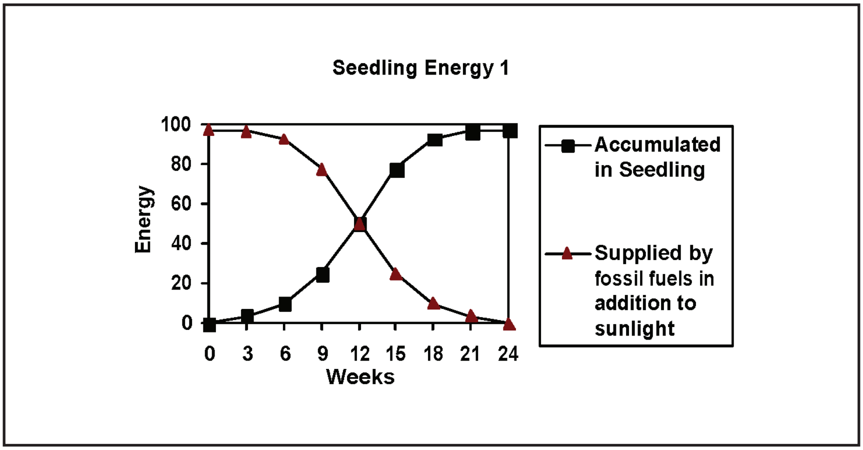

Figure 3. The rate at which energy is supplied to a seedling and how it accumulates energy over the course of its first growing season.

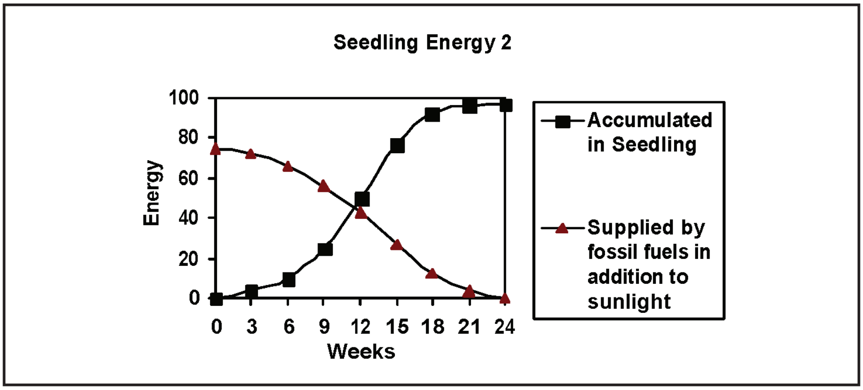

Figure 4. Energy accumulation in seedlings vs. energy supplied to optimize growth.

The large up-front fuel expense is due to the inefficient way heat is supplied to germinating seed. A handful of seed is distributed into a huge, virtually uninsulated, volume of air termed a greenhouse, which is subsequently heated. Is this worth the cost? Are there other ways to realize the objective?

Can we reduce energy use or increase energy use efficiency as in Figs. 4 or 5?

Q_{10}.

Assume a seed with stratification complete, and moisture, oxygen, and carbohydrate reserves not limiting. The rate at which biochemical processes proceed within a seed depends on seed temperature. The function that describes how the rate of a biochemical reaction changes with changing temperature is called the "Q_{10} factor." Over a specified range, it describes how the reaction rate changes per 10 °C interval.

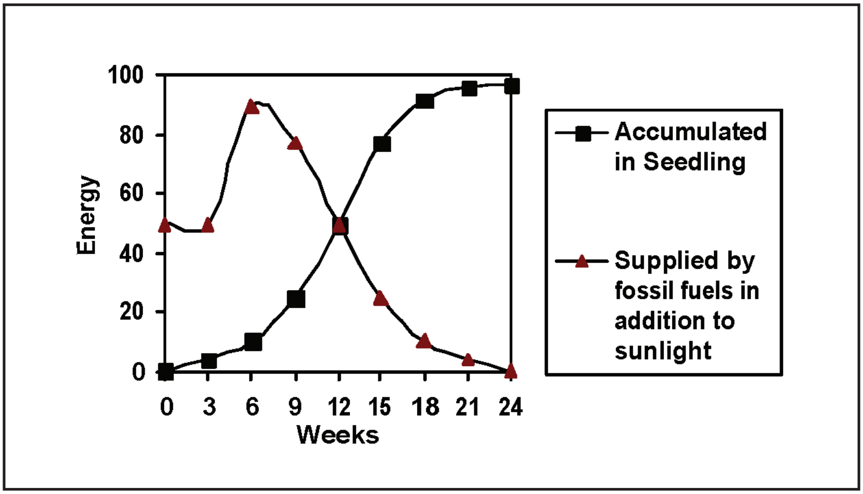

Figure 5. Energy accumulation in seedlings vs. energy supplied to optimize growth.

Between 5 °C and 35 °C for respiration in plants the Q_{10} factor is approximately 2. This is an exponential relationship. It means that over the specified temperature range, a 10 °C rise affects a doubling of the respiration rate (Fig. 6). From the onset of germination until green is showing, respiration rate = germination rate!!

Practically speaking, raising seed temperature from 5 to 15, 10 to 20, or 15 to 25 °C in each case doubles respiration/germination rate. Hence, going from 5 to 25 °C quadruples it! Keep this in mind when choosing germination and growing temperature regimes. At a higher initial temperature where respiration/germination rate is higher to begin with, a certain Celsius increase instills a much larger response than at lower temperatures, where initial rates are lower.

Obviously huge gains in germination speed and uniformity can be made by raising germination temperature into the mid-high twenties Celsius. But still the question…does it pay, especially at high per unit energy costs?

The cost of raising growing facility temperature is a function of the area of the structure, covering heat loss value, inside humidity level, air exchanges per unit time, and outside temperature/wind/precipitation conditions.

Combining Figs. 6 and 7 gives the following relationship shown in Fig. 8.

Figure 8 shows that with each successive increase in greenhouse temperature, the return on the heating investment increases (in terms of increased germination speed). In the above scenario (6-mil single poly at -10 °C outside temperature), the first unit of energy is consumed to achieve a greenhouse temperature of 5 °C. Respiration (germination) rate is at 1. Adding a 2nd unit of energy brings greenhouse temperature to 20 °C and instills a respiration rate of 3. Adding a 3rd unit of energy brings greenhouse temperature to 35 °C and raises respiration/germination rate to 9 times the rate at 5 °C! In other words, 3 days at 5 °C will give the same germination result as 1 day at 20 °C (seed temperature, not just greenhouse air temperature), saving 2 days of heating time at 5 °C = saving 33% on the fuel bill to attain the same level of germination.

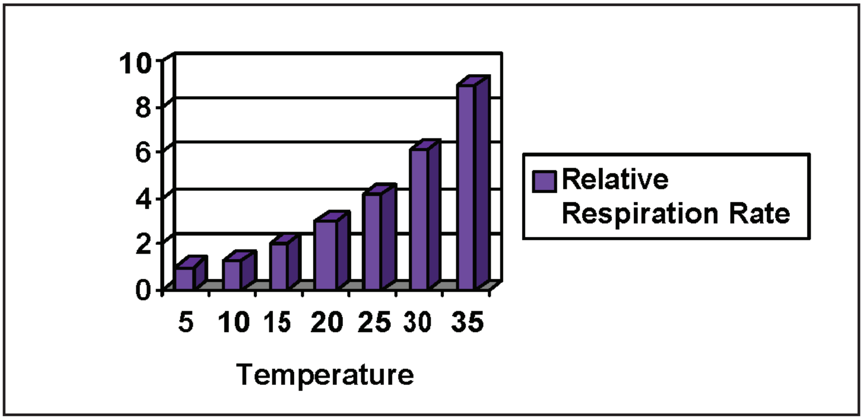

Figure 6. Q_{10} = 2 for plant respiration (5 - 35 °C).

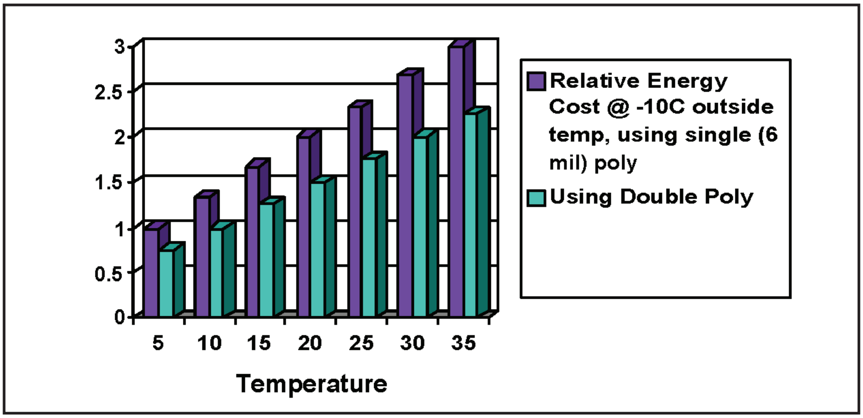

Figure 7. Greenhouse heating costs increase in a linear, not exponential fashion.

The bottom line is that it pays to increase germination temperature. In fact, the higher the per-unit energy cost, the more it pays! You have to spend money to make money.

DIF: AFTER GERMINATION

The difference between day and night time temperatures is referred to as DIF. Regular growth is an extension of germination; hence, temperatures that promote growth will promote germination. However, for many plants optimum germination temperatures are somewhat higher than optimum growing temperatures. This is due to the fact that respiring storage reserves in seed generates energy requirements for germination-type growth, which involves primarily a reactivation and "unfolding" of previously developed systems and structures. Photosynthesizing organs and "machinery" have maintenance energy requirements, which increase exponentially with temperature. This leads to the concept of "net growth," which equals gross photosynthetic production minus respiratory maintenance requirements.

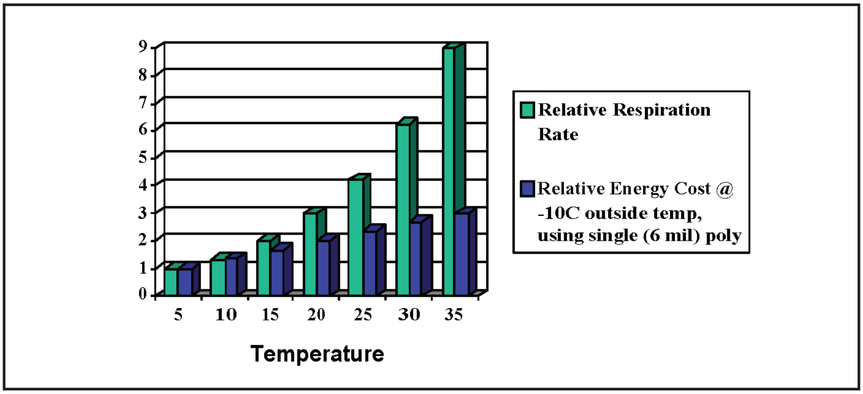

Figure 8. Q_{10} vs. Greenhouse Heating.

NET PHOTOSYNTHESIS

Energy conversion is the concept. In a greenhouse during winter/spring, with help from stored pre-historic solar energy (natural gas, propane, coal) converted to heat, we make it possible to convert current solar energy (sunlight) to chemical bond energy through the process of photosynthesis (Fig. 9).

- Photosynthesis (PS) only occurs in the presence of light (and carbon dioxide).
- Net photosynthesis = photosynthesis minus respiration.
- Net photosynthesis is positive if photosynthesis > respiration.
- Net photosynthesis is negative if photosynthesis < respiration.
- Twenty-four-hour net photosynthesis is positive if daytime net PS exceeds nighttime respiration losses.
- Annual net photosynthesis is positive if growing season net PS exceeds non-growing season respiratory losses.
- Once seed reserves are consumed, young plants start out with virtually no stored energy reserves.
- Net photosynthesis has a lower temperature optimum under low light. Fewer storage reserves are being generated for future use (night, etc.) (Fig. 10).
- Dark period temperature needs to allow for reallocation of resources generated during the day (physical growth, maturation, and reorganization within the plant) while minimizing respiratory losses (Fig. 11).
- Good net PS days can support warmer nights and may require them to process additional photosynthetic products generated during the preceding day.
- Poor net PS days do not require and cannot support long and/or warm nights, especially in plants with low stored energy reserves (small, young plants are more vulnerable).
- A poor net PS day can be bright and very hot, bright and very cold, dull and warm, etc.

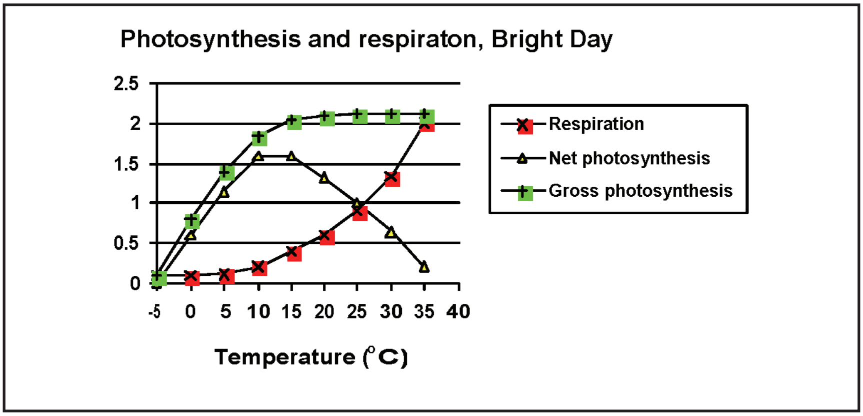

Figure 9. Gross photosynthesis - respiration = net photosynthesis. Respiration of stored carbohydrate (energy) reserves drive "growth."

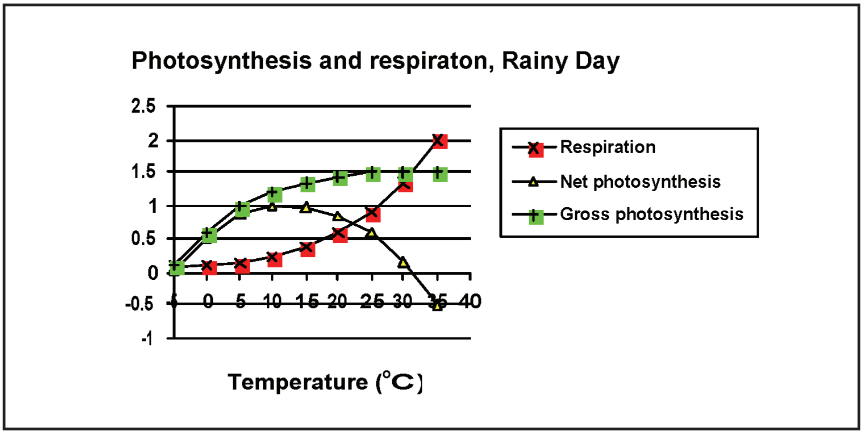

Figure 10. Reduced net photosynthesis on a cloudy day.

- The benefit of light-dependent temperature control is implied.
- The benefit of a positive DIF is implied.

With good solar gain during the day, a positive day/night differential is recommended. The cost/benefit of raising the temperature above ambient outside temperature (at night) and/or above ambient inside temperature maintained by solar gain (during the day) needs to be kept in mind.

To facilitate rapid germination, low to mid 20 °C temperatures are recommended. This allows transfer of the germinant from a "germinating" to a "growing" environment sooner. The germinating environment satisfies the heat sum requirement for seed germination. Respiration of stored seed reserves fuels the process and temperature drives it. A constant day/night temperature is desirable but not necessary. Maximizing heat sum in the most energy efficient manner is the goal. This can be achieved with variable temperatures so heating based on the cost of maintaining a certain delta T is prudent.

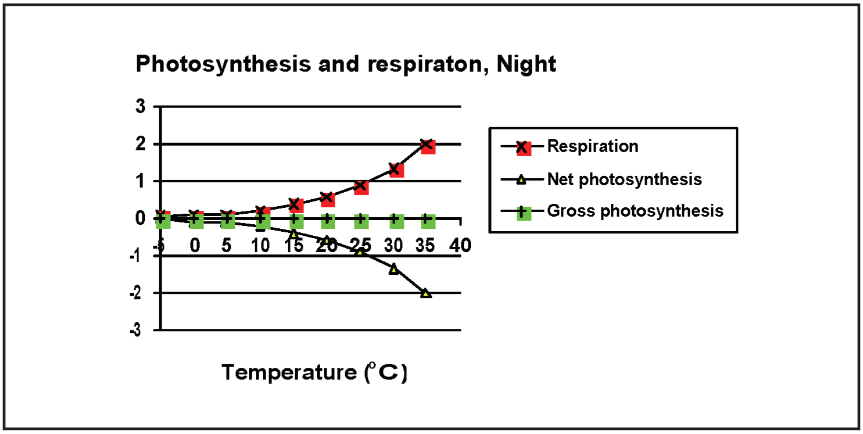

Figure 11. Net photosynthesis is negative at night.

The growing environment needs to balance heat with light to maximize net PS during the day. At night excess heat just increases maintenance requirements within the seedling, which deplete stored energy reserves. To minimize night-time losses, thereby maximizing the 24-h net PS gain, a positive DIF is logical.

SUMMARY

- Raising seed temperature during germination pays.
- Excellent forest seedling crops are being produced using low to mid teens (°C) night temperatures coupled with high teens to low twenties light dependent day temperatures.
- Other plant species grown from seed will respond to above concepts in similar ways, but may have differing optimum temperature regimes.
- Lower temperatures require additional attention to humidity conditions. In particular, one needs to closely monitor dew-point temperature in relation to plant temperature to combat diseases and physiological disorders.

QUESTIONS AND ANSWERS

Sylvia Mosterman: Was the heating system changed from forced-air to radiant heating?

Eric Van Steenis: Yes, infrared radiant heating.

Diego Martinez: Can you explain your use of single and double-poly and what your conclusions were?

Eric Van Steenis: I showed double versus single poly. At -10 °C I have prices per increasing unit of temperature for both types. Single poly just costs more than double poly to bring the greenhouse temperature up from -10 °C. It's cheaper to use double poly since each increment in temperature rise costs you less.

Cleaning Used Media and Containers With Steam and Hot Water©

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INTRODUCTION

Over the past decade Heritage Seedlings production has moved significantly from a field operation to containerized production of both seedlings and grafts. High quality, expensive soilless media are readily available to facilitate this transition. So each year we found ourselves not only purchasing a mountain range of medium, but also producing one of used soil. We started with a very coarse mix and after a single growing season the structure of the mix was little changed. The mix would be perfectly functional for another year of our needs, but intuitively we knew the cast-off media were unusable. Like most nurseries there are weeds in our production system, though we wish there weren't. We work hard to remove them, but the used mix has weed seed in it and is a source for the next generation of nursery weeds; that's not something we wanted. Additionally, there were other problems that made a switch to using recycled potting media impossible.

Because we germinate seed in baskets of medium, we had a concern about dormant seed germinating the following year and potentially contaminating new seed lots. This would be a particularly dangerous problem with lots of source identified seed used for their specific genetics. Another of the obstacles to overcome was sudden oak death (SOD). During the same time period we began participation in Grower Assisted Inspection Program (GAIP), Oregon's pilot program aimed at preventing SOD in nurseries. This program forbids planting host and associated plants (HAP) in recycled media unless it is cleaned of potential *Phytophthora ramorum* spores through composting or steaming. Composting, though socially appealing, just wasn't a viable option for us. And the last problem was our medium mixing system: it required a change from switch controls to a computer so we could use all the hoppers simultaneously, mixing new and used soil by proportion.

STEAM TREATING USED MEDIA

The particular approach we took to recycling our medium is steam treatment. Accomplishing this required the purchase of a steam generator, in our case a Steam Flo manufactured by the Sioux Corporation. It is completely self-contained; all we had to do was hook up a hose and plug it into an outlet and we were generating steam. The larger job was constructing a trailer and piping system for the steam and the medium but even that was made to seem easy by our more than capable fabrication specialist, Mike Heater. He built a 10-yd dumping trailer with a steel manifold, four 3-in. pipes raised just above the floor and automatic tail gate. There are holes drilled along the bottom of the pipes, directing the steam down, every 12 in. The engineers at Sioux were very helpful answering design questions along the way.

We grow our crops in baskets of medium and to harvest we mechanically shake the media from the roots. That used medium is stockpiled about as close to the generation point as we can get it, and now equally close to the steam generator. Later, when we begin planting we load the used soil into the steaming trailer, leveling the load with the tractor bucket (we are very careful to not cross contaminate the clean or new soil with equipment that has been into the used pile or the field where there are weed seeds or potential pathogens). Loading the trailer makes a huge mess and we have to make a point of cleaning off all the exterior trailer parts that can accumulate dirty medium, that is, medium contaminated with weed seeds that won't get steamed, but will fall from the trailer at dumping. This step is very important. We park the loaded trailer next to the steamer. It just so happens to be on a slight hill which works in our favor as there is a lot of water generated in the steaming process and the hill serves to drain it away a little quicker from the trailer than a flat parking space would. The Steam Flo is turned on and during cooler winter and spring weather we know we need to come back and start checking in about 3 $^1/_2$ h.

For the GAIP program we are required to hit 50 °C for 30 min. But because our main goal is killing weed seeds, we shoot for 80 °C for 30 min. The trouble with our trailer (I think really with all soil steaming in a pile) is that the bottom is hot fairly soon while the top is cold for a long time. So, by the time the top of the trailer's load has been 80 °C for 30 min the bottom is really well done. We measure temperature with a 20-in. soil thermometer and a digital thermocouple. Because the medium density is not consistent in a load, the heat doesn't necessarily transfer evenly. However, we measure the load temperature in no less than six locations. On more than one occasion we have found a pocket of "cold" soil that took much more time than the surrounding soil.

We turn off the generator and disconnect it as soon as we know the soil is hot enough. The equipment is quite safe to handle while hot, there are no pressure concerns, and then we dump the medium. We have found that waiting to dump the medium is a mistake because it tends to hang up in the trailer a lot more. Ideally we could steam during the summer months as the work load is a little less crushing and there is a lot less tractor competition, but we don't have a very large concrete slab to accumulate soil. Cleaned soil must not be stored on the ground as that could contaminate it with pathogen spores and new weed seeds.

We know this system works because there are no weeds in the soil and no stray seedlings emerging. There really haven't been any problems with this system. We haven't had issues with salts in this steamed medium nor has it adversely affected medium porosity; however, I expect the condition of the medium to change as we recycle it again this year. We will have to make multiple mountains segregated by age in order to deal with this. Currently we incorporate the steamed medium as a 50% component in our coarse planting mixes.

Critical Control Points. Soil steaming is only one of several critical control points for weed control in the nursery; media, containers, water, and the production spaces are the others. Our water sources are pure, surface water sources are tested monthly, four times during the irrigation season, and the medium we purchase is weed-free and we can apply herbicides and use ground cloth to prevent weeds in the growing areas. Once we started to steam recycled medium that left but one weak point in our production system, the containers we plant into because, just like recycled media, we reuse containers over and over for many years.

Reusing our containers over and over became a nightmare situation. It felt good on the front end, but it would leave us very sleepless on the other. The weeds would germinate simultaneously with the crop and the only thing we could do about it was plan the weeding labor or give up. We couldn't fix the problem of weed seeds sticking to the container wall with a homemade high-pressure flat washer and chemical cleaning had too many environmental concerns. Finally, we settled on steam and hot water treatments for cleaning our containers too.

HOT WATER DIP

At auction we purchased a hot water bath manufactured by Nothern (no longer in production) for the forestry industry where they commonly reuse their Styroblock® trays. This tank has thermostatic control. We run it at 76 °C and dip the trays for 10 min. This dip is a little longer than necessary if the temperature is really 76 °C, but to be sure we have good heat transfer into a dense stack of trays. This time works well for us to get other work done. We can dip a half pallet of trays at a time.

STEAM TREATING CONTAINERS

To steam our trays and heavier walled containers we purchased a used refrigerated shipping container (aluminum lined walls) and a Siebring Steamer. We can load and unload this unit with a forklift. The Siebring steamer is designed to treat only a couple of yards of soil at a time; it may be undersized for the shipping container but it works really well on the baskets as they don't have as much mass as occupied space. We run the system until the internal air temperature is 80 °C and then we turn the Seibring off. There is no thermostatic control on this machine and our truck can get so hot inside as to melt thinner walled polystyrene planting containers!

Both the hot water bath and steam truck do a great job, though they are a little more labor intensive than soil steaming. They are generally embraced by the staff. The only drawback to cleaned containers is that they look just like dirty ones. We attach ribbons to clean stacks and store them in designated areas, but even then there are mix ups as evidenced by an odd tray covered in weeds in an otherwise clean crop.

After a couple years of tray cleaning, you may ask if we will reduce the weed pressure enough to draw back from 100% cleaned trays. The answer is probably not. We still have weeds in our nursery, but now only a few and we can manage them.

QUESTIONS AND ANSWERS

John Low: I had a question about the hot water dip. Your plug trays are all nested together. What kind of penetration into the core of the stack did you see?

Eric Hammond: It penetrates in quite quickly. In my tests 3 min will work, but we go for a full 10 min to be sure. What we did find though is that the trays need to be upside-down. Our trays, and I imagine all trays, have a lip that can catch air and the air can't escape if they're right-side-up.

Bob Lovejoy: Is the steam saturating your soil with excess moisture?

Eric Hammond: Yes, it's very wet. The location where we steam is on a hill so that's very helpful for drainage. We don't have a large slab to stockpile soil.

Steve McCulloch: How has the steam changed the nutrient characteristics within the soil?

Eric Hammond: There has been some change; however, it's difficult for me to quantify. Generally speaking though, we're very satisfied with this solution.

Douglas Justice: I have two questions about the steamed soil. The first is, do you anticipate after doing this for 3 or 4 years that you'll have so many fines that you'll have to reduce the percentage? The second question is, are you concerned the high temperatures you're using are killing beneficial microorganisms?

Eric Hammond: Those are very good questions I've thought a lot about. I'll answer the second one first. I don't think our 10-yd trailer is the most ideal way to steam soil. I think the best way to do it would be to use a mixing machine that steams it very quickly and will also be more efficient. However, it's another moving part and another motor to break which concerns me. We inoculate all of our soils with mycorrhizae. As for the fines...I dread having to store another pile of soil, but I don't see any other way around it.

Lean Techniques at Bailey Nursery©

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Lean is a business philosophy that focuses on eliminating waste in a process or program. These lean practices can then be employed to dramatically improve profits leading to greater customer and employee satisfaction. Bailey Nurseries Management Team embraced the concept of lean management in 2008 by bringing in a facilitator/coach to conduct training at both of our Minnesota and Oregon divisions.

Lean management requires that your finished product be observed from the customer's point of view. Is the customer willing to pay for all the steps in your production process? Some of the steps that improve the product are things the customer wants and is willing to pay for. They are referred to as "Value Added." If some of the steps are a waste of time and money in the customer's eye then they are considered "Non-Value Added." There are some "Non-Value Added but Necessary" steps that include such things as EPA regulation, accounting, taxes, OSHA guidelines, shipping, etc. All costs will fall into one of these three categories.

Waste refers to all steps or processes that do not add value to the final product or service. There are eight forms of waste that must be reduced or eliminated in order to improve the efficiency of a process. They include over-production, waiting time, unnecessary transportation, over-processing, excess inventory, wasted motion, production defects, and disinterested employees.

A tool that is used to meet the goals of lean management is called "Kaizen." Kaizen is a Japanese concept that means "Acontinuous improvement" or "change for the better." It is a focused effort on a particular part of the operation. When doing a Kaizen, a team of people looks at every aspect of a particular process and identifies the waste. Subtle changes to reduce waste in a process can make dramatic changes to the efficiency.

A Kaizen begins by determining the Takt time of a particular process. Takt time is the maximum time it takes to produce a product in order to meet demand. It can be calculated on virtually every task in a business environment. It is determined by using the formula: Takt = Available time / Demand (or units per day).

If the production schedule for softwood cuttings is 5 million cuttings per year and those cuttings must be stuck between May 15th and August 1st, then the Takt time is calculated as follows:

Production Time:

Shift time (8 h)	480 min
Breaks 2 @ 10 min	20 min
Stretching exercises 2 @ 5 min	10 min
Production time per day	450 min
Working days (15 May – 1 Aug.)	× 58 d
Total number of working min	= 26,100

Cuttings to produce	5,000,000
Divided by total working minutes	26,100
Takt time	= 192 cuttings stuck per minute

The second step in a Kaizen requires that the team observe the people as they work and define their work sequence. These are the steps in the process that the crew goes through to complete their task. The Kaizen team must time each step and determine whether it is value added or non-value added. When areas of waste are identified, the Kaizen team discusses the options and begins to change the process to make it more efficient and eliminate the waste.

In 2008, the propagation department at our Yamhill, Oregon Division began to question the efficiency of one of its most basic processes, sticking softwood cuttings. There seemed to be a lot of wasted (non-value added) time in that particular process. Cuttings were stuck in ground beds inside a greenhouse structure. The rooting medium was tilled and leveled prior to being planted. The crew worked its way away from the end of the greenhouse where the automated irrigation equipment was parked. They used kneeling pads and worked on top of the very space they would be planting next. The crews created more work for themselves by packing the rooting medium down as they worked. The Kaizen revealed that approximately 50% of their time was spent loosening up the rooting medium and re-leveling it prior to sticking the cuttings.

A four-person Kaizen team was formed to evaluate this process and try to improve its efficiency. They began by measuring the Takt time of each step of the process. Next, an analysis of the results led the team to conclude that it would greatly improve the efficiency of the sticking crew if they did not have to "re-fluff" the medium prior to sticking the cuttings. A recommendation was made to build a cart that would allow the crews to ride above the ground beds and leave the medium undisturbed. Spending money on equipment is not usually part of a Kaizen event unless it is the only alternative. In this case, it made sense.

Our equipment fabrication department agreed to build a prototype cart. Once the cart was built, it was tested in the greenhouse and new Takt times were obtained. The results were very encouraging and then the benefit of Kaizen began. Minor changes to the design of the cart showed continuous improvement to the overall efficiency of the process. With input from the sticking crew workers, a simplified design proved to be very efficient. In 2009, four carts were built and tested under real propagation greenhouse conditions. Two crews worked simultaneously in the greenhouses. One crew used the carts and the other planted cuttings using the old method. The results speak for themselves. Labor to stick softwood cuttings was reduced by 40% using the carts versus the old method. In 2010, nearly 100% of the softwood cuttings were stuck in the greenhouses by this method. Only one crew of eight people plus one crew leader were used to plant all of the cuttings in the same amount of time that used to take two and sometimes three crews of the same size.

A Kaizen event should theoretically never end. Subsequent modifications to the process have included the construction of a hose cart to move the "watering in" hose, leveling equipment for smoothing out the propagation beds, and a very simple and efficient row marker. Minor changes with continuous improvement have greatly improved the efficiency of sticking softwood cuttings at Bailey Nurseries. The employees are also happy with the improvements because their work routine is much simpler and they are not as tired at the end of the day. As an added benefit, with less soil compaction, it makes harvest easier resulting in more root fiber being retained on the cuttings.

There are a few things to watch out for when conducting a Kaizen event.

- Do a lot of research prior to initiating lean management techniques. It may be advisable to hire a professional trainer to help facilitate the first Kaizen.
- Make sure that management gives their full approval to applying lean techniques to their operations.
- State the purpose of conducting a Kaizen to the work crew and communicate the goal of the project.
- Empower the Kaizen team to take full control of the process they are analyzing. They are now in charge of every aspect of that particular process. Some crew leaders may have emotional ownership of a process and will resist change. Everyone needs to "buy-in" in order to make this process work.
- Establish visual control of the process. Post the results of crew's activities. This can be on an hourly or a daily basis, but you must measure and post results or your time is wasted.

Calculate the financial impact your changes have made to the company.

There are several advantages to conducting a Kaizen event.

- It is low cost. Time is the major investment.
- It is targeted at specific bottlenecks in your operation.
- The results are almost immediate.
- Employees are more at ease.
- Results increased profitability with less waste of valuable resources.

The method of sticking softwood cuttings at Bailey Nurseries is somewhat unique. This article is not intended to convince your nursery to adopt this method. It is, however, intended to encourage you to give lean management and Kaizen a try at your nursery. You may find that you can eliminate some of the wasteful steps in your processes, which will help with your profitability and improve your employee's work experience.

QUESTIONS AND ANSWERS

Steve McCulloch: How has the process of lean management started to change the culture of your team?

Jim McConnell: If anything it's made us stronger. Since you're pulling people from all over the nursery, you're making new relationships. Everybody's beginning to look at the processes that we do and maybe pointing out other areas that could use a Kaizen. It does pull you together. And, once in a while it alienates someone. We've lost a few people along the way too.

Angela Anderson: I'm just wondering whether the device you built causes any neck strain?

Jim McConnell: Not that we've seen. If you compare the new process with the old one, it is a hundred times better. There's no back strain. That was the big issue before. The laying-down position is much easier on the back.

Growing Woody Plants With Limited Water Resources©

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INTRODUCTION

In Washington State the Department of Ecology sets strict limits on the amount of water that a farm can use. While the producer owns the land, the waters of the state collectively belong to the public. A Water Right Permit is the legal authorization to use a predefined quantity of water for beneficial use, including irrigation. The vast majority of Washington's available water is legally spoken for. Farmers have seen population growth, conservation demands, shrinking snow packs, and demand by industry all put a strain on this limited resource. A water right is necessary if you plan to divert or withdraw any amount of water for any use from surface waters (water located above ground) such as lakes, rivers, streams, and springs, or from ground water.

While there are many Washington farms with valid Water Right Permits, obtaining a new one is very difficult. Currently there are 5,700 new Water Right applicants on file. Due to budget contractions Department of Ecology estimates that for the 2009–2011 budget cycle they will only be able to review 370 (down from 500) applications. There are cases where applicants have waited for years to have their application reviewed, let alone approved.

Exempt Water Right Permit. Department of Ecology does have a groundwater permit exemption (RCW 90.44.050) that allows the uses of small quantities of ground water to construct wells and develop their own water supply without obtaining a valid Water Right Permit. For industrial purposes, which would include commercial nurseries, producers can use up to 5,000 gal of water per day (no acreage limit). This water can also be stored in a cistern for later use. Although exempt ground water withdrawals don't require a Water Right Permit, they are always subject to state water law.

Municipal Water. The Washington State Department of Ecology states that there are no restrictions on the use of municipal water for irrigation. Retail garden centers often connect to municipal water to irrigate their stock. Table 1 lists the cost of municipal water. Municipal water could be stored in a water cistern to supplant irrigation water derived from an Exempt well.

Table 1. Cost of purchasing 1 inch of irrigation water (27,000 gallons) for overhead irrigation on nursery stock. (Numbers are from 2009.)

Seattle: $137/acre	Vancouver: $63/acre	Yakima: $47/acre
Olympia: $96/acre	Mt. Vernon: $60/acre	Ellensburg: $30/acre
Bellingham: $66/acre	Wenatchee: $48/acre	Spokane: $23/acre

Rain Water Collection. On 12 Oct. 2009, Department of Ecology issued an Interpretive Policy Statement stating that a Water Right Permit would not be required for collecting and storing rain water collected from rooftops or guzzlers. Approximately 0.62 gal/ft^2 of collection surface per in. of rainfall can be collected during a rain event. Once collected there are no water restrictions on the use the water. A water cistern can be built on farm ground and can be used to both capture and store water from the winter rains, or to serve as a storage reservoir during the summer months if irrigation demands are low. There are companies that manufacture 10,000–100,000 gal corrugated steel cisterns that can be erected on a farm to capture water.

In the Pacific Northwest, however, there is a typically a 3-month (mid-June through mid-September) period where little rain occurs. The initial expense ($10,000–$22,000) for these tanks and lack of rainfall probably precludes their widespread use for nurseries over an acre in size.

Department of Ecology also states that a landowner could dig a shallow pond to store rainfall directed from a roof. As long as the reservoir does exceed 10 acre-feet no permits are required. A quarter acre pond would cost $10,000 to dig and line with plastic. Holding 815,000 gal of water it could add an additional 6800 gal of water per day over a period of 4 months to the exempt water allocation.

NURSERY USES

Field Production. In-ground tree production is possible with limited irrigation. Deciduous tree producers growing liners can bury drip tape beneath the rows during planting. For finished trees, there are examples of conifer growers that either don't irrigate their fields or only apply water during the initial years of growth. Some of the largest Japanese maple growers in the Northwest consider dryland farming a sustainable practice that enhances the hardiness and vigor of their trees. Fields are shallow cultivated every 8–10 days to create a dry layer, or dust mulch, which acts as a barrier to further evaporation.

Finished-tree growers can utilize above-ground drip tape or tubing that will provide consistent, direct application of water to the root zones. Using low-flow drip tape (15 gph/100 ft) growers simply lay tape along tree rows to wet down the root zone. On hilly ground pressure compensating drip tape is advised. Field production would include trees and shrubs grown in fabric bags set into the ground. Fabric bags greatly reduce root circling as would occur in a hard-sided container and, yet, still allow for water absorption from the surrounding soil.

Container Production. Overhead irrigation has been the traditional method of supplying water to container nursery stock, especially for the 1- to 3-gal containers. Agricultural engineers suggest that no less than 1-acre inch of water (approximately 27,000 gal) be applied per day on each acre of container stock. If a nursery owner is fortunate to have a valid Water Right Permit or can connect to the public water supply, the use of impact sprinklers will continue.

For the larger pot sizes (5 gal and above) growers prefer drip irrigation. If the farm only has a permit exempt well, which limits water use to 5,000 gal/day, drip irrigation will have to be practiced.

An informal survey of Oregon and Washington canyard growers was conducted. For 1.5-in. caliper shade trees growers used 15-gal pots with a single low-volume spray stake. Some growers reported moving this single stake over the course of the season to ensure even root distribution. For 2- to 2.5-in. caliper trees, a 25-gal pot is used, equipped with 2 spray stakes. With a 160° wetting pattern, spray stakes are placed near the edge of the container to ensure an even wetting pattern. Flow rates range from 5.5 to 11.5 gal/h. For hilly ground pressure compensating emitters are used.

With spray stakes, it is best to apply water in short segments over the course of the day. Single irrigation sets tend to force water all the way through the pot with little lateral flow. Growers reported using 3 cycles per day. With each successive cycle the wetting front moves 3–4 in. deeper in the container.

Depending upon the plant being grown in the pots, growers reported applying anywhere from 2–5 gal of water per day for 15-gal pots. Japanese maple growers reported using less water per day than growers raising larger red and Norway maples. Specimen growers raising trees in 45-gal pots reported using three stakes, delivering up to 10 gal of water per pot.

Pot-in-Pot Production. Pot-in-pot growers reported using drip systems almost exclusively. Liner pots range in size from 5 gal up to 25 gal. The smaller sizes (5–7 gal) are preferred for shrubs, while the larger sizes (10–25 gal) are used for trees. In relationship to above-ground pots, Pot-in-pot growers reported using less water. When the liner pots were smaller than 10 gal, growers reported using less than 1.0–1.5 gal of water per day. For shade trees in 15-gal liner pots, 1.5–2.0 gal of water was used per day.

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QUESTIONS AND ANSWERS

Anonymous: What's involved in digging a hole that big?

Charles Brun: The grading department at the county indicated that anything more than 50 yd^3 of soil would require a grading permit and a SEPA permit.

Care and Handling of Container Plants From Storage to Outplanting©

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INTRODUCTION

Nursery plants are in a period of high risk from the time they leave the protected environment of the nursery to when they are outplanted. During handling and shipping, nursery stock may be exposed to many damaging stresses, including extreme temperatures, desiccation, mechanical injuries, and storage molds. This is also the period of greatest financial risk, because nursery plants have reached their maximum value right before shipping (Paterson et al., 2001). Adams and Patterson (2004) concluded that improper handling of nursery stock had more impact on plant quality than the type of outplanting tool.

All the information in this paper is included in The Container Tree Nursery Manual Vol. 7: Seedling Processing, Storage, and Outplanting. It was published as Agriculture Handbook 674 by the USDA Forest Service (Landis et al., 2010) (Fig. 1).

Growers go to extremes to produce the highest quality plants and strive to have them at their best when they are sold or shipped to the customer. As plant people, we all know that nursery stock is alive and perishable and so should be treated with utmost care at all times. Unfortunately, customers or people who handle plants after they leave the nursery often don't appreciate this fact. Stressful injuries incurred between lifting from the nursery and outplanting, however, are often not evident until several weeks or even years after planting. Symptoms include browning, chlorosis, poor survival, or decreased growth and are commonly known as "transplant shock" or "check." It can be extremely difficult to pinpoint the exact stress that leads to these symptoms. It is a waste of time and money to produce or purchase high-quality plants only to have them die or grow poorly after outplanting as a result of these unnecessary stresses.

THE CHAIN OF PLANT QUALITY

Nursery plants are at their maximum quality immediately before they are harvested at the nursery, but they then must pass through many hands before being outplanted. Outplanting success is dependent on maintaining plant quality by minimizing stress at each phase of the operation. It is useful to think of plant quality as a chain in which each link represents one of the sequences of events from harvesting and storage at the nursery until planting at the outplanting site (Fig. 2). The cumulative effect of the various stresses can be much greater than any one individual stress. As stress increases, the plant shifts energy from growth to damage repair. Physiological functions are damaged and survival and growth are reduced. These effects are exacerbated further when plants are outplanted on harsh sites.

Each stage in the process represents a link in a chain, and overall plant quality is only as good as the weakest link. It is useful to think of nursery plant quality as a checking account in which all types of abuse or stress are withdrawals. Note that all stresses are cumulative and no deposits can be made — it is impossible to

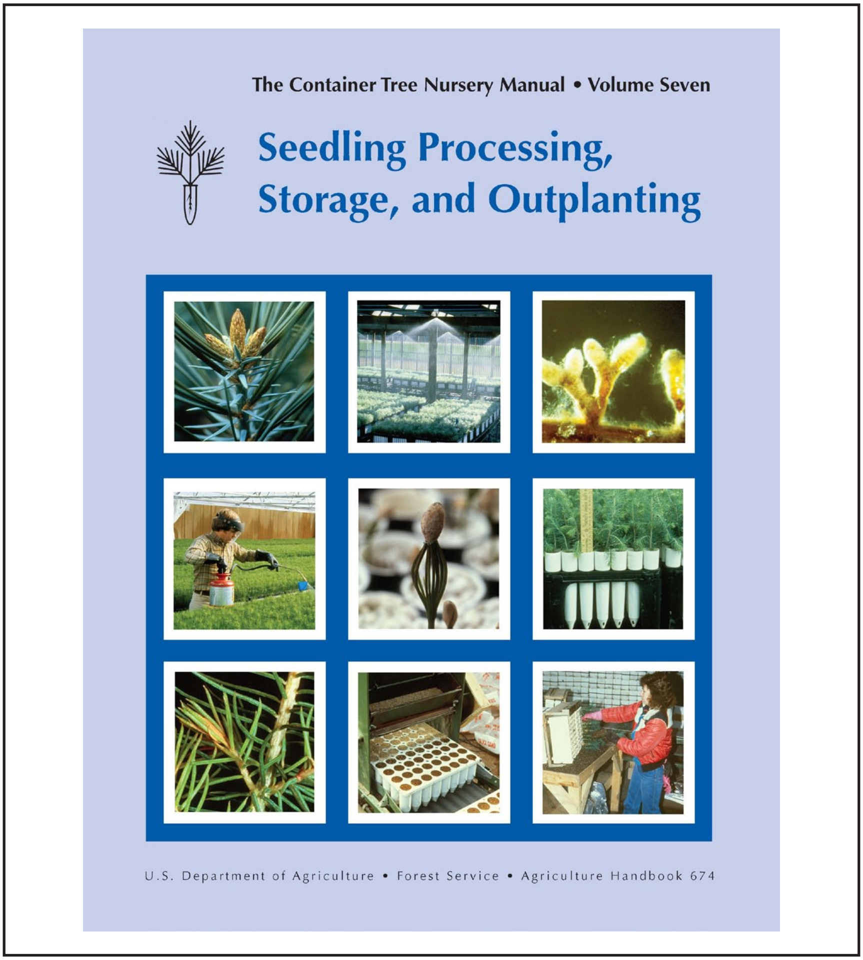

Figure 1. Container Tree Nursery Manual, Vol. 7 (covers from harvesting and grading at the nursery to out planting in the field). Softbound copies can be purchased from the U.S.A. Government bookstore <website: www.bookstore.gpo.gov>.

increase plant quality after nursery harvest (Fig. 3). Because all types of abuse or exposure are cumulative, it is helpful to think of nursery plant quality as a checking account. Immediately before harvesting, plants should be at 100% quality, but all subsequent stresses are withdrawals from the account. It is impossible to make a deposit — nothing can be done to increase plant quality after plants leave the nursery.

STORAGE

The first link in the plant quality chain is when nursery stock is harvested and stored. It is important to realize that plant storage is an operational necessity, not a physiological requirement (Landis, 2000), because of the following four reasons.

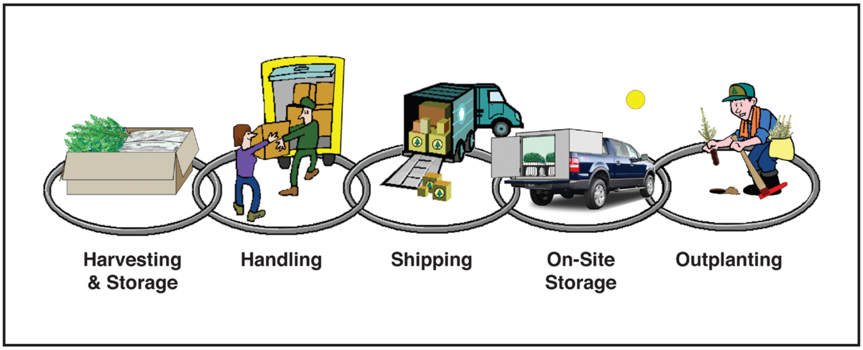

Figure 2. Nursery plant quality can be visualized as an interconnected chain of events from harvest to outplanting.

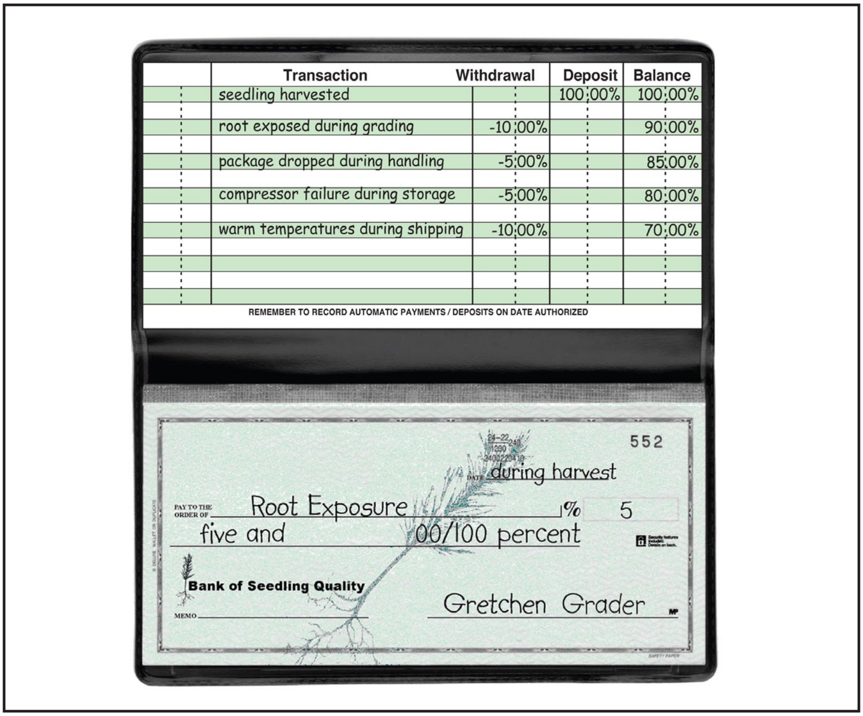

Figure 3. A checking account in which every stress is a withdrawal is a useful analogy for the stresses incurred after plants leave the nursery.

Distance Between Nursery and Outplanting Site. Today, most native plant nurseries are located at great distances, often hundreds or even thousands of miles, from the outplanting sites of their customers. This is particularly true of container nurseries because, as long as the proper seed source is used, high-quality plants can be grown in greenhouses in ideal growing environments located far away. The farther the distance from the nursery to the outplanting site, however, the greater the need for storage.

Differences Between the Lifting Window at the Nursery and Outplanting Windows. As mentioned in the previous section, container nurseries are often located in climates different from those of their customers. In mountainous areas, this is especially true, because nurseries are typically located in valleys at low elevation that have much different climates than outplanting sites at higher elevations. Differences between lifting and outplanting windows will also depend on the season of outplanting. If customers desire summer or fall outplanting, then short-term storage is all that is necessary. Often, however, the best conditions for outplanting occur the following spring, so it is necessary to protect plants throughout winter.

Facilitating Harvesting and Shipping. The large numbers of plants being produced at today's nurseries means that it is physically impossible to lift, grade, process, and ship stock in a short time. Therefore, one primary benefit of storage facilities is that they help to spread out the scheduling and processing during harvesting and shipping.

Refrigerated Storage Can Be a Cultural Tool. Many growers do not appreciate the fact that refrigerated storage can be used to manipulate plant physiology. Cold storage temperatures can partially satisfy the chilling requirement of dormant stock, and refrigerated storage has even been shown to improve plant quality (Ritchie, 1989). On the other hand, plants with atypical dormancy patterns may not benefit from refrigerated storage. Cold storing water oak (*Quercus nigra*) seedlings did not appear to prolong dormancy, increase stress resistance, or increase outplanting performance (Goodman et al., 2009).

While some nurseries use open or sheltered storage, most forest nurseries in the Pacific Northwest use one of the two types of refrigerated storage (cooler storage and freezer storage), which can be differentiated by their temperatures (Fig. 4) and the recommended duration of storage. Both nursery research and operational experience has shown that cooler storage is best for periods of 2 months or less, whereas freezer storage is recommended for longer storage periods. Cooler storage is preferred when nursery stock is outplanted throughout the winter, whereas freezer storage is recommended for periods longer than 2 months, especially for high-elevation sites when outplanting may not occur until June or even later.

HANDLING AND SHIPPING

During handling and shipping, nursery stock may be exposed to many damaging stresses, including extreme temperatures, desiccation, mechanical injuries, and storage molds (Table 1). By far, desiccation is the most common stress encountered during harvesting, handling, and shipping, and can have a profound effect on survival and growth. Plant water potential influences every physiological process, and at stressful levels, can greatly reduce growth, even if survival is unaffected. These damaging effects can persist for several seasons after outplanting. Roots are the most vulnerable to desiccation because, unlike leaves and needles, they have no waxy coating or stomata to protect them from water loss. Fine root tips have greater moisture content than woody roots and are therefore most susceptible to desiccation. If fine roots appear dry, then they are probably already damaged although it is difficult to quantify the amount of injury in the field. When exposed for just 5 min, bareroot conifer seedlings exhibited increasing moisture loss with increasing air temperature and wind speed (Fancher et al., 1986). This shows the critical importance of keeping nursery plants cool, out of direct sunlight, and protected from drying winds.

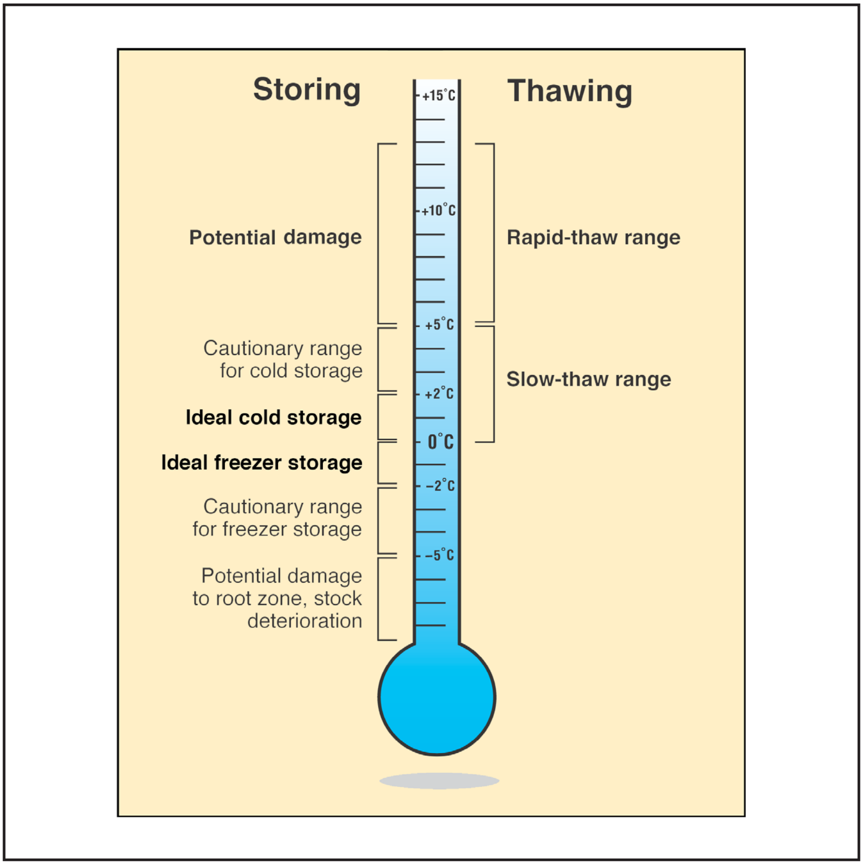

Figure 4. The actual temperature difference between cooler and freezer storage is minimal but those few degrees cooler make a tremendous difference in storage duration. Warmer temperatures are recommended for thawing frozen stock.

Because temperature affects all aspects of plant physiology, either hot or cold temperature extremes can quickly reduce the quality of nursery plants during handling and shipping. Besides increasing the risk of desiccation, high temperature exposure can increase the risk of storage molds such as *Botrytis cinerea*. Freezing temperatures can damage nursery stock. Because they are much less cold-hardy, roots are much more susceptible than shoots to freeze damage. Ambient and in-box temperatures should be monitored regularly; temperature monitoring equipment is now inexpensive and readily available. Freezing damage has even occurred in cooler storage during shipping because of equipment failure; unfortunately, this is relatively common, because refrigeration units on shipping vans are notoriously fickle and air circulation is restricted.

Boxes of nursery plants are handled many times from when they leave the nursery until the plants are finally outplanted. Rough handling can result in reduced plant performance after outplanting. Each person involved in the handling and shipping of nursery stock should receive training on how to minimize physical

Table 1. Nursery plants are subjected to a series of potential stresses from harvest to outplanting.

Process	Potential Levels of Stress			
	Temperature Extremes	Desiccation	Mechanical Injuries	Storage Molds
Nursery Storage	High	Low	Low	Medium
Handling	Medium	Medium	High	Low
Shipping	Medium	Medium	High	Medium
On-Site Storage	High	High	Low	High
Outplanting	High	High	High	Low

Levels of Stress: Low Medium High

stresses. The potential for physical damage to nursery stock can come from dropping, crushing, vibrating, or just rough handling. It is easy to forget that nursery plants are alive when they are in boxes. Studies have shown that the stress of dropping boxes of seedlings reduced root growth potential, decreased height growth, increased mortality, and increased fine-root electrolyte leakage. Stjernberg (1996) did a comprehensive evaluation of the physical stresses that nursery stock is subjected to during transport from the nursery to the outplanting site.

Shipping stock in refrigerated trucks is recommended whenever possible to maintain plant quality until outplanting. However, if open pickups must be used, then boxes of plants should be covered with a reflective tarp. Specially constructed Mylar® tarps with white outer and silver inner surfaces are available from reforestation supply companies (Fig. 5). In operational trials, plants under such tarps were as cool as those stored in the shade (Fig. 6). Dark-colored tarps, such as army-green canvas, allow plants to heat to damaging levels and should never be used (DeYoe et al., 1986).

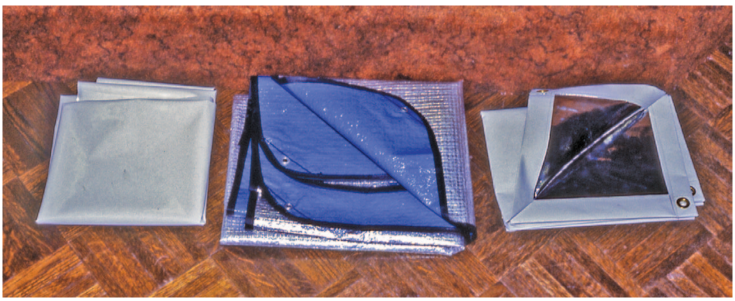

Figure 5. Special reflective tarps for covering nursery plants during delivery or during on-site storage are commercially available.

On-Site Storage. Nursery stock should be outplanted as soon as it arrives on the project site, but that is often operationally impossible. Weather delays, worker scheduling, and poor communication are just a few of the reasons why onsite storage may be necessary. The duration of onsite storage should last for only a few days, although, under unanticipated weather, such as heavy snow, it can reach a week or more. Therefore, it is always wise to plan ahead. Ideally, project managers should bring only as much stock as can be planted on a given day to avoid the need for onsite storage. Distance and other logistical factors, however, may make this difficult.

Overheating and desiccation are the major stresses that can occur during onsite storage. Because of significant differences in dormancy stage and hardiness, however, nursery stock for hot-planting must be treated differently from stock that comes from refrigerated storage. It is a good idea to conduct a thorough inspection of nursery stock when it arrives at the outplanting site. All boxes should be opened and checked for the following (Mitchell et al., 1990):

- In-box temperatures of refrigerated stock should be checked upon delivery and should be cool, no warmer than 2 to 4 °C (36 to 39 °F). Stock delivered in containers or hot-plant stock should be kept as cool as possible and out of direct sunlight.

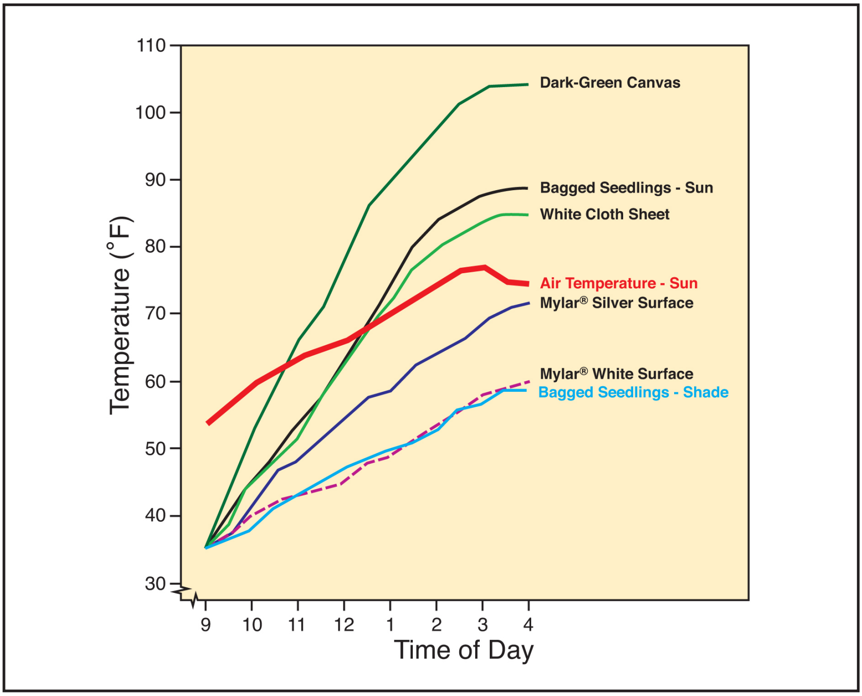

Figure 6. Research has shown that reflective Mylar® tarps provide much better insulation than standard green canvas ones (modified from (DeYoe et al., 1986).

- If possible, use a pressure chamber to check plant moisture stress of a sample of plants.
- Nursery stock should not smell sour or sweet, which is evidence that the stock has been too warm or excessively wet.
- Root plugs should be moist. If the plants have foliage, most often it should be a healthy green. For species with terminal buds, those buds should still be firm.
- Check the firmness of the bark around the root collar. The bark should not easily slough off and the tissue underneath should be creamy, not brown or black, which indicates frost injury.
- Spread the foliage to check for white or gray mycelia, which is evidence of storage molds, such as *Botrytis cinerea*. In particular, check foliage at the base of the crown. If mold is present, check the firmness of the tissue underneath. Soggy or water-soaked tissue indicates serious decay and those plants should be culled. Plants with superficial mycelia without corresponding decay should be planted immediately. Fungal molds will not survive after exposure to ambient conditions on the site.

SUMMARY

Overwinter storage should be developed to meet local climate, nursery stock type, and production factors. Storage of nursery stock becomes more important as the distance from the nursery to the outplanting sites increases, differences between climates at the nursery and field sites are great, and nurseries produce large quantities of plants requiring months to process. After a crop begins the process of leaving the storage area for the outplanting site, the financial and plant-quality risks peak because plants have reached their full economic value. Plants are living, perishable organisms and it is paramount to minimize stresses that can reduce their quality. The three primary types of stress that seedlings may encounter are moisture loss (desiccation), temperature extremes, and physical damage. Stock should be regularly monitored and handled gently to avoid exposure to stress. The effects of stress are cumulative — plants exposed to excessive stress may be dead at the time of outplanting or die shortly afterward. Unfortunately, the more common scenario is that the accumulation of stress causes a gradual and cumulative reduction in survival and growth that may or may not become apparent until weeks or months after outplanting.

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QUESTIONS AND ANSWERS

Todd Jones: I'm wondering about deciduous plants in plugs. How long can you hold them in a frozen state.

Tom Landis: It depends on the packaging. If they're in a moisture-proof polybag you can store them almost indefinitely. We store them 4–6 months in the freezer, but I wouldn't go any longer than that.

Steve Hottovy: Could you comment on how quickly you freeze the seedlings?

Tom Landis: It all depends on the plant's hardiness. The hardier the plant, the lower you can take it without damage. It's not so much the rate of freezing as it is the ultimate low temperature that's used.

Mark Krautmann: I probably speak for everyone here by thanking you for your lifetime of service.

Tom Landis: Thank you. It's nice to know it's appreciated.

Hot Water Treatments Are Effective and Disinfestants Are Ineffective in the Control of *Rhizoctonia* Infesting Stem Cuttings of 'Gumpo White' Azalea©

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Azalea web blight is an annual problem on some evergreen azalea cultivars grown in containerized nursery production in the southern and eastern United States. The disease is caused by binucleate *Rhizoctonia* species. From 5% to 20% of new shoot growth in the upper canopy of the plant can be colonized by Rhizoctonia during the spring when new growth is harvested for propagation. In our study, pathogen elimination was assessed using leafless stem pieces of *Rhododendron* 'Gumpo White' ('Gumpo White' azalea) that had been inoculated and colonized with an isolate of binucleate *Rhizoctonia* AG P. Potential tissue damage from hot water was assessed using leafy, terminal stem cuttings of 'Gumpo White' azalea. Disinfestants (sodium hypochlorite, hydrogen dioxide, and quaternary ammonium chloride) and fungicides (chlorothalonil plus thiophanate methyl, and flutolanil) did not eliminate *Rhizoctonia* from stem cuttings. However, *Rhizoctonia* was eliminated by submersing stems in 122 °F (50 °C) water for 21 min and in 131 °F (55 °C) water for 6 min. Minor leaf damage resulted from submersion of cuttings in 122 °F water for up to 40 min.

OBJECTIVE

Azalea web blight is a problem on some azalea cultivars during nursery propagation and production. We have discovered that spring shoot growth used for stem cutting propagation can harbor the pathogen, thus the pathogen is unsuspectingly propagated with the plant. The objective of this study was to evaluate and select disease control methods, including commercially available disinfestants and hot water treatments, which could potentially eliminate the pathogen from cuttings without damaging plant tissue.

MATERIALS AND METHODS

Pathogen control was assessed with 1.2-in. (3-cm) leafless stem pieces that had been inoculated and colonized with an isolate of binucleate *Rhizoctonia* AG P. When testing disinfestants, colonized stem pieces were fully submersed in the solution for 10 min. When testing fungicides, stem pieces were submersed in the solution for several seconds, and then allowed to air dry for 2 h. When testing the use of hot water, stem pieces were submersed for the specified time period (30 sec to 45 min). Treated stem pieces were placed on water agar to determine the percentage of recovery or absence of the pathogen.

Potential tissue damage from hot water was assessed using terminal cuttings of *Rhododendron* 'Gumpo White' that had green leaves. After submersion in hot water for the specified time period, cuttings were placed in a humid chamber for 24 h to allow visible expression of leaf tissue damage. Overall damage was calculated from the number of leaves expressing no, moderate, or severe leaf damage.

RESULTS AND DISCUSSION

Disinfestants (sodium hypochlorite, hydrogen dioxide, and quaternary ammonium chloride) and fungicides (chlorothalonil plus thiophanate methyl, and flutolanil) at their respective rates did not eliminate *Rhizoctonia* from stem cuttings. These results were surprising, but demonstrate the importance of experimental evaluations.

Rhizoctonia was eliminated by submersing stems in 122 °F (50 °C) water for 21 min and in 131 °F (55 °C) water for 6 min, but was not reduced by submersing stems in 113 °F (45 °C) water for up to 45 min. Minor leaf damage resulted from submersion of cuttings in 131 °F water for 6 min and in 122 °F water for up to 40 min. The level of tissue damage was judged to be low enough that rooting would not be negatively affected; this is currently being verified with further experiments. The margin of error in treatment duration between killing the pathogen and severely damaging plant tissue is narrower at 131 °F than at 122 °F. Severe leaf damage occurred when cuttings were submerged in 131 °F water for 14 min or in 135 °F for 30 sec.

Although hot water submersion is the only treatment to date that has effectively eliminated *Rhizoctonia* from azalea stem pieces, further studies with fungicides are planned. Based on results from bench-top studies, the application of fungicides to plants prior to collecting stem cuttings has shown some potential for preventing *Rhizoctonia* from growing upward onto the current season's shoot growth. Several fungicide timing patterns will be evaluated in field trials for this purpose. Additional laboratory studies are planned to determine if surfactants and/or application methods can improve chemical efficacy.

Table 1. Experiment number, treatment description, and type of tissue treated, and experimental results from a series of experiments examining efficacy of chemicals (disinfestants and fungicides) and hot water submersion (temperature and duration) for eliminating *Rhizoctonia* AG P from stem cuttings of 'Gumpo White' azalea. Stem pieces colonized with *Rhizoctonia* AG P were used to assess recovery of the fungus in response to chemical and hot water treatments, while terminal stem cuttings were used to assess leaf damage in response to hot water treatment.

Expt.	Chemical and hot water treatments	Tissue	Results
1	Sodium hypochlorite (household bleach) at 0, 3050, 6100**, 9150, or 12,200 ppm a.i. for 10 min;	Stem pieces colonized by *Rhizoctonia* for 7 days	Disinfestants were all ineffective against *Rhizoctonia*.
	Hydrogen dioxide (Zerotol; Biosafe Systems, Glastonbury, Connecticut) at 0, 1350, 2700*, 13,500, or 27,000 ppm a.i. for 10 min;		
	Quaternary ammonium chlorides (Green Shield; Whitmire Micro-Gen Research Laboratories, Inc., St. Louis, Missouri) at 0, 500, 1000*, 5000, or 10,000 ppm a.i. for 10 min.		
2	Chlorothalonil + thiophanate-methyl (Spectro 90; Cleary Chemical, Dayton, New Jersey) at 0, 431 + 108, 863 + 216*, or 1726 + 431 ppm a.i. for 3 to 4 sec;	Stem pieces colonized by *Rhizoctonia* for 7 days	Fungicides were all ineffective against *Rhizoctonia*.
	Flutolanil (Contrast; Scotts-Sierra Crop Protection Co., Marysville, Ohio) at 0, 157.5*, 315, or 630 ppm a.i. for 3 to 4 sec.		
3	Deionized water for 10 min (control);	Stem pieces colonized by *Rhizoctonia* for 3, 5, and 7 days	Disinfestants and fungicides were all ineffective against *Rhizoctonia*.
	Sodium hypochlorite at 12,200 ppm a.i. for 10 min;		
	Flutolanil at 315 ppm a.i. for 3 to 4 sec.		

Table 1. Continued.

4	Sodium hypochlorite at 0 or 12,200 ppm a.i. for 10 min; Sodium hypochlorite at 12,200 ppm a.i. + Surf-Ac 820 (Drexel Chemical Co., Memphis, Tennessee) 820 at 1920* ppm a.i. for 10 min; Hot water at 113 or 131°F for 5, 25, or 45 min.	1. Stem pieces colonized by *Rhizoctonia* for 7 days 2. Terminal stem cuttings (hot water only)	Sodium hypochlorite was ineffective against *Rhizoctonia.* Hot water at 113 °F was ineffective against *Rhizoctonia* at all durations. Hot water at 131 °F was completely effective in eliminating *Rhizoctonia* at all treatment durations. Minor leaf damage on cuttings occurred using hot water at 113 °F, while moderate to severe damage occurred at 131 °F. Leaf damage increased with increasing duration of exposure using hot water at 131 °F.
5	Hot water at 122 °F for 0, 1.5, 3, 4.5, 6, 7.5, 9, 10.5, 12, 15, 18, or 21 min; Hot water at 131 °F for 0, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5.5, 6.5, or 7.5 min;	Stem pieces colonized by *Rhizoctonia* for 7 days	*Rhizoctonia* was eliminated from azalea stem pieces with increasing duration of exposure to hot water at 122 °F and 131 °F.
	Hot water at 122 and 131 °F for 0, 1, 3, 5, 7, 9, 15, 20, 25, 30, 35, or 40 min.	Terminal stem cuttings	Minor leaf damage occurred with submersion of cuttings in 122 °F water, and that damage did not significantly increase over 40 min. Leaf damage increased with increasing duration of exposure to hot water at 131 °F.
6	Hot water at 126, 131, 136, 142, 147, 153, or 158 °F for 0, 30, and 60 sec.	(1) Stem pieces colonized by *Rhizoctonia* for 7 days; (2) Terminal stem cuttings	*Rhizoctonia* was eliminated from stem pieces with increasing water temperature when stem pieces were submerged for 30 sec and 60 sec. Leaf damage on cuttings increased with increasing water temperature when stem pieces were submersed for 30 sec and 60 sec.

**Commonly used rate.

*Registered label rate.

Rooting Rose Cuttings in Whole Pine Tree Substrates©

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Increased demand for alternatives to pine bark (PB) and peat moss (P) has led to extensive research on wood-based substrates, such as processed whole pine trees (WPT), for nursery and greenhouse crop production. Limited information is available on how WPT may perform as a rooting substrate for cutting propagation. Four substrates [WPT, WPT : P (1 : 1, v/v), PB, and PB : P (1 : 1, v/v)] were used to evaluate root development of single-node cuttings of *Rosa* 'Moorcap', Red Cascade™ climbing miniature rose. Cuttings rooted in WPT had the least total root length and total root volume, while cuttings rooted in PB : P exhibited the greatest total root length and total root volume. The addition of peat resulted in increased root development for WPT and PB, suggesting substrate physical properties may have a greater effect on root development compared to substrate chemical properties. Future analysis of substrate physical properties, together with substrate bioassays, will assist in the development of protocols for enhancing root development in WPT substrates.

OBJECTIVE

The objective of our experiment was to evaluate processed whole pine trees (WPT) as a rooting substrate for cutting propagation of *Rosa* 'Moorcap', Red Cascade™ climbing miniature rose. A number of experiments have been conducted to demonstrate the effectiveness of wood-based substrates for container production, while cutting propagation in such substrates has not been widely addressed. Demonstrating the versatility of WPT substrates is essential to expanding their commercial use and availability.

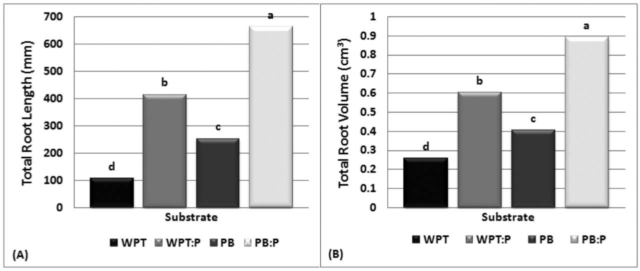

Figure 1. Total root length (A) and total root volume (B) of single-node *Rosa* 'Moorcap', Red Cascade™ climbing miniature rose cuttings rooted in 100% whole pine tree (WPT), (1 : 1, v/v) whole pine tree : peat (WPT : P), 100% pine bark (PB), and (1 : 1, v/v) pine bark : peat (PB : P) substrates. Means with different letters indicates significance at $\alpha = 0.05$.

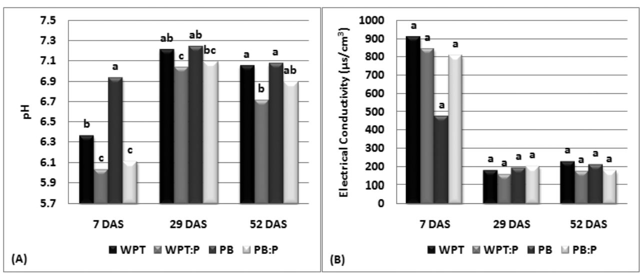

Figure 2. Substrate pH (A) and electrical conductivity (B) of fallow containers of substrate at 7, 29, and 52 days after sticking (DAS) cuttings. Substrates include 100% whole pine tree (WPT), (1 : 1, v/v) whole pine tree : peat (WPT : P), 100% pine bark (PB), and 1 : 1, (v/v) pine bark : peat (PB : P). Means with different letters for each DAS indicates significance at $\alpha = 0.05$.

MATERIALS AND METHODS

Root development on single-node *R.* 'Moorcap', Red Cascade™ climbing miniature rose cuttings was evaluated in four substrate [peat (P), pine bark (PB), and processed whole pine trees (WPT)] treatments [WPT, WPT : P (1 : 1, v/v), PB, and PB : P (1 : 1, v/v)]. The WPT (made from *Pinus taeda*) was processed with a hammer mill to pass through a 0.95-cm (0.375-in.) screen. Each substrate was amended with 1.07 $kg{\cdot}m^{-3}$ (4 lb/yd^3) Harrell's 16-6-12 (N-P-K) Plus 5-month formulation and 1.36 $kg{\cdot}m^{-3}$ (5 lb/yd^3) dolomitic limestone. Single-node cuttings of container-grown *R.* 'Moorcap', Red Cascade™ climbing miniature rose were prepared on 17 Apr. 2009. All cuttings received a 1-sec basal quick-dip in a 1000 ppm IBA solution (Dip'N Grow Lite, Dip'N Grow Inc., Clackamas, Oregon) and a single cutting was inserted into each container. Throughout the experiment, intermittent mist was maintained at 8 sec every 15 min from 8:00 am to 6:00 pm. Root development was evaluated at 60 days after sticking (DAS) cuttings. At that time, roots (if present) were washed and digitally scanned for analysis using WinRhizo software to obtain total root length and total root volume. Substrate pH and electrical conductivity (EC) were obtained from pour-through extractions performed on fallow containers of substrate at 7, 29, and 52 DAS.

RESULTS AND DISCUSSION

Cuttings rooted in WPT had the least total root length and total root volume among all treatments, but the addition of peat resulted in 75% and 57% greater total root length and volume, respectively (Figs. 1A and B). Similarly, the addition of peat to PB resulted in 62% and 56% greater total root length and volume, respectively, compared to PB. In a previous experiment, substrate physical properties (air space and container capacity) were significantly affected by the addition of peat and a correlation between root development and substrate physical properties was noted. Substrate physical properties will be analyzed for this experiment to determine if they had an effect on root development. Substrate pH was between 6.7 and 7.2 for all treatments at 29 and 52 DAS (Fig. 2A). Further investigations into physical and biochemical properties will be conducted to determine their effect on root development in WPT substrates.

Fig Mosaic Virus (Fmav) Elimination and Commercial Micropropagation in *Ficus carica* 'Sierra'©

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Fig (*Ficus carica* L.) ranks as one of the earliest domesticated plants by man. Fig mosaic disease is found wherever figs are grown. The symptoms appear as yellow, chlorotic patches or spots on leaves that can become deformed with various vein banding patterns and shapes resulting in defoliation, stunted growth, and fruit drop. While several viruses belonging to Closterovirus, Mosaic, Luteovirus, and Umbravirus groups were found in infected trees, the causal agent for fig mosaic still remains unknown. One most common sequence detected resembled in homology to European mountain ash ringspot associated virus (EMARAV) (Walia, 2009) and a name, fig mosaic associated virus (FMaV) was suggested for the disorder.

The University of California recently released a promising, dual purpose, hybrid fig cultivar, 'Sierra' in 2005 from their breeding program. However, it is also susceptible to FMaV. As part of our efforts to provide "clean" fruit tree and vine nursery stock to growers, studies were undertaken to eliminate viruses by combining conventional plant tissue culture procedures like shoot apical meristem culture and heat therapy.

The stem cuttings of 'Sierra' were procured from Kearney Agricultural Experiment Station of the University of California. They were grown under mist in the greenhouse.

Actively growing shoots were excised, surface sterilized, and explanted in vitro on a proprietary medium. Apical meristems from actively growing shoots were aseptically isolated under a microscope and transferred to the growth medium in test tubes. They were grown under normal culture room conditions (25±2 °C; 30 $\mu mol \cdot m^{-2} s^{-1}$ fluorescent light; 16 h day/8 h dark). When established, the actively multiplying cultures were subjected to high temperatures of 37 °C for 6 weeks. The surviving, disease-free shoots were mass multiplied, rooted, and acclimatized in the fog house and finished in pots in the greenhouse on benches.

The plant material was tested and selected for freedom from viruses after meristem culture and heat therapy, and before mass micropropagation. Thermotherapy alone did not kill all the viruses and there were a few "escapes" that tested positive for FMaV and later showed visible symptoms of the disease. However, when it was preceded by apical meristem culture, we could get "clean," healthy nursery stock that tested negative and showed no visible symptoms even after 9 months of growth in our facility.

Acknowledgements. Acknowledgements are due to Dr. Bryce Falk and Ms. Jeevan Jyot Walia, Department of Plant Pathology, University of California, Davis, for testing samples for fig mosaic associated viruses. Thanks are also due to Mr. Jim Doyle of Kearney Agricultural Experiment Station, University California Davis, for providing us the plant material.

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TECHNICAL SESSIONS

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How We Transition and Plan for the Future©

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INTRODUCTION

Weston Nurseries is a 4th generation nursery that has recently gone through a transition from being a majority grow/sell operation to a majority buy/sell operation of plants and garden related goods. Our transition was particularly complicated because two brothers who were 50/50 owners differed significantly in their business philosophy. Only after my father succeeded in buying out his brother could our transition really take place. This painful experience made it all the more essential to run the business profitably by transitioning away from much of the growing and become a sales-driven organization that buys and sells plants and related products.

OUR TRANSITION

Our company needed outside board of directors and an outside CEO to try and separate one brother away from the business and allow the other brother to purchase the other brother's share of the business. Despite the outside help, an agreement could not be reached amicably and we were forced to protect the business by taking the company into Chapter 11 bankruptcy protection. Through this process, we were able to acquire adequate funding to continue the business. When we emerged from bankruptcy, we were able to secure a term loan and an operating line of credit with our bank. We were also able to pay off creditors all money owed to them.

With one brother now owning the company, we were finally able to define a clear strategic objective for the company to become profitable and viable. In our case, the objective was to transition out of being a large grower and become a more customer-centric, market-focused organization. The growing we did was not profitable and we did not have the type of customer base to support a large growing operation.

It became obvious that the managers needed to operate the business, not the owners, if we were to succeed. The managers were very well equipped with the technical aspects of the business, but many did not have the skill set or the desire to work with other managers for the betterment of the company. Many years of disagreement between the two brothers on how to manage the business resulted in a culture where many of the long-term managers believed that knowledge was power and were unwilling to share and trust in others. The company had a management team that did not want to work with one another just like the owners could not work with one another. We needed to flip the equation the other way around where a good manager would now be defined as one who aligned with the company goals, worked cooperatively within the management team, and hired motivated people who wanted to help make the company better.

It was clear that we needed to reduce the amount of managers and put more attention to things that directly impacted our customers. A few business-minded managers were brought in while some of the long timers who were not on board with the new strategic goals of the company were let go, or decided to leave the company on their own. We managed to cut about 45% of our payroll over a 5-year period while restructuring the roles of our managers to take on more of the overhead parts of the business. The management team began to interact positively and cohesively, and changes began to take place:

- We became much more operationally efficient by doing things such as consolidating three separate plant collecting areas into one shipping yard within the sales area with the operations manager assuming the role of shipping manager.
- We combined the facilities manager and the garage manager position.
- We eliminated the harvesting/production manager position and put that responsibility on the operations manager.
- We sharply reduced our production staff by selling much of our in-ground and container grown stock at attractive grower prices to re-wholesalers and garden centers in the region.
- We held team member meetings monthly and shared how well we were doing with meeting our sales and cost savings goals. The company management and staff shared with how well we did.
- We put incentives in place with all three sales channels so that everyone could make more money if they or their departments sold more.
- We held many off-site meetings so that all managers were aligned and working in synch toward common company goals.
- We established systems that defined HOW we did things so that we could operate the company in a reliable manner and new hires could come on board with a clear understanding of how we do things in accordance with our company values.
- We achieved scale and capitalized on our brand by starting a second garden center that will open in spring 2011.

HOW WILL YOU TRANSITION YOUR BUSINESS?

The critical "takeaway" from our experience is that business ownership does not necessarily equate with competent management (leadership). Although it is possible for many owners to become effective leaders, leadership skills are independent of ownership. The nursery industry has traditionally assumed that owners must be the people who run the business — Weston Nurseries (and some other nurseries now) have discovered (often painfully) that these are two independent issues.

Owner Agreement. What I've learned is that you have to settle family matters or owner matters first, or the business will undoubtedly suffer. Owners must agree on financial and strategic objectives, and a set of values that make their company unique. They must also look at themselves as employees with specific roles in meeting the objectives.

Once owners have clear paths of where they want to go, they must also agree that they have to put personal preferences aside and do what is best for the business. Deciding on what is best for the company must be based on carefully analyzing where the business is making money, where it is not, your company's unique value proposition you provide to your customers, and ompetitive analysis now and in the future. Don't be afraid to poll your customers as well as your staff. Often times you will be surprised that this feedback is different than what you expected to hear.

Leadership Strategy. The leader of the company has to first commit to be accountable for meeting strategic objectives that are set. Leaders often have boards or peer groups that can be used to hold themselves accountable. The leader needs to commit to meeting with the group regularly and the group has to be engaged by asking questions, providing feedback, and holding the leader responsible for setting and measuring initiatives.

Well run companies are clear about who is in charge. If two people are in charge, it sends a confusing message to your reports. Reporters always need to know who they are reporting to and where the buck stops.

Once the owners have agreed on the strategic direction of the company and who will lead the charge, it is their job to make sure your company is filled with team players who are all in it for the good of the company.

Management Strategy. The biggest factor is assembling a good management team is trust among individuals. Good teams talk openly about what their own personal strengths and weaknesses in order to put themselves in the best position to help the company. Without this sense of trust, egos will get in the way and there will be a fear of healthy conflict resulting in "artificial harmony" among the team and a general lack of commitment and accountability. Without trust among your management team, the tough decisions are hard to make because people do not want to engage in constructive conflict necessary to make best decisions, or hold themselves and others accountable to carry out the decisions.

With a strong team in place, managers will set goals for their areas and operate the business. They will build trust among their staff and get bottom up input on how they will meet their goals. They will look forward to periodic meetings with the other managers to give updates, and talk about challenges and solutions. It is good to have these meetings off site without interruptions. A well run business should be able to get away from the day-to-day operations without too much worry because they have built up their staff to be committed, confident, and accountable for covering all areas. Specific action items will be reviewed and established at each meeting. Managers will not want to let down the team and will take their action items seriously. They will hold meetings with their teams, get their input on the best way to achieve goals, get buy-in from their staff, and expect to see results and behavior that meets objectives.

The leader's role is to prioritize the most important issues affecting the company and steer the manager's meetings. The leader should lead by example in that they praise often and make quick corrections when a manager is not in line with the best interest of the team. The leader should make sure the managers are doing the same with their staff. The leader should give constant feedback to the entire organization through team meetings or company newsletters. All managers and staff need to share in the success of meeting financial goals of the company. These could be quarterly sales goals, cost savings goals, or specific initiatives such as inventory accuracy improvements. Given the nature of the business, it may be beneficial to have department goals where the team, the individual, or the combination of each is rewarded if certain sales goals are met.

Systems Strategy. Well run businesses put systems in place that everybody clearly understands and operates within. When systems run the company, the knowledge is shared among many rather than confined to one person. This will allow the company to not miss a beat when someone leaves.

Systems tell employees "this is the way we do things." Employees can do great things when there are clear systems in place. New hires will become great employees quickly if they clearly understand what they will be doing and why they do their jobs a certain way. Employees like to be involved with a company that is clear on how they do things.

Customers buy from you because of the way they feel. Your company is your product. With people understanding the systems a company operates in, a consistent presentation is made to customers so they have a consistent experience with your company.

There should be systems for everything you do; how you clean your equipment, equipment repair, safety, hiring, job descriptions, performance reviews, pay scale, purchasing, selling, how you dress, how you greet customers, how you answer the phone, how you fill orders, how you handle plants, how you post availability, how you take inventory, etc. Systems should be documented in an operations manual by managers.

Once systems are created, your company can "franchise" itself by repeating what works in other locations. Without systems, the ability to grow is limited and experiences presented to employees and customers are inconsistent. Automate wherever you can, using the best technology available. Review systems often by involving your staff. They are not meant to be static and encouraging staff to find better ways to do things creates a positive, constructive culture that good employees want to be part of because they feel valued.

People Strategy. You want to create an environment that provides opportunities for people to advance and improve themselves. You should invest at least 1% of your sales in training. This will be the best investment you can make as you will retain more people who can do much more for your business versus the real cost of bringing on new people. Open positions should be offered internally first so that people have the opportunity to advance and the company can take advantage of the tribal knowledge that is inherent with existing staff.

Hiring is critical. The candidate must understand what the company is all about and decide and understand the idea behind the work they will do that makes your company special. This usually involves managers expressing this directly and being involved with assessing the candidate. Putting the candidate through a comprehensive hiring process demonstrates the type of company they will be affiliated with and gives the selection team a good view of how the candidate responds so they can make a better decision on whether or not to hire and the best position to place the candidate.

Managers have to be rated on how well they hire and train their people. They need to have the mindset that they will work themselves into a higher position by making great hires and training staff to take on more responsibility through better systems that they develop. As long as the company's strategic objectives are well known and include specific growth areas, managers will see a path for themselves.

All employees must have job descriptions and performance reviews at least once a year. Performance reviews should be directly linked to weighted areas of responsibilities clearly defined in their job descriptions. Performance reviews should also be tied to company values and provide feedback to as to how well they did their jobs with meeting the values of the company. For example, a sales person may have done a good job being aggressive with servicing customers, but may not have been dressed properly or may not have used great body language when greeting customers.

One of the hardest things for most managers is to act quickly when a staff member demonstrates poor behavior. Most times we wait too long to let people with poor attitudes go only to find out that the rest of the team wondered what took you so long. You are only as good as your worst employee. Hanging on too long brings the rest of the team down, while acting quickly keeps the best employees more supportive of their company because it remains true to its stated values.

CONCLUSION

It is important to focus the business on what you do best and try to be the best at what you do. The company brand represents the feeling your customers have when they think of you. Ownership should periodically step back and decide on who possesses the most aspiration and skills to lead the company. The leader needs to enforce the company brand through clearly defined strategic objectives, a set of company values, an aligned management team, open book communication with staff, systems for HOW you do things, rewarding of good performance, quick action on poor behavior, and a commitment to hold themselves and their management team accountable for making constant improvements to the business.

Production Planning for an Uncertain Future©

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At Klyn Nurseries we do not consider ourselves a specialty nursery, but a nursery that serves the landscape industry with special plants. We do not produce commodities but rather produce a diverse line of plants ranging from bog and marginals, bamboo, grasses, perennials, shrubs, and trees both in containers and in the field. Our goal has been to produce a high quality, broad-ranged inventory with smaller numbers of many items. We try to introduce people to unique plants and through this approach have developed a loyal customer base.

Over the years, this philosophy has worked well to grow our diversity as well as our customer base. As for so many others, business was great through 2007 when the bottom fell out of the economy. Like others we have experienced a reduction in sales but have developed a flexibility to respond to the needs of our customers.

Changing times and changing trends affected our bottom line as it has done to so many others. As an industry we have been affected by many factors beyond the economy. Charlie Hall was warning us that we were a maturing market and that a leveling off and even shrinking market was occurring. On top of this an increasing awareness of being "green" and invasives has complicated our future. We have always thought of ourselves as the "Green Industry" but today even concrete trucks advertise "Going Green."

Then there is the invasive issue. This movement started well before the economic downturn but continues to cause confusion within the industry, native area restoration people, and the general public. Today such plants as barberries and burning bush have come under attack in many areas. Plants that were commodity items that added profit to many nurseries bottom line were now outlawed or considered bad. Many people found themselves with plants that were always reliable sellers becoming difficult to sell regardless of the economy. Add to this invasive species like emerald ash borer, Asian long horned beetle, and viburnum leaf beetle that are attacking our plants and our bottom line.

Maintaining a diverse line of plant material is difficult, but it has proven to be our salvation. Like many of you we have ridden the highs of a good economy only to wake up one morning finding ourselves in a recession plagued with gluts in the market and falling prices. This one is unique in its depths and longevity and like nothing any of us have experienced before.

Staying the course has been something we have worked hard to maintain at our nursery. I think all of us are changing how we do business, but at the same time are we changing who we are and who our customers perceive us to be? There is no set answer to these questions and the answer will be different for different nurseries.

We are comfortable with who we are and have worked toward fine tuning our strengths and minimizing our weaknesses. A strength that has served us well is our philosophy of educating not only our staff but our customers and where possible, the gardening public about unique plants. Our catalog is perceived as much as a teaching tool as it is a pricing system. We spend a great deal of time educating our staff as well as encouraging tours, and lecturing to the industry, garden designers, landscape architects, and master gardeners about plants and their proper usage. Selling through education helps us listen to our clientele as well as getting an inclination of the next changing trend in plants.

Our product diversity has been our greatest success as well as our greatest struggle. We have chosen to focus on the unique and what we feel are plants that meet the current trends. Being optimistic we have looked at issues such as invasiveness and realized that growing natives has become an opportunity. As urban foresters struggle with emerald ash borer and other invasive pests, a rising awareness has shown a need for diversity in the urban forest. Though we still grow a few *Acer platanoides* cultivars in minimal numbers we have greatly increased our production of native trees and species that have not been widely used, always looking for the best cultivar or seed source.

Often these trees are not easy to find on the open market or we are not satisfied with what is available to us. We have always propagated the majority of the plants we grow; we feel it has become even more important to us now. It has helped us differentiate ourselves by being able to offer a diverse line.

Seed production is important for controlling consistent sources of many plants. For example, through observation we have selected a hardy strain of *Koelreuteria paniculata* that we first observed for cold hardiness during the brutally cold winters of the late 1970s. Not only are these trees very cold hardy, but produce straight trees much easier than many other seed sources. Through careful observation and seed selection we have been able to improve the quality of certain species. Years ago I purchased seedlings of *Sorbus alnifolia*. After spending several years growing these trees to saleable caliper size most were discarded because of inferior quality. We selected seed from the best plants in the group and improved the quality of the plants we were growing. By the third generation of seed produced trees we had what we were looking for with crops of consistent high quality plants with a superior form.

The call for natives also had us looking at local hardy seed sources of several species. Some were readily available in the market place but we saw the opportunity to produce trees and other plants from known seed sources. *Aesculus glabra* are native on many of the flood plains of local streams and rivers. This is a tree that may get positive or negative response from people. If you talk to some, you hear that it is susceptible to guignardia leaf blotch. Through observation and selection we find that we can produce consistent crops of clean-foliaged trees that are free of leaf blight. On further observation we find variability in fall color and continue to select our seed trees for disease resistance and better fall color than the norm.

We also use softwood cuttings to propagate a wide range of plants. Working with some of the original plants distributed from the National Arboretum we were able to increase our elm production on *Ulmus americana* 'Valley Forge' and offer caliper plants at a time when this plant was new and in short supply.

Through our potted tree liner program we can raise the rooted cutting to an 8 ft whip ready for fall field planting in a single season. The potted tree liner program also allows us to grow otherwise difficult species such as tap-rooted plants like *Nyssa* and *Carya* that insure successful movement and transplanting of these otherwise difficult species.

Root cuttings are yet another way that we can produce certain species that have proven difficult by other means. *Rhus copallina* 'Lanham's Purple' and

R. javanica var. *chinensis* 'September Beauty' are two examples of plants that are best propagated by root cuttings.

In winter we maximize our propagating facility by using one of our greenhouses to produce a range of grafted plants many of which would be difficult to find or costly as purchased liners. Another benefit is enabling us to keep important employees on staff giving them something to do in the winter that adds positively to the bottom line.

We also produce many plants from hardwood cuttings including *Taxus*, *Thuja*, *Juniperus*, *Chamaecyparis*, *Buxus*, and *Ilex*. This helps control costs of purchased liners and spread the work load and pressure on valuable propagating space enabling us to propagate 12 months a year.

Without proper management and inventory control it would be very easy to over produce in any market let alone the trying times we are experiencing. When times were good it was easy to produce more than last year because the market could accept them. Today we must face the reality of costs and reduced sales. As we plan our liner production or liner purchases we look at sales over the last 5 years and assess each plant considering the length of production cycle, current trends, and availability in the market place. We look at what plants are being produced in great numbers by other nurseries and, rather than enter the fray of commodity and price, we choose to focus on new trends and specialty plants that tend to hold their price because of reduced availability in the market place. This niche marketing has helped us weather the storm through these difficult times.

No matter what you produce, it is imperative that you understand your market and keep a focus on your buyers. As we plan for the next several years we foresee shortages especially of field crops. On the other hand container crops have a shorter cycle. We are being conservative in planning container production but have worked hard to keep our field planting at a somewhat more consistent planting cycle. In a few years there will likely be a shortage of caliper shade trees. If you are a tree producer will you be ready? If you are a container producer it will be far easier to increase quickly and keep up with a recovering economy. Will we learn from these times or will we overplant once again?

I once saw a plaque that read "If you think you can or you think you can't. You're right!"

From Genesis to Revelations: A Review of New Plants From Great Britain and Beyond©

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This paper will discuss some of the new plants that are becoming available both in the United Kingdom and around the globe and plans to examine some of the reasons behind the success of these new plants. In the context of this paper the work of the plant breeder in collaboration with the grower might be considered the start point (the genesis) of this process of introducing new and exciting and often improved plants, while the end point is the work undertaken by the garden centres who "reveal" the work of the breeder to a wider audience.

In offering an invitation to speak at the Eastern Region conference I imagine there may have been an expectation on behalf of the conference organisers that I would be able to enthral Eastern Region members with a series of stunning photographs of new magnolia, coprosma, and skimmia cultivars, all of which do exist. However the international trade in ornamental plants is driven most often by the ability of an individual to maximise royalty returns and for the grower to gain the greatest profit margins. This has led to breeders and growers bringing a very particular plant type to the market place. Garden centre plant material will be the main focus of attention within this paper and these retail outlets fill their shelves with two types of plants: A–Z and the promotional ranges. Plant breeders more and more focus on securing the promotional slot within the nursery catalogue to ensure far greater volume sales. In the U.K. a Garden Centre may order five *Cornus alba* 'Elegantissima' to top up the A–Z bench, while at the same time ordering the latest new herbaceous perennial promotion by the Danish trolley load. No prizes for guessing which plant will make the most money all the way along the supply chain.

Before looking more closely at what I consider to be the main reasons behind successful new plant introductions I would like briefly to explore the significance in today's world of what have often been considered the trend setters within our industry. Let's start with gardening writers, are they currently doing much more than commentating on what is already happening within our industry? One of the greatest garden writers and gardeners of the twentieth century, here in the U.K., was a gentleman by the name of Christopher Lloyd. He spent much of his time chronicling his gardening experiments at his home Great Dixter in East Sussex (Fig. 1).

I think it is true to say that he influenced a certain style of gardening which may have increased the sales of both herbaceous perennials and more recently garden exotics but very few of the plants that he either used in his garden or wrote about in books and magazines were the stuff of plant promotions. One notable exception is the plant *Ranunculus ficaria* 'Brazen Hussy', which he found growing within his woodland. This is now a lesser celandine of international reputation and is a promotable plant. With any new introduction it is always good to get the garden writer and the full range of gardening media on side, but it is no longer considered an essential as the media has become much more fragmented, and consequently it is more difficult to be certain of where the gardening public is tuning in.

Figure 1. Great Dixter home to Christopher Lloyd.

Has the gardening charity, the Royal Horticultural Society (RHS), had a significant impact in the field of new plant introductions? Clearly an organisation that got started in 1804 has had a major influence on the way in which people in Britain garden, but less so recently, and this probably explains why it is currently playing catch-up, with the new Director General Sue Biggs seeing her main priority as making the RHS more "approachable and accessible." During my time working for the RHS I was responsible for the growing of many trial plants which were assessed for the Award of Garden Merit. (AGM). These trials often reflected current plant fashions and the decision to assess specific genera more often than not, was based on the amount of new breeding happening within them. Rarely, during the more than 10 years that I was directly involved with the trials, did the award of an AGM lead to that plant being commercialised or widely promoted. The plant trials at RHS Garden Wisley often produced an excellent visual spectacle, but were fraught with difficulties, if attempting to deliver an objective assessment. This subject could take up a complete paper of its own and so I will only provide a couple of examples which are always mentioned when criticising the trials. The trials relate to how they grow at Wisley only, and surely the AGM applies to the clone being trialled and therefore this plant would need to be bulked up and distributed to the trade to maintain the integrity of the award.

Having discussed all the above it is still better for the industry as a whole to have plants being trialled and written about as your new plant may be the one that gets an AGM, is written up in the Guardian on Saturday, or has fifteen seconds of fame on the BBC coverage of the Chelsea flower show.

So what is really influencing plant breeding? Most of the new breeding programmes focus on the development of herbaceous perennials that flower over a long period, but come into flower bud early — having just grown out to the edge of the container, but not extended upwards beyond 30 cm. There are very few shrubs that can meet this specification and so at a stroke most shrubs rule themselves out from the promotable plant category. Plants with interesting colour foliage and texture may creep into the promotable plant category, currently most obviously would be the genus heuchera.

There are different reasons why the grower, the garden centre, and the gardener like compact plants but all stem from ease of handling. The preferred pot size for many of the UK's leading suppliers is the 2 L (17 cm), as in the case of heuchera, it will fill the pot within 10 weeks during the summer months, providing a great autumn patio offer from August through to Christmas. This smaller pot size reduces transport costs, as a "reasonable" number of plants fit on each layer of a Danish trolley (4×6 unit marketing trays) and also ensures that a minimum of 96 plants fit onto a single trolley. The Danish trolley is the number one method of transporting plant material across Europe. The ease with which plant promotions can be delivered to the garden centre has led to them stocking many more promotions, which when placed on hot spot benches, complete with a marketing board and attractive colour labels, sell quickly and in far larger numbers than traditional A–Z lines. A garden centre may purchase a seasonal promotion by the trolley load as compared to five of six plants within an A–Z range.

Before moving on from the added value of promotions to the grower, the trick with any new plant is to match it up with others from the same genus to create a collection. Current hot examples within the U.K. include phlox flame, geum, heuchera, sedum, and scabiosa. Collections work best when the plants have very similar growth patterns, as nothing is more frustrating than having the bulk of a collection ready when, one or two cultivars are not quite to size. In the promotion's game the grower only gets one or two chances to deliver large volumes to a customer before the next promotion is set to roll in.

So the skill of the plant's person is still paramount and trialling new selections is not simply about assessing the performance of individual plants, it is also important to compare its performance against those plants within existing collections. Fine tuning will take place each year. As an example *Heuchera* 'Jade Gloss' has been growing well for the last couple of years but is just that little bit slower than other heuchera in our collection ('Obsidian', 'Mahogany', 'Paris', and 'Plum Royale'). Following assessment 'Silver Scrolls' will take its place and should be a much better match. Are there too many heuchera? Well yes of course, however we are still searching for a lime green or yellow that is not prone to badly scorched foliage, to fit into our collection. Our experience of growing *Heuchera* 'Amber Waves'; 'Tnheu042', Dolce Series Key Lime Pie™ alum root; Rainow Series 'Lime Rickey', and ×*Heucherella* 'Alabama Sunrise' is that they all scorch easily.

A promotion provides the Garden Centre with a quality product, which has good shelf life as its size will less likely lead to drying out or blowing over. Compact, well branched plants full of flower and bud always sell first and fast. This will lead to much quicker bench turnaround and restocking and so increased turnover and profits should follow.

The U.K. gardener likes small attractive plants as many live in properties with small or no gardens and as a result looks to take home impulse purchases that make their way into a flower box, seasonal tub, or the front of a border.

Figure 2. *Geum* 'Totally Tangerine', a recent introduction by Tim Crowther of Walberton Nursery.

ARE THERE ANY PROMOTABLE SHRUBS?

For a shrub to become a sales success it needs to have a number of promotable qualities which will allow it to go beyond the A–Z bench and be recognised as no longer only just a shrub, but a garden centre product with multiple uses. In effect it needs to perform like an herbaceous perennial!

In the U.K. very few shrubs have succeeded in achieving star status. So few in fact I can probably name them all, *Photinia* ×*fraseri* 'Red Robin', *Sambuscus nigra* f. *porphyrophylla* 'Black Beauty' and now 'Black Lace', *Choisya ternata* 'Lich', Sundance™ Mexican orange, and *Spiraea japonica* 'Walbuma', Magic Carpet® Japanese spirea. These are all great plants, not in every case exceptional, but have made it for a number of reasons. First they all look great as a container plant and have in most cases more than one season of interest. Crucially all have names that are instantly recognisable, and the gardening public can associate these names with other things that they already perceive positively. A red robin is loved by all and the Sundance kid is admired and glamorised by all, and no other horse in children's literature is more popular than Black Beauty. So a good name is essential.

Why has the excellent shrub *S. japonica* 'Genpei' (syn. 'Shirobana') not taken its place alongside 'Magic Carpet'? Most probably because it has a green leaves and not foliage that turns from red, through gold to yellow. It has a less compact habit, and a far less snappy name. Success with both a shrub and perennial is dependent on its season of most impact, so a shrub like 'Magic Carpet', that comes into bright red bud in March and continues to change colour throughout the spring and flowers in May and June is always going to more successfully attract the customer's eye than a plant that performs in the height of summer when footfall is dramatically reduced. Little chance then of success for the breeder who is working on new hibiscus, caryopteris, crocosmia, or perhaps lobelia taxa. There are a number of new *Caryopteris* selections being released, all appear to be improvements on existing cultivars, but 'Jason', Sunshine Blue™ bluebeard; 'Lisaura', Hint of Gold™ bluebeard; or 'Lissilv', Sterling Silver® bluebeard are unlikely to sell in large quantities as they are perceived as being more shrub-like than herbaceous, and they flower when customers are less interested in gardening and more interested in summer holidays.

ARE THERE ANY NEW EXCEPTIONS TO THE RULES?

Promotable shrubs are few and far between but if you are able to make a success of the genus *Daphne* then good sales numbers will follow. At Walberton Nursery our objective is to develop good relationships with plant breeders with a view to developing new plants. This process has probably been made easier as we are a nursery with a significant track record in this department as our owner is the plant breeder David Tristram and our general manager Tim Crowther has also introduced a number of plants into the market place. Two of Tim's most recent introductions are *Geum* 'Totally Tangerine' (Fig. 2) and *Yucca gloriosa* 'Bright Star'. In the U.K. Robin White of Blackthorn Nurseries has done some of the best daphne breeding and we are currently building up stock of *Daphne* ×*transatlantica* 'Blafra', Eternal Fragrance™ summer daphne and the deeper pink sport, 'Pink Fragrance' (Fig. 3).

I am sure that had we not shown the right kind of interest in making Robin's plants a commercial success he would be far less likely to pay our nursery regular visits with some of his latest breeding. These two daphne taxa have the magical quality of compactness and so transcend the shrub category, are in almost constant flower from spring to autumn, and are heavily scented. Daphne still has that star quality in the mind of the British public which allows us to add several pounds onto its wholesale price. A plant well worth promoting if you are able to grow it successfully!

The aforementioned *Y. gloriosa* 'Bright Star' lives up to its name, but only outside of the U.K. Despite this plant having been bred on our own nursery, Farplants who are our sales and marketing team have yet to show any interest, but in Europe and North America it is being micropropagated in the hundreds of thousands. The plant has strong yellow and green variegation, a deep red winter hue, and large white flower spikes which are produced on young plants.

IT DOESN'T ALWAYS NEED TO BE BRAND NEW

Often, as long as it is new to your catalogue it is sufficient to encourage the garden centre buyer to take a look at your latest offer. This happened recently for us with the flowering shrub *Desmodium elegans*. This is a plant that is easy to propagate and within weeks will nicely fill a 2-L pot ahead of winter. The following spring its first flush of new growth includes masses of purple panicles. While in the garden this shrub may become a little straggly without careful pruning, grown on a short time frame and sold in early spring it becomes the perfect promotable plant. The key is to have a great sales and marketing team who sell your offer not simply as *Desmodium elegans*. If we sold this as an A–Z shrub we would be lucky to shift a

Figure 3. *Daphne ×transatlantica* 'Pink Fragrance', a new introduction from Robin White of Blackthorn Nurseries.

couple of hundred plants each year but by elevating it to a specific time of year and placing it into a promotions catalogue we will sell ten, twenty , thirty times the amount. The price tag is not high but neither do we have to pay a plant breeder royalties. We are always on the lookout for this type of opportunity.

SO WHAT MAKES A PLANT PROMOTABLE?

To conclude I feel that it is a combination of factors that is driving new plant introductions forward. Yes good media coverage will help to lift sales but will not make or break a new plant introduction and it is much more down to providing a plant with a strong instantly recognisable name. A new plant needs to fit the criteria of having its main focus of interest at a time that the public are interested in buying plants, and more often than not these plants must have a pot size no greater that 2 L.

Below in Table 1 is a list of plants featured within the presentation many of which are available through Plant Haven <www.planthaven.com> in the U.S.A. and Plants for Europe <www.plantsforeurope.com> within the U.K. and mainland Europe.

Figure 4. *Scabiosa* 'Butterfly Blue', one of the best promotion plants.

Table 1. Plants featured in this presentation.

Caryopteris incana 'Sunshine Blue'
Choisya ternata 'Lich', Sundance™ Mexican orange
Crocosmia ×*crocosmiiflora* 'Miss Scarlet'
Daphne ×*transatlantica* 'Blafra', Eternal Fragrance™ summer daphne
Daphne ×*transatlantica* 'Pink Fragrance'
Desmodium elegans
Erysimum 'Walfrastar' PP13,432 Fragrant Star
Euphorbia ×*martinii* 'Rudolph'
Geum 'Totally Tangerine'
Helleborus 'Walberton's Rosemary'
Heuchera Rainbow Series 'Lime Rickey'
Leucanthemum 'Real Galaxy'
Rhododendron 'Sunny'
Rhododendron jasminiflorum
Scabiosa columbaria 'Butterfly Blue' (Fig. 4)
Scabiosa 'Pink Mist'
Spiraea japonica 'Walbuma' PBR, Magic Carpet® Japanese spirea
Spiraea japonica 'Genpei' (syn. 'Shirobana')
Yucca gloriosa 'Bright Star'

Lean Flow in the Green Industry©

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LEAN FLOW

Lean Flow is a business strategy that has been around for decades, dating back to Henry Ford and the Ford Motor Company. The Japanese took Ford's concept improved it and added some key words like "Kanban," "Kaizen," and others that are now common words in Lean Flow. In recent years Lean Flow has become a buzz word in the green industry.

Typical Savings for Growers.

- Increased productivity: 15%–30% improvement.
- Optimized floor space: 3000 ft^2–10,000 ft^2.
- Increased growing space turns: double the turns in the same space.
- Reduced shrink: up to 50% reduction.
- Improved sell-through: as high as 95%.
- Improved quality: fewer credits.

LEAN FLOW IN THE GREEN INDUSTRY

When implementing Lean Flow in your facility, you have to ask yourself, "where is my cost the highest?" In most cases, the greatest costs are in labor. So the focus is to improve productivity, but how can you improve it — old-school says push your employees harder and make them work faster. Lean Flow says focus on non-value-added activities and eliminate them. As you observe your operations, have you ever noticed the following?

- You have employees pre-labeling flats or pots, or pre-building boxes.
- You pre-fill flats, put them on a cart and then move them to the greenhouse to so they can later be used for sticking.
- You pull orders 2 days in advance, or in some cases 1 week ahead of when they are going to ship, so you can inspect them, grade them, or do whatever you think is necessary to make them look good.
- A large crew bulk-pulls the day's product to be shipped, while a smaller crew prepares shipping racks laid out by truck load. As all bulk-pull products are brought to shipping near the end of the day, the entire crew hastily off-loads bulk products to multiple shipping racks in multiple locations, in a short and tight time frame, and trucks cannot be loaded until the last bulk pull has been off-loaded to shipping racks.

These are classic symptoms of doing work in a batch methodology. With Lean Flow, the goal is to flow product one piece at a time whenever possible. By producing in batches, costly extra touches are added that may impact the quality of the product, you have more inventory, you require more space to put the inventory, and in the end your productivity is lower.

LEAN FLOW IN THE PRODUCTION AREA

The goal of Lean Flow in the production area is to keep your people sticking, planting, or seeding more minutes and seconds of the day — not to make them do it faster. In many facilities, growers have employees sticking or planting on a belt conveyor, because the grower thinks that the conveyor makes the employees work faster. They may work faster on a conveyor, but are they more productive? Also, how is the quality of the work they are doing? Have you ever watched the *I Love Lucy* show where Lucy and Ethel are working in a chocolate factory, packing chocolate bon-bons on a belt conveyor? The belt speed is too fast; they can't keep up with the speed of the belt conveyor and are not packing the chocolates correctly. This is what your employees look like. When this occurs the quality of the product is compromised. Spend 10 min observing your employees on the belt and you will think of Lucy and Ethel.

The other problem with employees working on a paced belt conveyor is that they are less productive — contrary to intuition. You will notice that a portion of your employees are always waiting for product to come to them. The reason this occurs is because it is impossible to balance the work of employees when the product is moving.

With Lean Flow, we take the belts out and have the employees work on a stationary surface where the product moves only when the employee moves it. The line is set up as a Progressive Sticking™ or Progressive Planting™ line. Let's say that your employees are sticking cuttings into a 72-cell tray. Instead of having one employee stick the entire tray, have three employees each stick about 1/3 of the tray (24 cells). Set up the workstations like an assembly line, you will be surprised how more relaxed your people are working, and how much more they will produce with much better quality.

There is one more person you need to have on the line, the material handler. The role of this person is to keep the stickers sticking more seconds and minutes of every day, by making sure they have cuttings, tags, filled trays, root hormone, etc. The Material handler is considered the non-value-added person on the line; yet his coordinated efforts ensure that the value-added people (stickers, planters, and seeders) are constantly working, not waiting for material.

The other key to improving the productivity on this line is to make sure that the changeovers are transparent. When you change from one tray size to another, change plant material or change soil, the line should not stop. To put it in perspective: if you have 12 people on the line and you have 10 changeovers a day that each take 3 min (stickers not sticking), by the end of the day you have accumulated 360 min of idle time. How long does it take to stick a cutting—perhaps 5 sec? The 360 min equals 4,320 cells, or sixty 72-cell trays. This is how we improve productivity—by eliminating waste, not by making people work faster.

Typical productivity improvement that you should see is anywhere from 15% to 35%. One grower who implemented Progressive Sticking™ got a 6-to-1 payback in the first season of running the lines. Another grower who was sticking in the greenhouses went to progressive sticking and realized a 33% productivity improvement.

LEAN FLOW IN THE SHIPPING AND PACKING AREA

The goal of Lean Flow in the shipping area is to improve the response time to the customer, productivity, and the product quality. In the shipping area, a "supermarket" is set up. A supermarket is a physical location where product is staged, typically a third of a day to a day's worth. The amount depends on the physical space available and how long the product can stay in the supermarket without affecting the quality. A crew of people pulls product from the greenhouses, ranges, and fields to the supermarket.

As one crew is pulling material, another crew is picking product from the supermarket to fulfill customer orders. With the supermarket you have product flowing into the supermarket and product flowing out at a steady rate.

By having material in the supermarket first thing in the morning, the order-picking crew can immediately begin fulfilling customer orders. Within the first 30 to 45 min, a truck should be loaded and ready to go. Having the ability to load trucks first thing in the morning allows you to load trucks throughout the day. By the end of the day (9–10 h), all the trucks should be loaded and your employees are ready to go home. Currently, during peak weeks, you are probably working countless hours of overtime, yet with a supermarket in place, the peak weeks don't feel like peak weeks.

A grower in Michigan that sets up a supermarket did not work any overtime during their peak weeks in spring. This was the first time in the company's history that they did not have to work overtime. Another grower was able to improve productivity 30% the first year and 12% the year after, simply by setting up a supermarket in the shipping area.

The two techniques described above are just two specific applications for growers. The same Lean principles that are implemented in production and shipping are also implemented in the office processes.

Lean Experience at Van Belle Nursery©

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INTRODUCTION

Doesn't matter the size of your company, anyone can implement lean flow if they have a desire to improve their company. Lean flow is the desire to eliminate waste from all processes. Waste can take the following forms:

- Overproduction
- Waiting
- Unnecessary transport or conveyance
- Over-processing/incorrect processing/re-work
- Excess inventory
- Unnecessary movement
- Defects
- Unused employee creativity

One problem with going on a lean flow journey is that you are never "there" — there is always room for improvement.

A principle of lean flow is people empowerment — making information visible. If you have staff that will resist this, and you aren't willing to champion lean flow, it will fail.

VAN BELLE NURSERY LEAN PROJECTS

1) Propagation of liners
2) Shipping of liners
3) Shipping of containers
4) Just in time production of custom tags

In each case, we analyzed the data, made the calculations necessary to determine our ideal takt time, and then designed the layout. Generally speaking, each lean implementation has resulted in:

- Significant labor savings
- Better transparency of daily results
- Greater consistency of process
- Greater employee involvement/empowerment
- Cost savings

Using a professional such as Gary Cortés from Flowvision.com has been instrumental to our success.

PROPAGATION PROCESS

Our propagation process before lean was disjointed. For example, flats were prefilled ahead of use. The process was also unpredictable, for example, we didn't know how many people to assign to the cutting and sticking processes. It was always a bit of a gut feel, based on a hunch, and then we just did it. We also didn't know the productivity per hour we were getting. And many companies know these numbers, but what often happens is that they don't know the waste involved in the actual process. So, they know they are doing X/hour, but don't know that it could be increased through utilizing lean principles. In our case, we looked at the entire process from start to finish, and identified all the areas of waste. Waste is anything that doesn't contribute value to the product or process. Some are obvious, such as extra materials handling. Some forms of waste are not obvious. One example is the amount of time a given unit has to wait before being worked on. In our case, we were taking cuttings, storing them in the fridge, and then sticking the following day. The time between the cutting and sticking represents waste; in this case it was 24 h. After we identified the areas of waste, we worked to eliminate them. Using math, you can prioritize which areas to eliminate first, starting with the areas of greatest return. Our results were dramatic. We think we achieved a 30% increase in productivity. We also reduced the square feet needed to achieve this by over 66%. Additionally, we now have a very good idea of how many staff to put on the line each day, and using the flow rate boards, can tell if we are meeting our targets on an hourly basis. One further example, our cuttings are now stuck within 2 or 3 h maximum from when they were cut. This improved our rooting percentages, our cutting accuracy, and eliminated two fridges for overnight storage. As an added benefit, our people are more self-managed, making for a happier workforce. Using a qualified experienced lean instructor, such as the ones from Flowvision.com, has been very beneficial to us.

Ten Basic Principles for Improved Nursery Performance

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INTRODUCTION

I have been involved with commercial horticulture all my life and I am well aware that there have always been cycles of varying prosperity for commercial growers. I am around the same age as IPPS and it is noticeable that in the early years of our society the focus of meetings was mainly on improved techniques for propagating and growing plants. Improved methods generated better plants more efficiently and improved the profitability of growers.

However it is noticeable that despite the increase in knowledge there are some nurseries that prospered and some that did not. Conference organisers obviously made the same observation and adapted their subject matter accordingly. The subjects covered in later years show the recognition of the increasing importance of mechanisation, marketing, and business skills.

My period of service on the International Board has enabled me to see, and compare a wide range of management techniques in most of our member regions. That period has coincided with a period of changing global economy and difficult trading conditions for most growers. It has been interesting comparing the strategies that have been adopted to maintain viability and build for the future. My impression is that there are no quick fixes, rather a series of basic principles that are common to successful growers worldwide.

FORWARD PLANNING

Most places make an effort to tidy up for visitors, but there are some nurseries that stand out from the crowd, because their whole enterprise and culture is logical. It is obvious that a great deal of thought has gone into what they do and how they do it.

Anything and everything that can be planned has been planned. With greater demands for uniformity of product it is important to have a nursery layout that provides uniform growing conditions when needed. Production plans have been integrated with sales demands and the pressures of short notice despatch requirements. Batch potting has been used to reduce travelling between cultivars at harvest time and to give a longer sales period. Bed dimensions facilitate ease of mechanised trimming, counting, spraying, and spray calculations. A skilled workforce is a very valuable asset so time has been spent planning how best to use their skills and maintain their job satisfaction.

FOCUS ON QUALITY

Everyone claims to be a quality producer, but who is the judge. There are many definitions of quality, but to me the simplest, yet deepest definition is the following workplace sign that I spotted on a nursery several years ago. “Quality is a smiling customer.”

Discerning customers, who buy on quality, will be more loyal than those who are always seeking lower prices. Those customers recognise that there is more profit, and less waste, to be had by paying a little extra for quality plants.

The nurseries that stand out to me are the ones that have identified their target market and planned a production system to meet the requirements of that market. Total quality regimes encompass all elements of the business, not just the final grading process. Nurseries that focus on high standards in propagation and young plant stages benefit from less waste at the later more expensive stages of plant growth. Well-trimmed, well-branched young plants reduce inputs to the final pot stage.

Having grown good plants it is important to follow this through with good presentation and service. Anything that helps the retailer sell plants faster will keep their customer smiling.

RECORD KEEPING

Traceability is vital to plant production. Whether we are trying to repeat successes or solve problems it is important to have accurate records of all factors involved in the growing process. Whilst we cannot control all the things that nature sends our way it is useful to be able to identify what the optimum growing conditions are so that we can do our best to provide these conditions and avoid threats. Improvements need a base point to measure from. I have observed that much of the information that was once kept in closely guarded notebooks is now displayed on notice boards near to the work area. Computerisation allows much easier recording, sorting of information, and presentation of results. Statistical process control has been imported from car factories to potting sheds and improved our problem solving capabilities.

STAFF INVOLVEMENT

The most noticeable factor that is common to the best nurseries worldwide is the enthusiasm of the employees. The owners have recognised the wealth of knowledge accumulated by key staff and involved them in planning nursery improvements. They have shared in the ownership of the resulting success and a really good team spirit has evolved. When the operators have been involved in the planning process the new systems will meet with less resistance and have a greater chance of success than if they are imposed on staff by top management.

CUSTOMER INVOLVEMENT

Some growers visit customers regularly, others invite customers to visit the nursery. The key factor is to encourage discussion and react to the feedback that clients provide. Retailers have more contact with the eventual consumer and will also have experience of which other products sell well. Garden designers have influence on trends and can help forecast future demands. Customers are encouraged to provide suggestions of plants that they would like but cannot obtain normally. If the challenge is to make your customers smile, it can be extended to include internal customers. Often there are departments within a nursery who supply each other. The best nurseries enable them to communicate their needs and compliment each other when things go well.

BUILD ON YOUR STRENGTHS

Some nurseries stand out from the crowd because they have identified elements that they are particularly good at, or circumstances that give them the edge over their competitors, and then concentrated their resources in these specific areas. Equally they may have identified things that they find difficult or unprofitable and reduced or eliminated them. The consequences are enhanced reputation, improved profitability, and increased job satisfaction all around.

SIMPLIFY OPERATIONS

As successful nurseries develop and expand there is a tendency to become increasingly complicated. The dangers of complexity are that quality control and efficiency become more difficult to manage. With careful planning this can be avoided. Some nurseries have used method study or lean management to develop efficient systems. They may then document this in method statements, which detail the best way to perform each task. Large nurseries may be divided into specialist divisions to maintain focus and manageability whilst the retaining their overall economies of scale. Simplified operations can help overcome communication difficulties that occur with increasing seasonal peaks and casual labour.

WISHFUL THINKING

The IPPS has been very instrumental in the process of continuous improvement throughout the nursery industry and the transfer of knowledge has been beneficial to all members. However it is interesting that there are more imitators than innovators, so there is a vital factor that sets the innovators apart. I describe that factor as wishful thinking. Rather than just modifying existing methods and equipment the real innovators imagine the dream scenario where everything succeeds. They start with "wouldn't it be great if…" and then seek to eliminate the factors that prevent their desired result. Sometimes new equipment or techniques are developed; sometimes a complete new system is needed. Occasionally it may involve a complete break with tradition, but more often it involves a return to basic principles that may have been neglected during the process of gradual progress.

TRIALS

Whatever the source of new ideas it is important to conduct trials, in commercial conditions, before making major changes to established methods. The scale of the trial will depend on how way out the experiment is, but should always start with a clear objective and be accurately recorded at all stages. Successful nurseries are always open to new ideas and they generally have trials in progress at all times. The resulting knowledge will be invaluable when future developments are undertaken.

SEEK AND SHARE

Although the benefits of seeking and sharing plant knowledge have been well proven over the past 60 years, it is still noticeable that some members have a much more open approach to learning than others. Whilst some growers only visit nurseries that produce similar crops to themselves, the smart ones realise that there is much to be learned from more diverse sources. Many of the management techniques now familiar in horticulture have been developed in other manufacturing industries. Logistics and ergonomics are common challenges to all production sites.

Leading nurseries are normally willing hosts to visitors. They recognise that in return for sharing their knowledge they will gain from the observations of the visitors and the questions raised may stimulate ideas for future innovation.

CONCLUSION

Obviously these ten points do not cover all the elements involved in managing a nursery. There are important marketing and financial principles that other people are better qualified than I am to identify.

With the inevitable changes that our industry must make in coming years it will be interesting to monitor future developments and try to recognise which factors have the most influence on business success.

The Production and Use of Compost Tea Xtract for Improved Plant Growth©

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I work for Rhizopon BV, a Dutch company that has produced plant rooting hormone since 1940. I have been a consultant for almost 30 years giving advise based upon field research..

INTRODUCTION

Growers are well aware that rooting hormones influence root formation when propagating plants from cuttings. Over the years we confirmed that healthy mother plants produce cuttings that rapidly produce quality roots. Among the questions that arose during my early research was, what makes the best cutting to use for plant propagation? My answer came in the past 20 years of testing. 2010 is called the "YEAR OF BIODIVER SITY." My conclusion is, "biodiversity" produces the best cuttings.

High microbial diversity in the rhizosphere and on the leaves of plants provides protection and optimal nourishment. These are critical parameters for high quality mother plants. The resulting cuttings have a population of diversity dynamics.

In 1998 I started research on the use of compost tea. The primary reason for this research has been to vitalize the plant's above- and below-ground environment.

My research was focused on:

- Rhizosphere enrichment of bare soil.
- Substrates such as peat and coir but also rockwool.
- Phylosphere enrichment through foliar application.
- Decomposing fallen leaves.
- Soil structure improvement.
- Support of the natural disease suppression systems of plants.
- Organically bound nutrients and root development in cuttings.

Figure 1. Philosphere of a tree in the tropics. Covered with plants and trillions of different microorganisms.

Controlled Microbial Composting. Dr. Ehrendfried Pfeiffer (Fig. 2) developed controlled microbial composting (CMC) in the early part of the last century. The method allows growers to produce valuable humified compost from organic residues. Extracts made from CMC compost provide growers with option to restore and maintain microorganisms anywhere they need them.

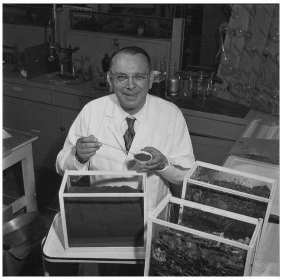

Figure 2. Dr. Ehrendfried Pfeiffer (from the Collection of Threefold Educational Center).

These extracts produce high yields and quality plants. I found that especially seedlings and rooted cuttings, treated with compost teas, and organic nutrients, are better than those treated with synthetic fertilizer compounds.

COMPOST XTRACTOR®

Compost and compost tea improve soil characteristics, and they can even vitalize an inert substrate. In the 1990s compost tea use was rediscovered in North America. Compost teas are water-based extracts of good quality compost. Organisms are removed from their humus structure and are hosted in the liquid. The tea's microorganism population can be applied through conventional irrigation and sprinkler systems. Bob Baars, an organic plant researcher and worldwide renowned consultant, developed a compost tea extraction method for optimum plants use.

The equipment is called the Compost Xtractor®.

There is a distinction between brewing and extracting compost in water. In compost tea brewing systems, 50 gal are made from 20 lbs of compost (200 L are made from 10 kg of compost) in 18 to 24 h.

The Compost Xtractor however extracts 50 gal of compost extract and it uses only 2 lbs of compost (200 L with 1 kg of compost) in just 8 h. In the Xtractor compost is

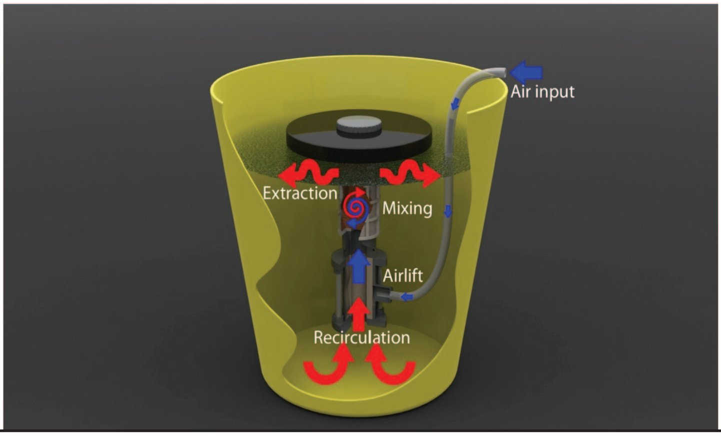

Figure 3. Compost extraction machine XTRACTOR. Figure copyrighted by Alexander Eigenraam©.

put together with special nutrients into a filter tube. Fine air bubble diffusion and airlift principles remove most organisms and their spores from the compost (Fig. 4). Many organisms in the compost extract come in spore form. They are activated in the soil or substrate. The plant is actively involved and regulates this. The shelf life of what we call an Xtract, is up to 7 days.

APPLICATION OF COMPOST XTRACTS

Compost Xtract is applied and dosed with venturi Dosatron mixers or low pressure injection systems. It may also be applied through the water supply system, irrigation, drip irrigation, mini sprinklers, ebb and flood irrigation systems, capillary mats, pure fogging systems, pure low-volume mist, or backpack fogging machines.

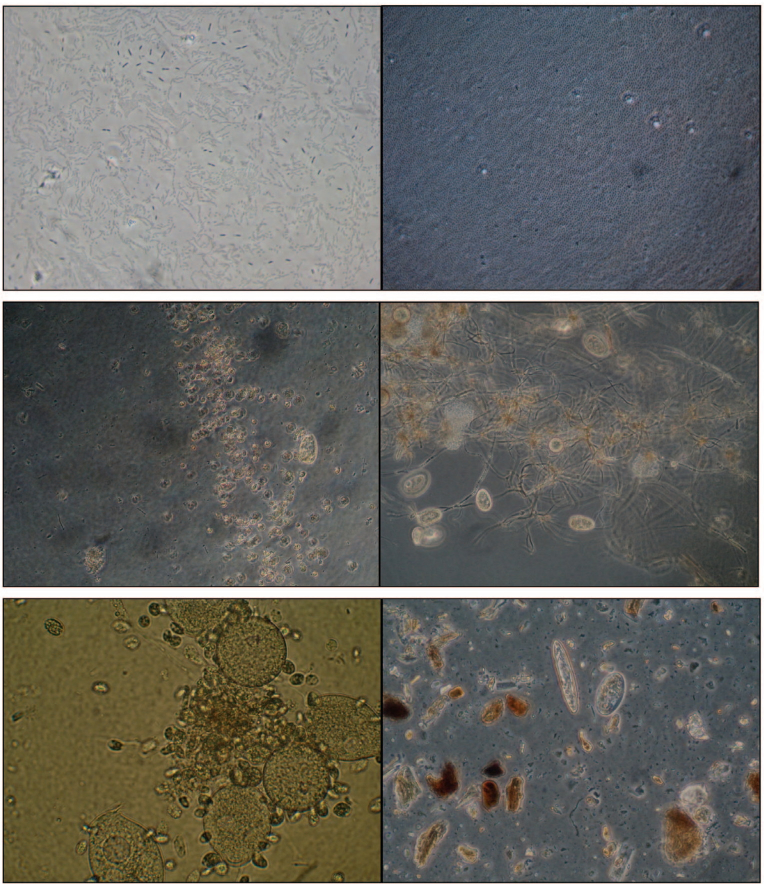

Figure 4. Compost Xtract organisms: top left *Bacillus* active and spores; top right spores of different organisms; left middle; protozoas; right middle: protozoa and fungi; bottom left: protozoa different sp.; bottom right protozoa, bacteria, and spores. Magnification: 600X Bob Baars©.

Some of the crops that are candidates to use compost Xtract on are:

- Seedlings and cuttings (Fig. 5).
- Horticultural crops such as bedding plants, cut flowers including roses, mums and orchids.
- Agricultural crops such as arable crops, orchards, viticulture.
- Field crops such as strawberries, vegetable gardens, and vegetables under glass in soil and in substrate.
- Many uses on turf and golf courses, public gardens and parks, tree nurseries.

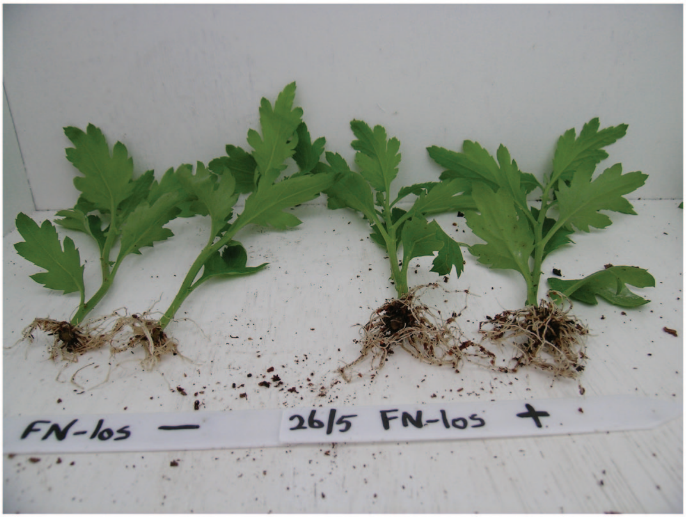

Figure 5. Chrysanthemum cuttings (left) only water spray (right) after sticking treated with compost Xtract after 10 days from treatment. Pre-treated with RHIZOPON #2 powder. FN-los means a coir substrate named: Fiber Net.

DISCUSSION

Human Digestive System. There is a similarity between plant growth regulation and the human digestive system. Human health is largely determined by the functioning of our digestive system. That system is controlled by industrious microorganisms in our intestines. The foods we eat are the building blocks for the billions of microbes that live there. These microorganisms produce the nourishing substances that we need to develop and maintain a healthy body. To perform optimally, the system needs healthy organic food with high-energy and nutritional value.

The microbes communicate with human body functions, thus insuring that the digestive system properly maintains our bodies and our immune system. When we eat industrially refined products, the digestive system does not function to its full potential. When the digestive population does not receive adequately nourishing building blocks it may lead to their decline. That in turn may be the cause for life-threatening situations.

Some specialized digestive organisms cannot extract food from refined products or produce secondary metabolites. To feel good, people compensate for lack of metabolites by replacing organic food with synthetic substances, such as man-made vitamins and products of questionable value.

The Soil as a Digestive Organ for Plants. Nature in general and agriculture in particular are no different from the above example. In nature the digestive system is the soil or cultivation substrate. We might think of the "soil" as the "stomach" of the plant. We ought to feed the soil microorganisms so that they in turn nourish and stimulate the plants. The task of microorganisms is to release and transport minerals from the soil, as well as regulating the natural disease suppressive system.

In and on the plant and in the soil there's a fine-tuned symbiotic communication system that acts between the plant and the microorganisms. Plants produce assimilates that are used by microorganisms to grow and multiply. During the process of growth and multiplication, the microorganisms in return supply nutrients and minerals that are needed for plant growth and flower and fruit production.

If we only supply our plants with refined nutrients such as fertilizer, than an important part of the diversity of microorganisms in the soil or the substrate is redundant. Artificial fertilizer substance, mostly salts, causes microorganisms to go to sleep or even die.

The result is that multiple types of microorganisms stop producing vital nutrients and minerals. Lacking those substances, the plant may weaken or even die of malnutrition.

Plants therefore prefer absorbing organically bound nutrients, mostly sugars.

Organic nutrient binding is an exclusive job of microorganisms.

Nutrient leaching is non-existent when microbial life is healthy and active in the soil or substrate. Water- and nutrient-holding capacity in soils and substrates is greatly improved when microorganisms are present and active. Soil structure and diffusion of gasses is also an activity of microorganisms, as is the natural disease suppression of pathogens.

CONCLUSION

To develop the highest quality, plants must be able to adequately use nutrients. Application of compost teas that contain a large diversity of microorganisms help the roots to extract organic nutrients from the rhizosphere. Refined nutrients do not provide adequate stimuli.

Young plants, such as seedlings and root developing cuttings, are very sensitive for artificial fertilizer (salts) and develop much easier and better with organically bound nutrients (sugars).

Especially in mother plant, "stock plant," and young plant culture, I recommend the application of compost extract instead of commercial fertilizers.

Soil-borne micro-organisms are the greatest reservoirs of biodiversity on the planet and are known to be critical to terrestrial ecosystem functioning. However, our mechanistic understanding of microbial activities in soil and the genetic basis for these activities are still poor, hampering our ability to harness and manage this tremendous diversity.

Acknowledgements. Test centre; "De Kas" <www.vanderknaap.info>; and Ron Schoutsen R&D Dekker Chrysanten <www.dekkerchrysanten.nl>.

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New Jersey Soil Health: <http://www.njsoilhealth.org/>

Nederlands Instituut voor Ecologie: <www.nioo.knaw.nl>

Growing Plants Hydroponically for Cutting Production©

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INTRODUCTION

The application of hydroponic growing techniques for the production of plant propagules, across a range of genera, is a reasonably recent practice. The system is used widely in South America, Brazil, and Uruguay for the maintenance of stock plants and subsequent production of plant propagules of *Eucalyptus* hybrids, for use in the forestry plantation industry.

At Narromine Transplants, we have endeavored to broaden the range of genera that can be treated in this way and have had success with *Prunus* spp., in particular sweet cherry cultivars, and a range of cherry root stocks.

BACKGROUND

After two visits to South America, Chile, Brazil, and Uruguay, to investigate the propagation of *Eucalyptus* hybrids and single species in the early and mid 2000s, we found that stock plants were being maintained via a number of different treatments. These included in-ground, sand beds with drip lines, and ebb and flow systems. The methods being employed in the latter two cases incorporated the use of hydroponic solutions both as run to waste systems and as ebb and flow.

In addition, the stock plants were physically treated in such a way that they retained juvenility thus maximising the number of propagules that eventually formed roots. The comparison between in-ground grown stock plants spaced at 1 m, which were essentially used for the production of macro-cuttings, was in stark contrast to sand bed and ebb and flow culture where the stock plants were grown in densities of up to 340 plants per square meter.

The adaptation of this system to suit Australian conditions as well as reducing the capital outlay and ongoing costs associated with both sand beds and ebb and flow, has been quite successful and has now been further adapted to other genera.

MATERIALS AND METHODS

Since the late 1990s we had grown our *Eucalyptus* stock plants in 50-liter bags and taken a range of cutting material without much concern for the age of that material, it would take another 12 years before we fully realised the significance of maintaining the stock plant in a continual state of juvenility. We adapted our system, still in 50-liter bags, so that we could take what is now termed mini-cuttings mainly by constantly taking cuttings from the stock plants.

However after the two visits to South America and an escalation in demand for clonal hybrids, we needed to dramatically increase our strike rates and our production volumes.

We initially approached the problem by costing the purchase of an ebb and flow system or constructing sand beds both of which would need to be under cover. These systems proved to be expensive and as well, in the case of sand beds, the medium needed to be replaced every 2 years and the ebb and flow system required the renewal of the nutrient solutions periodically, and the dumping of the old in an environmentally accepted way.

A friendly competitor, Jayfields Nursery, was also searching for a way of economically producing *Eucalyptus* clones and happened to see Ball Australia conventionally growing New Guinea impatiens in coir bags routinely used in Australia by the hydroponic greenhouse tomato industry. Jointly we decided to adopt this medium using a Netafim drip system.

We had learned in South America, particularly from Teotonio de Assis (De Assis, 2004; De Assis and Fett-Neto, 2004), at the time a plant breeder and propagator with the pulp and paper company Aracruz and the University of Sao Paulo, of the need to carefully treat *Eucalyptus* stock plants with the correct nutrient solutions. The reasoning for this was that the propagules that were subsequently produced under this regime would have just the right degree of hardness and maintain their turgidity under mist, not need supplemental nutrition while under mist, would not require the use of hormone to assist callus and eventual root initiation, and would allow a high percentage strike rate.

As most of the literature on the subject in the early stages of our experimentation was in Portuguese we had to rely on a translator who had no training in chemistry or nutrition to decipher what little information we had. We started with a very basic A and B solution which we gradually refined, initially through trial and error and eventually with the help of Teotonio de Assis and Aracruz (Tables 1 and 2).

Table 1. Stock solutions for *Eucalyptus* stock plant maintenance.

Stock solution A	$g{\cdot}L^{-1}$	Stock solution B	$g{\cdot}L^{-1}$
$CaNO_3$	32.0	KNO_3	4.0
KNO_3	4.0	KH_2PO_4	7.25
Fe (as EDTA)	2.0	$MgSO_4$	7.25
		Mn	0.05
		Z	0.05
		Cu	0.005
		B	0.15
		Mo	0.00125
		Co	0.0005

We found that to fine tune these solutions we needed to take regular tissue samples for analysis and to continually monitor the EC and pH of the delivered nutrients.

Table 2. Desired nutrient levels of leaves of *Eucalyptus* stock plants.

Macronutrients (%)					
N	P	K	Ca	Mg	S
2.5	0.2	1.5	1	0.25	0.15
to	to	to	to	to	to
3	0.4	2	1.5	0.4	0.25

Micronutrients ($mg \cdot kg^{-1}$)				
B (ppm)	Mn (ppm)	Zn (ppm)	Fe (ppm)	Cu (ppm)
40	100	50	100	10
to	to	to	to	to
70	500	60	200	15

Stock plants were fed on a daily basis via drippers spaced at every second plant and flushing with straight water took place every 10 days to ensure there was no accumulation of salts in the coir bags.

We commenced full production using hybrids based on *E. grandis* ×*E. camaldulensis* (gxc), probably two of the easiest species to propagate, using the mini-cutting system where stock plants are kept small and as juvenile as possible. With only a few errors along the way, we managed to launch into a production run of 3 million cutting produced trees over a 6-month period.

We found that as we proceeded we were able to dispense with the use of hormone and that our strike rates increased as well, from an initial 70% to as high as 92% in the middle of summer. We also found that bottom heat (22 °C) was essential to increase throughput, with rooting occurring within 12 days in midsummer, and cuttings were able to be removed from mist within 20 days. Without bottom heat these timings increased to 18 and 28 days, respectively.

Without doubt this system works exceptionally well when plants are kept as juvenile as possible. As we have subsequently found, not all *Eucalyptus* hybrids are as easy to propagate as gxc and they are not so prolific if the stock plants are derived from cutting material rather than from seed. Cutting-derived material does not develop a lignotuber from which we are able to harvest the most juvenile material.

An approach by a cherry grower to look at the propagation of grafted cherry trees led to us experimenting with the coir bag and hydroponic system to propagate root stocks for dormant grafting. We started with approximately 100 Colt® dormant, bare-root trees which we trimmed and first placed in 200-mm pots. We then took tip cuttings from these plants, propagated them under mist, grew them to a height of 100 mm, and then planted them into our coir bags.

Within a 1-year period we were able to increase our stock plant base to 5,000 in coir bags and we are currently harvesting green tip material from these plants for mist propagation. Success rates are as high as 90% utilising the same hydroponic regime as we are also using for eucalyptus-hybrid production. Cuttings were rooted and ready to be potted on within 21 days and we have found with cherry green tip cuttings that hormone is needed to ensure uniform rooting.

Cherry rootstock cutting production commences in late September and concludes in late January. Plants are grown in 800-ml pots and then dormant grafted the following winter and sold as a 1-year-old tree at the beginning of summer.

Table 3. Cherry cutting production from coir bags.

Coir bag	\$3.11 (landed)
Bag life	3.0 (years)
Plants per bag	7
Cuts/m^2/month	100 (over 6 months)
Bag dimension	0.17 (m^2)
Cuts/bag/month	16.5
Cuts/plant/week	0.5 (minimum – Max = 3)
Cuts/bag/3.0 years	297 (6 months/year)

We are now confident enough with this system to proceed with other rootstock varieties, namely the Krymsk® series that are now in demand in Australia. We are also intending to test a range of peach, nectarine, and apricot rootstocks as well.

CONCLUSION

The use of a hydroponic growing system for the production of *Eucalyptus* hybrids and cherry rootstocks has been very successful allowing production to be carried out under cover and on benches. The system has also allowed us to maintain high standards of hygiene to which we are committed, under the Australian Nursery Industry Accreditation Scheme.

We believe that the system we are operating may also be adaptable to a range of other genera, probably with some adjustment to the solutions we are currently working with. It has also been our experience in using this system that once our staff are given a set of EC and pH parameters of the delivered solutions with which to work, as well as flushing dates, we have experienced very few problems with growth rates or nutritional problems.

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Wild Urban Plants©

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The basic goal of my recent book, *Wild Urban Plants of the Northeast: A Field Guide* (Cornell University Press, 2010), is to help the general reader identify plants growing spontaneously in the urban environment and to develop an appreciation of the role they play in making our cities more livable. The 222 plants featured in this book are those which fill the vacant spaces between our roads, our homes, and our businesses; take over our neglected landscapes; and line the shores of our streams, rivers, lakes, and oceans. Some of these plants are native to the region before it became a city, some have been brought there intentionally (or unintentionally) by people, and some have gotten here on their own, dispersed there by wind, water, or wild animals. They are the plants which grow and reproduce in the city without being planted or cared for by people. They are everywhere and yet they are invisible to most people.

Given that cities are totally human creations and the original vegetation that once grew there has long since been wiped out, one can make the argument that spontaneous plants have become the de facto native vegetation of the city. Indeed, a basic premise of this book is that the ecology of the city is defined not only by the cultivated plants that require on-going maintenance to survive and the native species which are restricted to protected natural areas, but also by the plants which dominate the neglected interstices of the urban environment. This wasteland flora — which no one plants and no one takes care of — occupies a significant percentage of the open space in many American cities, especially those with a faltering economy. Recent research has begun to show that this "emergent vegetation," if left undisturbed long enough to develop into woodlands, can provide cities with critically important social and ecological services at very little cost to the taxpayer.

There is no denying the fact that many — if not most — of the plants covered in this book suffer from image problems associated with being labeled as "weeds" or, more recently "invasive species." From the plant's perspective invasiveness is just another word for successful reproduction, which of course, is the ultimate goal of all organisms, including humans. From a utilitarian perspective, a weed is any plant that grows by itself in a place where people don't want it to grow. It's a value judgment that we apply to plants we don't like, not a biological characteristic. Calling a plant a weed gives us license to eradicate it. In a similar vein, calling a plant invasive allows us to blame it for ruining the environment and it's certainly easier to blame a plant for that than to blame ourselves. From the biological perspective, weeds are plants that are adapted to disturbance in all its myriad forms, from bulldozers to road salt to acid rain. Their pervasiveness in the urban environment is simply a reflection of the continual disturbance that characterizes this habitat. Weeds are the symptoms of environmental degradation not its cause, and as such they are poised to become increasingly abundant in our lifetimes.

Developing the list of plants covered in this book has been a lengthy, 5-year process. Part of the difficulty arose from trying to distinguish between the terms "urban vegetation," "invasive species," and "weed." Given that the meaning of these words varies depending upon who is using it, I have developed my own definitions that are consistent with the goals of this book. I use the term “urban” to refer specifically to any part of a city or town where more of the land is covered with pavement and buildings than not, and most traces of original native habitats are long gone. The urban environment is also characterized by high levels of disturbance associated with pedestrian and vehicular traffic, infrastructure maintenance and new construction. In this book, plants which can survive and reproduce under such conditions — regardless of where they come from — are referred to as “spontaneous urban vegetation.” From a plant’s perspective, it is the abundance of paving and disturbance rather than the density of the human population that define the urban environment. In other words, a sidewalk crack is a sidewalk crack whether it’s in a city or a suburb.

Most of the plants included in this book display — to a greater or lesser extent — an ability to colonize disturbed ground across a broad range of unmanaged, urban habitats. From the ecological perspective they can be considered, with relatively a few exceptions, disturbance-adapted, early successional species. In the absence of maintenance, the default vegetation of the cities of the Northeast is the cosmopolitan collection of plants described in this book. They are preadapted to the early successional conditions that we humans have created in the urban environment, and as such they can legitimately be considered its natural vegetation. Roughly speaking, 40% of them are native to North and Central America, 48% are from Europe and Central Asia, and 12% are from Eastern Asia.

It is a foregone conclusion that the world as we know it today will continue to deteriorate over the next few decades as people continue to pump more heat-trapping carbon dioxide into the atmosphere and more acid rain falls back to earth to pollute both the water and the soil. The worldwide migration of people from the countryside into cities is also contributing to environmental degradation because it replaces land which was once covered with vegetation that lowers surface temperatures with buildings that generate heat and pavement that retains it. The confluence of climate change and urbanization — acting in concert with the global spread of invasive species — has set the stage for spontaneous vegetation to play a major ecological role in the human-dominated landscapes of the future. Regardless of how we feel about this brave new ecology, the plants described in this book are well adapted to the world we humans have created and, as such, they are neither good nor bad — they are us.

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Biological Control of Invasive Forest and Landscape Pests: An Overview of Current Problems©

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Birch Leafminer (*Fenusa pusilla*). Birch leafminer (BLM), native to Eurasia, was introduced to Connecticut in 1923. It spread throughout the Northeast and Midwest, causing nearly complete defoliation of landscape and roadside white and gray birches. In Europe BLM is widespread, but relatively scarce — apparently because of 17 species of parasitoids which cause 38%–47% annual parasitism. In recent decades the European parasitoid *Lathrolestes nigricollis* was released in mid-Atlantic and southern New England states. Now BLM is rare and parasitism is high except south of mid-New Jersey.

Winter Moth (*Operophtera brumata*). Winter moth, native to Europe was found in 1935 in Nova Scotia and New Brunswick. In 1950 it was discovered in Washington and Oregon and in 1977 in British Columbia. A new introduction was found in 1996 in Southeast Massachusetts which by 2004 spread to Rhode Island. North American hosts include: Norway maples (*Acer platanoides*), birches (*Betula*), apple (*Malus*), red oak (*Quercus rubra*), blueberry (*Vaccinium*), ash (*Fraxinus*), and rhododendron (*Rhododendron*). Males emerge in November and seek flightless females that crawl up trees to mate and lay eggs. Males are attracted to lights! Females lay eggs in cracks in tree bark in November. Eggs hatch around bud break (March and April). Larvae feed on buds, then leaves, completing development and pupating in the soil in May. A European fly, *Cyzenis albicans* (Diptera: Tachinidae) provided excellent control in the Canadian Maritimes and in Pacific Northwest about 6–8 years after release. Joe Elkinton, University of Massachusetts, started releasing this parasitioid in 2005. It is now established in Seekonk, Hingham, and Falmouth in Massachusetts.

Hemlock Woolly Adelgid (*Adelges tsugae*). Hemlock woolly adelgid (HWA), native to China and Japan, was introduced into Virginia in mid 1950s. It has spread from Georgia through Maine, limited in the north by extreme cold. Canadian and Carolina hemlocks are uniquely susceptible. Introduced biocontrol agents appear ineffective. Asian and western North American species are resistant. *Tsuga heterophylla* is the best match for *T. canadensis*. Small stands of HWA-resistant *T. canadensis* were located in Connecticut and New Jersey. University of Rhode Island is working on improving propagation and distribution. Meanwhile, imidacloprid soil drench provides at least 8 years of protection. The lowest labeled rate is effective and may reduce problems with spruce spider mites.

Emerald Ash Borer (*Agrilus planipennis*). Emerald ash borer (EAB), native to Asia, was found in Detroit in 2002. Initial spread was 30–40 miles per year, but more recently closer to 100 miles/year. I expect southern New England to be infested within 2–3 years. All native ashes (*Fraxinus*) are susceptible. Larvae tunnel beneath the bark, killing trees within a few seasons. Chinese (*F. chinensis*), Manchurian (*F. mandschurica*), and Syrian (*F. syriaca*) ash are all apparently resistant to EAB but may have other problems. Current research includes interspecific hybrids and transgenic (Bt) plants. "Lingering" native ash trees are also under investigation. There are presently no ash species or cultivars to recommend for EAB resistance. Three species of Chinese parasitoids were released in Michigan and nearby states. Establishment is confirmed but it is too early for impact assessment.

Asian Longhorned Beetle (*Anoplophora glabripennis*). Asian longhorned beetle (ALB) was introduced to North America in Chinese shipping materials. If it spreads, it will have a major impact on tourism, and the sugar maple industry, timber, and nursery industries. Key hosts: maple, horse chestnut, elms, poplars, birches, willows. The ALB was found established in New York City in 1998; Illinois in 1998; Hudson County, New Jersey in 2002; Toronto, Canada in 2003; Middlesex/ Union Counties, New Jersey in 2004; Richmond County, New York in 2007; Worcester, Massachusetts in 2008; Boston, MA in 2010. Eradication efforts include quarantine, inspections, tree removal, and insecticide treatments. Current status: Illinois ALB population was declared eradicated in 2008, Jersey City — eradicated 2008, New York City — still under way, Worcester — 76 sq. mile quarantine 18,000 trees removed, Boston — infested trees removed July, 2010 with no additional detections. Biological control research is under way, but the emphasis is on eradication.

Purple Loosestrife (*Lythrum salicaria*). Purple loosestrife, native to Europe, was introduced into North America in early 1800s. Dense stands throughout northern U.S.A. and southern Canada displace native plants and animals. This plant is widespread but relatively uncommon throughout Europe where 120 insect species feed on it. Four European beetle species were released in mid-1990s throughout North America. Experience is generally similar to Rhode Island — periods of defoliation/ plant decline followed by beetle decline/plant rebound, then beetle rebound/ plant decline, etc. There is now more plant diversity as a result of biocontrol. (You don't need 100% effectiveness in weed biological control — just give competitive species a chance.) Beetles continue to spread.

Phragmites australis. *Phragmites australis* has become a major pest of wetlands throughout the northeastern North America and the Midwest in recent decades. Problems are due to an introduced European species, not the native North America species. University of Rhode Isand and Cornell biocontrol specialists are working with Commonwealth Agricultural Bureaux International (CABI)-Europe to find effective biocontrol agents among the 175 insects that feed on phragmites in Europe. We are presently conducting host-specificity tests on insect species that appear to have potential for controlling exotic phragmites without adverse impact on native stands.

Mile-a-Minute Weed (*Persicaria perfoliata*). Mile-a-minute weed was introduced in the late 1930s to a nursery in eastern Pennsylvania when holly seeds from Japan were planted and mile-a-minute came up with the holly. This "kudzu with thorns" has since spread throughout the mid-Atlantic and the southern New England states. The current biocontrol program looks very promising: a stem-boring weevil, *Rhinoncomimus latipes*, released in mid-Atlantic states and in Rhode Island has established at virtually all release sites and is having a substantial impact on the weed.

Garlic Mustard (*Alliaria petiolata*). Garlic mustard, native to Europe, was introduced to Long Island about 1986 and has since spread through the Midwest. Foliage is toxic so deer won't eat it. (People shouldn't either — it has high levels of cyanide.) Root exudates kill mycorhhizae and inhibit growth of tree seedlings. Garlic mustard infestations are linked to high deer populations (eat plant competitors) and invasive earthworms (turn leaf litter into rooting media). Several European weevils are ready for release as biological control agents.

Japanese Knotweed. Japanese knotweed, *Fallopia japonica, F. sachalinensis* and their hybrid were introduced into North America in late 1800s as ornamentals. These are not pests in Japan where native insects and diseases apparently provide control. A psyllid insect (*Aphalara itadori*), introduced in the U.K. this year, will likely be released in North America within 2 years.

Black and Pale Swallow-Worts. Black (*Vincetoxicum nigrum*) and pale (*V. rossicum*) swallow-worts, both European species, are targets of biological control research at University of Rhode Island. We are focusing on two European moths that appear to be host specific and offer potential for control.

Japanese Stiltgrass (*Microstegium vimineum*). Japanese stiltgrass, is a widely distributed invasive plant that is not often recognized. We should learn to identify it and not further distribute this annual plant or its seeds through our landscaping efforts.

Development of Two Intelligent Spray Systems for Ornamental Nurseries©

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INTRODUCTION

The ornamental industry produces an abundance of flowers, nursery shrubs, and trees to beautify our environment and improve our lifestyle. This abundance is predicated on the use of pesticides to protect them from pests. However, the application efficiency of conventional pesticide spray technologies for crop protection is very low. Consequently, excessive pesticides are often applied to target and non-target areas, resulting in greater production costs, worker exposure to unnecessary pesticide risks, and adverse contamination of the environment. The industry has constantly demanded the development of new advanced intelligent sprayers that delivers pesticides economically and accurately and requires minimum human inputs during the entire spray application process.

The capabilities of conventional sprayers are limited and unable to optimize spray outputs and thus cannot compensate for the rapid changes of growth characteristics in nursery crops. Although traditional ultrasonic sensors coupled with variable-rate sprayers are an improvement (Giles et al., 1987; Molt et al., 2000; Solanelles et al., 2006; Gil et al., 2007; Balsari et al., 2008), they are usually used for relatively uniform orchard trees but cannot evaluate nursery trees with wide growth diversities. Consequently, the high-speed ultrasonic sensors or laser scanners are needed for advanced sprayers that automatically adjust spray outputs based on canopy sizes. The laser scanners offer promising opportunities to detect tree canopy characteristics due to their fast response to the target surfaces (Wei and Salysni, 2004; Lee and Ehsani, 2008; Rosell Polo et al., 2009).

The objective of this research was to develop advanced and affordable spray systems that employ intelligent technologies to continuously match system operating parameters to crop characteristics during pesticide applications. Significance of this research would be to provide critical technology to increase application efficiency and reduce uncertainty associated with current pesticide sprayers used in nursery crop production, and to achieve real cost benefits to producers, consumers, and environments with new pesticide application strategies.

MATERIALS AND METHODS

Two types of experimental variable-rate precision sprayers were developed as an introduction of new generation sprayers for nursery crop applications. The first one was an economic, hydraulic vertical boom spraying system which was proposed to spray relatively small narrow trees such as liners, and the second one was an air-assisted spraying system which was proposed to spray wide range of nursery crops.

Variable-Rate Hydraulic Boom Sprayer. The intelligent variable-rate boom sprayer (Fig. 1A) integrated a 20 Hz detecting frequency ultrasonic sensing system, a custom-designed sensor-signal analyzer and variable-rate controller, and variable-rate nozzles. The sensing system detected the occurrence of a plant, its size and volume, and the sprayer travel speed. The controller along with a microprocessor analyzed sensor signals and actuated pulse width modulated (PWM) solenoid valves in real time to automatically provide variable flows to nozzles. Laboratory tests were conducted to verify deposition uniformity inside canopies with various sizes of trees at different travel speeds. The laboratory field consisted of two rows of six different taxa of trees (*Acer rubrum* 'Franksred', *A.* ×*freemanii* 'Jeffersred', *A. palmatum*, *Carpinus betulus*, *Malus toringo* subsp. *sargentii,* and *Prunus* ×*cistena*). Tree taxa had different heights which ranged from 0.8 to 2.5 m, and their calipers

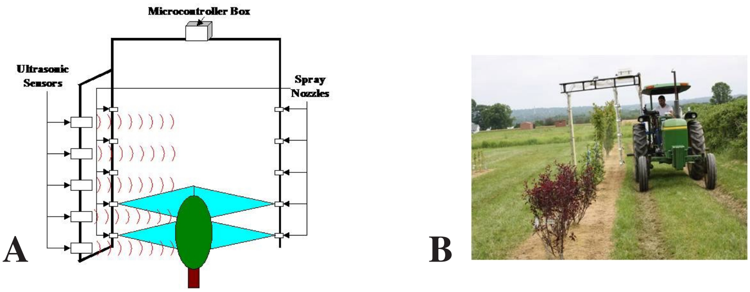

Figure 1. Ultrasonic sensor-controlled hydraulic vertical boom sprayer to provide variable-rate functions based on tree size, shape, and occurrence.

A) Schematic diagram of ultrasonic sensors to detect canopy and control spray nozzles.

B) Ultrasonic sensor-controlled variable-rate sprayer in a laboratory field.

at 18 cm above the ground ranged from 0.5 to 5.4 cm. The travel speeds for the test were 3.2, 4.8, 6.4, and 8.0 km/h. Water-sensitive papers were mounted inside canopies to measure the spray coverage, and a fluorescent tracer brilliant sulfaflavine was mixed with water to form spray solution to quantify spray deposits.

Variable-Rate Air-Assisted Sprayer. The intelligent variable-rate air-assisted sprayer (Fig. 2B) integrated a high speed laser scanning system, a custom-designed sensor-signal analyzer and variable-rate controller, variable-rate nozzles, and a multi-channel air-assisted delivery system. The sprayer intended to have the capability to achieve variable spray rates for different canopy volumes and densities, by using nozzles of one size to obtain different flow rates instead of changes of nozzles of different sizes. Spray consumptions between the intelligent sprayer and a conventional air blast sprayer in an orchard were compared at three different growing stages. The comparison tests were conducted in April when trees just started sprouting, in May when trees developed half foliage, and in June when trees developed full foliage. Application rate for the conventional sprayer was 470 $L \cdot ha^{-1}$ (50 gpa) which was determined by a tree-row volume method.

RESULTS AND DISCUSSION

Tables 1 and 2 show the mean spray deposits and coverage inside canopies of six different taxa from the variable-rate hydraulic boom sprayer at travel speed of 3.2, 4.8, 6.4, and 8.0 km/h, respectively. The mean spray deposit and coverage inside canopies slightly varied with the changes in tree species (or tree size) and travel speed. For example, at 4.8 km/h travel speed for the six taxa of trees with their heights ranged from 0.8 to 2.5 m, the mean spray deposit ranged from 0.38 to1.08 $\mu L \cdot cm^{-2}$ and the mean spray coverage ranged from 9.2% to 20.4%. Moreover, for the travel speed ranging from 3.2 to 8.0 km/h, the spray deposit inside the *A. rubrum* 'Franksred' canopy varied from 0.82 to 1.21 $\mu L \cdot cm^{-2}$ and spray coverage varied from 13.7% to 18.5%. However, compared to the variations in field condi-

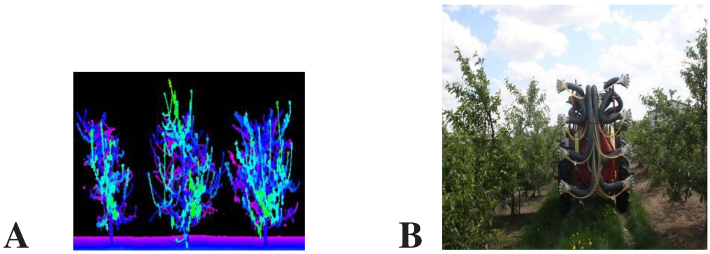

Figure 2. Laser-scanning sensor-controlled air assisted sprayer to provide variable-rate functions based on tree sectional canopy volume, density and occurrence

A) Images of trees scanned by a laser scanning sensor.
B) Laser-scanning sensor-controlled air-assisted sprayer.

tions, this variation in spray deposition and coverage from the variable-rate boom sprayer was very small and was acceptable for quality spray applications. That is, the sprayer achieved its anticipation that spray deposit and coverage were relatively uniform regardless of changes in the canopy size and travel speed.

Table 1. Mean spray deposits inside canopies of six different varieties from the variable-rate hydraulic boom sprayer at travel speed of 3.2, 4.8, 6.4, and 8.0 km/h. Values in parenthesis present the standard deviation.

	Spray deposit (μL·cm^{-2}) Travel speed (km/h)			
Trees	3.2	4.8	6.4	8.0
Acer palmatum	0.78 (0.21)	1.08 (0.47)	1.23 (0.41)	0.97 (0.30)
Acer ×*freemanii* 'Jeffersred'	0.67 (0.29)	0.68 (0.56)	1.13 (0.27)	0.91 (0.24)
Prunus ×*cistena*	0.96 (0.34)	0.92 (0.34)	0.68 (0.21)	0.72 (0.30)
Malus toringo subsp. *sargentii*	0.86 (0.35)	0.56 (0.26)	0.84 (0.30)	0.82 (0.33)
Carpinus betulus	0.77 (0.30)	0.38 (0.23)	0.53 (0.41)	0.49 (0.25)
Acer rubrum 'Franksred'	1.21 (0.60)	0.88 (0.46)	0.82 (0.31)	0.97 (0.41)
Mean	0.90 (0.41)	0.72 (0.43)	0.81 (0.38)	0.79 (0.35)

Table 2. Mean spray coverage inside canopies of six different varieties from the variable-rate hydraulic boom sprayer at travel speed of 3.2, 4.8, 6.4, and 8.0 km/h. Values in parenthesis present the standard deviation.

	Spray coverage (%) Travel speed (km/h)			
Trees	3.2	4.8	6.4	8.0
Acer palmatum	13.0 (4.5)	20.4 (10.8)	19.4 (8.6)	18.2 (9.6)
Acer ×freemanii 'Jeffersred'	12.4 (6.1)	14.4 (26.6)	16.2 (7.3)	18.8 (6.8)
Prunus ×cistena	12.3 (8.8)	13.3 (8.0)	10.4 (7.9)	8.3 (6.5)
Malus toringo subsp. *sargentii*	15.8 (9.5)	10.9 (5.8)	11.9 (7.0)	14.7 (6.7)
Carpinus betulus	14.9 (8.9)	9.2 (8.7)	6.8 (5.5)	6.7 (5.1)
Acer rubrum 'Franksred'	18.5 (8.3)	14.5 (7.4)	13.7 (8.5)	16.6 (8.0)
Mean	14.5 (5.1)	13.8 (5.5)	13.1 (6.0)	13.9 (6.4)

Figure 3 shows consumptions and percent reductions of the sprays with the intelligent air-assisted sprayer in an orchard in April, May, and June. The percent reduction was based on the 470 $L{\cdot}ha^{-1}$ (50 gpa) used by the conventional air-blast sprayer. The intelligent sprayer used 140 $L{\cdot}ha^{-1}$ (15 gap) with 70% spray mixture reduction in April, 159 $L{\cdot}ha^{-1}$ (17 gpa) with 66% spray mixture reduction in May, and 224 $L{\cdot}ha^{-1}$ (24 gpa) with 52% spray mixture reduction in June. The pesticide consumption reduction with the intelligent sprayer is obvious.

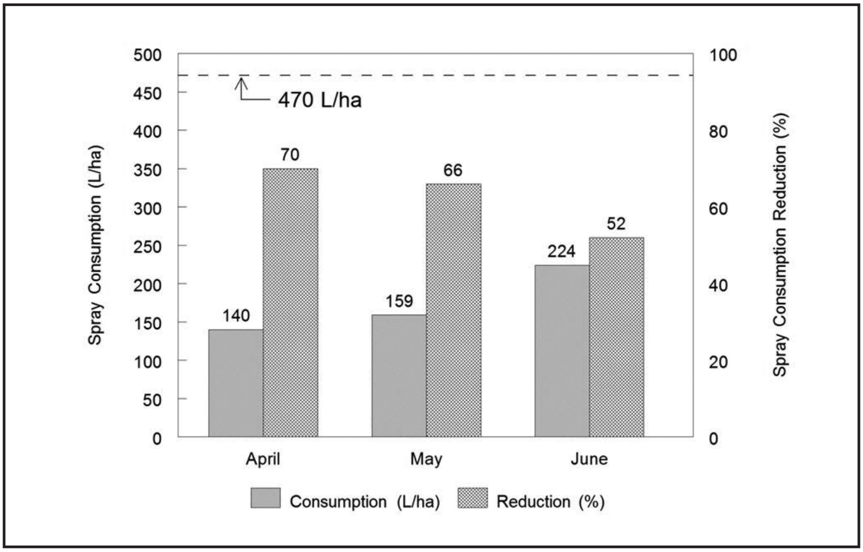

Figure 3. Spray consumption and percent reduction from intelligent sprayer, compared with the conventional 470 $L{\cdot}ha^{-1}$ (50 gpa) spray application rate.

SUMMARY

Current application technology for floral, nursery, and other specialty crop production wastes significant amounts of pesticides. Two different real-time variable-rate sprayer prototypes for ornamental nursery and tree crops were developed to deliver chemicals on target areas as needed. The first prototype was a hydraulic vertical boom spraying system that used 20 Hz ultrasonic sensors to detect tree size and volume, and the second prototype was an air-assisted spraying system that used a laser scanning sensor to quickly measure the entire tree structure. The automatic controllers developed for the prototypes consisted of a computer program, a signal generation and amplification unit, and pulse width modulated solenoid valves. The controllers analyzed sensor signals and actuated the solenoid valves to automatically provide variable flows to nozzles based on tree characteristics and plant occurrence. Preliminary laboratory and field tests demonstrated that both experimental sprayers had the capability to control spray outputs that continuously matched canopy characteristics in real time, and significantly reduce pesticide spray application rates.

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Irrigation: Rough Waters Around the Bend©

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What if someone tried to stick a target on your back?

Worse yet, what if it stuck and you couldn't get it off?

I'd like to share our company's experience with a local activist who tried to do just that. A young, determined individual who took a legitimate concern to a level that questioned the essential rightfulness of modern-day agriculture — while promoting himself and his cause. Fortunately, the target didn't stick.

My story starts with a secluded local lake about 1 mile from our nursery that began to develop algae problems around 5 years ago. As is human nature, rightful concern by lakeside residents was soon channeled into an exercise of finger pointing — with the dogged guidance of this neighboring activist. The nursery industry became the scapegoat for what environmental consultants and the Department of Environmental Protection would go on to characterize as a complex problem with a multitude of potential causes. In other cases throughout the state — where lakes were experiencing far worse conditions — such factors as: geese, drought, natural contaminants, and septic systems were cited in addition to agriculture as contributing sources. But not here, we were the sole culprits. The target was positioned squarely on the back of our nursery and a neighboring grower.

Seeing this evolve into the headlines of a major regional paper was not a pleasant turn of events. A prior call from the journalist gave me a few days advance notice. After providing my perspective, I hoped for a balanced story about the problem. Instead, there we were, along with our neighboring nursery, as the headline targets of blame. Fortunately, the article included an off-the-cuff quote from me that, in hindsight, probably served as well as anything I could have scripted. It walked a fine line between presumed innocence and a total denial of responsibility. Here is what I said, *"We don't think we're part of the problem, we recycle 95% of our irrigation runoff. But, as we've mentioned from Day One, we'd be glad to take a hard look at that. We think that what we've been doing over the years, as far as proactive management, is keeping us out of the equation of this particular problem."* The article went on to say that a call to the other nursery was not returned. As it turns out, the owners were away on vacation. Unfortunately though, it made it look as though they were hiding from the issue.

And then, the online postings started. Inflammatory and exaggerated comments began to characterize this as yet another environmental disaster with an agricultural cover up. Wisely or not, I felt compelled to respond. I posted my thoughts in defense of our neighbor and ourselves. Fortunately, others likewise tried to add reason to the discussion.

This ultimately grew into a face-saving effort, on the activist's part, to make his case to environmental groups, local government agencies, and the state Dept of Environmental Protection. Along the way, I tried to counter misstatements with a reasoned and factual rebuttal. Some of the main points I cited:

- Our ongoing openness with all concerned parties.
- The extent of our conservation efforts over the years.
- The fact that only a few acres of our production area drains in the direction of the lake, and that is only because of a network of government-sanctioned conservation diversions and waterways we installed soon after we purchased the property in 1988.
- Drainage from that area dissipates in our intervening 16 acres of woodlands — well before it reaches the lake nearly a mile away.
- The existence of a wide range of potential contributing sources besides agriculture.
- The fact that our nursery couldn't have been a triggering cause to a problem that started 5–6 years ago, since the production practices utilized in that portion of our nursery have been the same for the last 10 years.
- And, contrary to claims that lakeside septic systems had no role in the problem, I was able to provide a copy of a hypocritical letter our neighboring activist had written a few years prior to a farmer across the street. In that letter, he asked the farmer to relocate the house his daughter was building out of concern that the septic system might contaminate a lake nearly 1/2 mile away!

Shortly after making that point, and others, in a final letter to the New Jersey Department of Environmental Protection, I received a letter of apology. While magnanimous on his part, it unfortunately did nothing to rectify the public wrong that was done with his prior rush to judgment. Nor did it give me any false sense of security that his zealous pursuit was finally finished.

Changing gears, what I would like to now focus on are the conservation measures in which our company invested during the years prior to this incident, along with those additional measures which we initiated coincidental to this event. It is proactive steps, such as these, that provided credibility to my arguments during our rebuttal. An approach you might want to consider for your own circumstances.

Our efforts started with our first recycling project in the early 1990s. A retention basin was installed at the low point where most of the drainage from our nursery flows. In addition to capturing irrigation runoff, this basin serves as the main source of irrigation water for our nursery. This system was expanded in 2002. More recently, we have added two new basins adjacent to the original one. When completed, these will add an additional 3.3 million gal of storage capacity.

Around the same time as this latest expansion, we started work on yet another water retention project. This fourth basin allows us to capture runoff from an area on the other side of our property where we plan to extend production. Topography prevents this section from gravity-flowing into our primary recycling system. But, with the help of an automated pumping system, retained water can now be pumped back over the hill to be recycled.

In addition to capturing the water from future production in this area, this latest basin has now allowed us to capture the small percentage of irrigation runoff that previously drained into our woodlands — via the conservation diversions mentioned earlier. With an upcoming final project, we will be able to capture a remaining fraction of irrigation runoff. This will allow us to go from a current recycling rate of over 99% to essentially a 100% capture rate. Our ability to retain storm water runoff will also be increased significantly. All of which should remove ourselves from any consideration whatsoever as a potential contributing factor to circumstances at the nearby lake.

In addition to our water recycling efforts, we have long utilized a range of other conservation measures that help support our claim of being a responsible steward of the lands under our ownership. Our work with drip irrigation, erosion control, topsoil preservation, materials recycling, and energy conservation help us make the case that our actions indeed demonstrate our intent.

In total, these measures have cost us a lot of money. But these are costs that each of us pays, one way or the other — either proactively before the accusations, or reactively afterwards.

The choice between those alternative approaches is certainly everyone's to make. On our end, we prefer the peace of mind, and credible defense, that proactive planning provides.

Starting a Biological Control Program: Challenges and Rewards©

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Prides Corner Farms is a large nursery with mostly outdoor production. We grow trees, shrubs, roses, perennials, and herbs. The plants and the conditions that beneficial insects are going to be used in are very important. Using biological control with indoor production is generally more successful than outdoor production because the environment is enclosed and can be controlled. Our biological control program focuses on using beneficial insects on Sara's Superb Herbs, which are produced in heated greenhouses in the spring.

There are numerous challenges to beginning a biocontrol program. First of all, at least one person on the farm must learn about all the beneficial insects and their behavior to determine which ones are right for your situation. There are numerous beneficial insects that are marketed by the biocontrol companies. Each beneficial insect behaves in a certain way that affects whether it will be effective in your operation. To illustrate the need to learn these insects, we will look at the aphid biocontrols. These include: *Aphidoletes aphimyza* (predatory gall midge); *Aphidius colemani* (parasitic wasp); *Aphidius ervi* (parasitic wasp); *Aphelinus abdominalis* (parasitic wasp); *Chrysoperla* spp. (predatory lacewing); and *Adalia bipunctata* or *Hippodamia convergens* (predatory lady beetles). Within these beneficial insects, not all life stages feed on aphids; some need special programs, like banker plants, to be successful (*Aphidius* spp.); most are highly perishable; some are cannabilistic (*Chrysoperla* spp.); some only feed on specific aphid species (*Aphelinus* and *Aphidius* spp.); and most need to be released preventatively (will not clean up infestations).

In addition to learning the insects, there are many suppliers and products that affect the outcome of a biocontrol program. Several companies produce beneficial insects including Biobest, Syngenta Bioline, Koppert, Applied Bio-Nomics, and IPM Labs. Within these companies, lead times, ordering dates, availability, quality, and prices are just a few of the differences. Biocontrol insects are available in different quantities, mixes, and with different carriers or release devices. Each company has different names for each of the insects and forms. Quality and freshness are very important, and the different companies produce different quality products. It is a little bit of guesswork and trial and error to determine which companies and products work in your company's situation.

To start a program, it is important to first make a plan. Determine your crop and the associated pest problems, and then choose multiple biocontrols for each pest problem. Begin applications as soon as plants are stuck or seeded, and increase the quantities and application frequencies as plants get larger. Be willing to spot spray to control hot spots.

Trial and error is an important part of any biocontrol program. Begin with a plan but be prepared to change it as you go. Try different suppliers and different packaging to determine which works for you. Also, learn application frequencies and quantities, and which biocontrols work for your set-up and crop (crawling vs. flying insects, pest pressure, and time of year). Be prepared to spend more on biocontrols the first year or two before it begins to pay off economically. It is important to keep track of the levels of pests versus predators, so developing a scouting and monitoring system quickly pays off. Biocontrols are largely a preventative program, so monitoring for pest populations will help you decide when and where to apply more aggressive beneficials or whether to spray for hot spots.

There are many rewards that come with using a biocontrol program. Many times the challenges faced during the establishment of a program lead to solutions to larger problems. At Prides Corner Farms, first year challenges with our biocontrol program led to larger changes in the herb program. We re-thought the schedule of planting dates, and re-worked which plants to group together for ease of care. Thinking about ways to improve the biocontrol program led to ways to improve the crop overall.

We also re-examined our growing practices. We really had to think about sanitation and proper crop handling to avoid issues that we would have previously dealt with using chemicals. This led to improvements with crops that were still being grown traditionally.

Another reward was that we used less chemicals. We didn't have to spray insecticides on our herbs at all this spring. The limited insecticides that were available were not very effective in the past years, so we actually had cleaner plants. There was less worker disruption due to spraying, and worker safety is improved whenever we don't need to use chemicals.

In addition to using fewer chemicals, we also began using softer chemicals farm-wide. The need to use chemicals that are "softer" on the beneficial insects gave us more experience with new or low impact chemicals. Familiarity with these less harmful chemicals led to using them more farm wide. There was also a growth of interest in environmentally friendly products or chemical alternatives like RootShield®, compost tea, nematodes, water sanitation systems, organic fertilizers, Jiffy® pots, etc.

Finally, be skeptically optimistic about what the "experts" are telling you, as each situation is different. Educate your employees and co-workers — most people find beneficial insects interesting, and they will appreciate that you are exposing them to less chemicals. Also, know when to cut your losses, but don't give up too easily!

Challenges of Propagating Medicinal Plants©

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INTRODUCTION

Over 75% of the world's population relies on plant-based medicines for primary healthcare. Populations using pharmaceutical drugs obtain about 120 prescription drugs with origins from plants (Abelson, 1990). Used mostly by developing countries, 70%–90% of medicinal plants are still being harvested in the wild. If this trend continues, eventually these wild populations will no longer sustain the ever-increasing market demand. Examples of popular wild-harvested plants are *Achillea millefolium* (yarrow) and *Hypericum perforatum* (St. John's wort). Yarrow flowers are used in treating colds, fevers, Crohn's disease, and St. John's wort for patients with mild to moderate depression (Foster and Duke, 2005) These two species can easily be propagated from seed and stem cuttings to avoid over harvesting in the wild.

SUSTAINABLE APPROACH

The production of medicinal plants is still at its infant stage worldwide and is considered a minor crop by growers. The predominant growers of medicinal plants are located in Europe, Canada, Asia, Africa, and the United States. The United States is gaining momentum with increased production of nontraditional crops such as mint and ginseng (Craker et al., 2003). In recent years, the pace of commercialization of traditional medicines has accelerated and caused a sharp increase in demand for plants in the local and world markets (Singh et al., 2007). Eventually, plant sources from the wild will be depleted and more sustainable methods must be implemented. Propagating medicinal species has been on the increase and positive benefits are assured standard quality of compounds and replacement of endangered plant populations (Purohit and Vyas, 2008).

PROPAGATION OF MEDICINAL PLANTS

Propagating medicinal plants is on the rise due to the interest of people who want products of natural origin. The push for alternative medicines and the limiting use of pills is an indication of the current "green movement." The real indicator of this trend is the current buying of high-quality products from local markets. Small-scale cultivation, which requires low economic outputs, can be a response to non-existent or declining wild stocks, generating income, and supplying regional markets. Growing operations are increasingly a focus of medicinal plant propagation and introduction programs intended to encourage the use of traditional remedies for common ailments by making the plant sources more accessible to the public (Shippmann et al., 2002). Two approaches for growers of medicinal plants are field-grown plants and container-grown plants. Field plants are grown for specific compounds utilizing plant parts or whole plants. This is done on a commercial level that may require special equipment for propagation, planting, harvesting, and processing. Container-grown plants are more suitable for retail and wholesale operations. Most plants can be propagated easily from plugs, seeds and cuttings supplied by commercial propagators, seed companies, and local stock. Many plant species like mints, and other popular perennial species are probably already in production programs, but need to be marketed as medicinal plants.

CHALLENGES TO PROPAGATING MEDICINAL PLANTS

There are many challenges to propagating medicinal plants, one being the limited knowledge of growing and propagating wild species. When propagating from seed there are usually dormancy issues, low or sporadic germination, and longer growing time to maturity. Stratification, the artificial emulation of environmental conditions required for seed germination such as soaking or chilling, can sometimes provide the key to success. In *Panax quinquefolius* (American ginseng), the use of a controlled environment substantially shortens the stratification period required, increases germination rate and seed viability, and enables seed germination any time of year (Canter et al., 2005). Because many of these plants are species and are found in the wild, there is limited plant material for seed and vegetative propagation. Also, many species are very difficult to root from cuttings, requiring hormone treatments.

RECOMMENDATIONS

In order to propagate and grow wild medicinal plant species, growers need to create their own stock plants or seed banks. Many of these species are very difficult to transplant or develop so utilization of wild stock plants is feasible. A special type of cultivation of medicinal plant species is the so-called quasicultivation. This means a sustainable utilization of natural populations by intervention in propagation and harvesting (Yaniv and Bachrach, 2005). One endangered harvested forest plant, *Actaea* (syn. *Cimicifuga*) *racemosa* (black cohosh) is one species currently being studied in the wild for the use of such sustainable intervention to maintain its natural populations. An easier method for obtaining propagation material is contacting native nurseries that grow wild species exclusively. They are set up for long-term growing of these plants and would be a valuable source of knowledge. Experimenting with seeds and cuttings would be another way to learn and become proficient at growing wild plant species. Try propagating easily grown plants like mints. There are many sizes and shapes of plants in the Lamiaceae family that could fit well into the medicinal plant market. Finally, go out and observe the various growing habits and environments of medicinal plants. Some plants could root from natural layering of pendulous branches that can be reproduced in the nursery. Research for this purpose should include determining the suitability for the propagation, cultivation of various plant species under different climates and soils, plant identification, time of planting and method of planting, fertilizer and irrigation requirements, and weed, insect and disease control (Singh et al., 2007).

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Seed Collections and Documentation: A Propagator's Perspective©

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There are many techniques for propagating woody plants. I am going to talk about an aid to the traditional way of growing seed, the digital image. This is the fusing of digital seed imagery to part of the protocol in plant production work, research, education, and propagation. This can be a positive step in ensuring the virtual preservation of plant material, and an increase in plant knowledge with insights in morphology, phenology, and even cytology.

Before the growing season begins, I photograph the taxa I will be sowing (Fig. 1). I do this for two reasons — one, I am building a visual virtual propagule database, detailing and magnifying the diversity of seed shape, color, and size. I cannot always commit this to memory. And two, I am also able at times to visually pinpoint disease or other phenomena in these seed batches.

They may not germinate, or they may demonstrate some kind of unusual quality that becomes worthy of documentation. This kind of digital capture gives me more clues to the seed, as well as additional information that may be interesting, beneficial or germane to colleagues. This image-based component is one part of a puzzle that needs to be studied and implemented in various manners. Of course this could also go hand-in-hand with lab testing for seed viability, germination and vigor. But a high resolution image leaves behind a visual record for future study.

In the digital lab, I use three separate photo stages. The stages depend on the size of the seed or fruit, the larger the seed, the larger the copy stand. The standard procedure I employ is to photograph a seed; a group of seeds; seed plus fruit; and any anomalies that might be present or that may need further imaging at closer magnification. When seeds of closely allied species are available, comparisons of these are photographed as well. This is a quick, visually precise, and in no way a cost prohibitive routine. The equipment and supplies necessary for this type of project could easily be integrated into any existing protocol, or procedural methodology within the propagation, and nursery industry.

I have imaged over 1,000 seed species from 35 genera, including digitally documenting the seed of the Arnold Arboretum's seven North American Plant Collection Consortium collections (NAPCC). Here genus and species are observed and conserved. The evolution and development of my digital imaging seedwork comes from various assignments — collections of historic value, rare and endangered seed, native and nursery seed, as well as the capturing of seed for research purposes.

These images create online access with documentation, a digital voucher of an image, one directly tied to an identified specimen, able to be viewed, studied, and visually dissected at any time. Along with this, a hard copy of archival images could be maintained as well. These image datasets could be uploaded to mobile devices with apps producing millions of scientific interactions.

Maybe the genetic integrity of a collection batch was at stake? Possibly just the presence of too much chaff and not enough seed was the answer? What does the seed look like? The visual image of a seed can be vital to the engineering of its

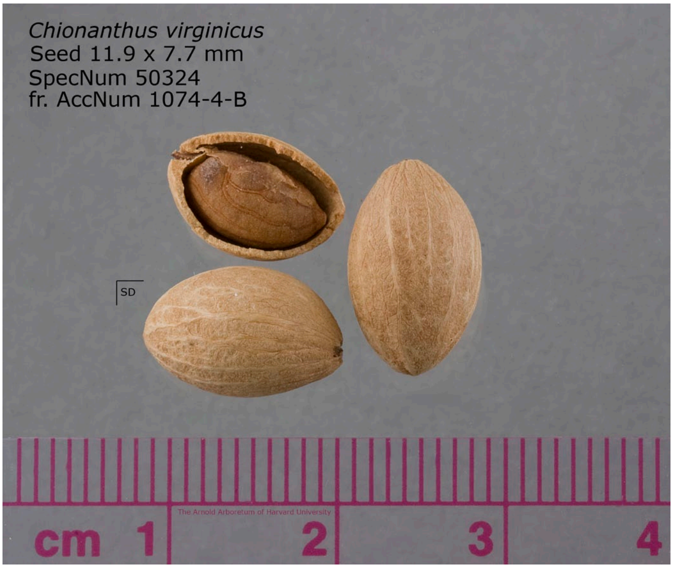

Figure 1. Digital seed image of *Chionanthus virginicus*.

use. With this in mind, the prospects of seed image cross sections, with lateral and transverse views, work in swaths of genera to create functional visual databases.

The possibilities exist with seed imaging to document clonal relationships between seed, and even the possibility of color relationships between seed and flower. Seed images would be a benefit to seed science. Having an accurate digital image online could reduce the need of sending specimens back and forth. And by attaching accompanying documentation, such as provenance, accession, specimen numbers, and qualifiers this extensive data, through a plant collections system, could be available. This would aptly facilitate information-sharing, linking the images of seed with data, including those seed demonstrating disease-damaging characteristics.

I think that incorporating propagule digital photo technology as an adjunct to phases of procedure and protocol in the plant sciences, nursery work, and education, will aid in verification of collections, documentation of morphology, the creation of a new diagnostic tool, as well as help to verify seed shipments. This could be a positive step, with enormous importance to ornamental horticulture.

Seeds ubiquitous in nature are neither standardized, nor uniform. Like snowflakes each one is different. With these qualities in mind, I developed a system with a simplified schema so that users could easily get the visual information they are looking for.

Do Chinese Ashes Offer Hope in Combating Emerald Ash Borer?©

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THE PROBLEM

The emerald ash borer (EAB), *Agrilus planipennis*, was found in Detroit, Michigan, in July 2002. It established there and developed into a highly invasive pest within the urban landscape of Detroit. The adult beetles feed on ash foliage but cause little damage. Their larvae feed on the inner bark of ash trees, disrupting the tree's ability to transport water and nutrients. As a result, healthy trees typically die or are reduced to a suckering coppice within a few years after the initial infestation.

Emerald ash borer probably arrived in North America in solid wood packing material from freight shipped from its native Asia. While the country of origin and year of arrival have not been determined, based on initial data, it is hypothesized that EAB may have been introduced from the Tianjin City area, a large municipal zone southeast of Beijing, China. The core of infestation (southeastern Michigan and the adjacent area of Ontario, Canada) now extends over thousands of square miles, and outlying infestations have been found in 14 states throughout the central and eastern United States and southeastern Canada (Fig. 1).

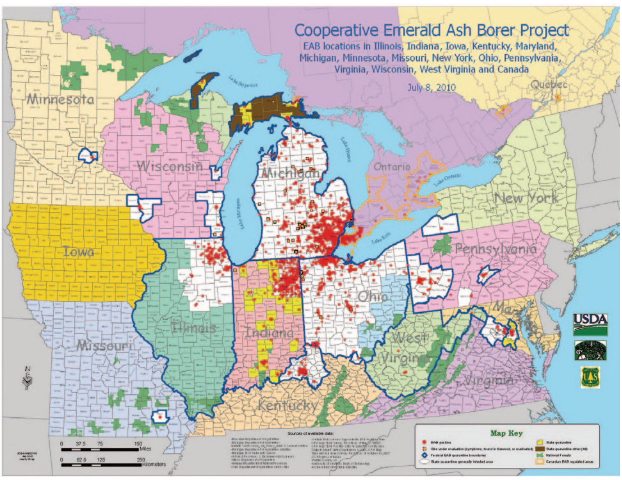

Figure 1. Current emerald ash borer infestation zone, as of 10 Sept. 2010.

To date, it is estimated that over 40 million ash trees have been killed by this pest and there are an estimated 8 billion ash trees currently growing in the U.S. It appears that no North American ash species is resistant to this pest, although researchers have found a few individual trees in heavily invested EAB zones that remain alive with minimal infestation. These trees are being propagated to determine if they possess some level of genetic-related resistance.

This insect's impact has cost municipalities, property owners, nursery operators, and the forest products industry tens of millions of dollars. Each year as the infestation spreads, losses continue to build. Because ash are relatively easy to grow and are tolerant of typical urban conditions, they are commonly planted. Ash accounts for 5%–20% of all street trees in many Midwestern and Canadian cities. For example, 14.4% of the leaf cover in Chicago is made up of the city's 600,000 ash trees (Nowak et al., 2010). Green ash (*Fraxinus pennsylvanica*) is an especially useful tree for urban planting because of their general tolerance to salt, drought, compaction, and pH. However, the popularity of cultivars in the urban landscape has resulted in near monocultures that increase both the risk and the impact of EAB damage. The loss of ash trees has and will continue to affect nursery production and tree sales.

THE POTENTIAL VALUE OF CHINESE ASHES

In China, EAB is usually a secondary or periodic pest on the few species that have been studied, infesting only stressed trees and not necessarily resulting in tree mortality. There are several Chinese ash species where no information regarding EAB resistance is established. Most outbreaks in China have been associated with urban and restoration plantings involving North American species. Both green ash and velvet ash (*F. velutina*) have been extensively planted in many northern Chinese cities.

There are 22 *Fraxinus* species listed in the Flora of China (Flora of China, 1996). Some of these species are tropical, and not suitable for regions of the U.S. currently under siege by EAB, but are of potential utility for expanding the range of ash adaptation or for responding to EAB, should the pest adapt to tropical or subtropical areas in the New World.

The identification of various Chinese ash species is difficult because no modern monograph exists. In two documented instances, seed collected by the Chinese Academy of Sciences was incorrectly identified as Chinese ash, *F. chinensis*. Not until after researchers used this material in in-depth research studies did the true identification become apparent — the plants were determined to be green ash. Similar mistakes have also been documented with seed lots imported from China by reputable U.S.A. seed companies.

For future work it is important to gain access to true-to-type plants of known wild origin. Tree species that share a long co-evolutionary history with insects and pathogens are likely to have developed mechanisms of resistance that allow them to coexist. When insects and pathogens are introduced to different parts of the world, high levels of susceptibility can be observed, presumably in part due to the lack of co-evolutionary history between the insect (or pathogen) and host. In such cases, use of non-native tree species as a source of resistance for introgression into native susceptible tree species can be quite helpful. Examples of successfully developing interspecific hybrids include hybrid hemlocks (*Tsuga chinensis* × *T. caroliniana*) with resistance to hemlock wooly adelgid and hybrid chestnut trees (*Castanea mollisima* × *C. dentata*) resistant to the chestnut blight (Koch et al., 2010). If first generation hybrids show good resistance to the insect (or pathogen), then a back-cross breeding program may be initiated to produce seedlings containing the introgressed resistance and the characteristics of the native parent species. This is the approach being used by The American Chestnut Foundation, and would be the model approach used to produce EAB-resistant North American ash species (Hebard, 2005).

In 2008, I had the opportunity to participate in a collecting expedition to Shaanxi Province, China, along with other staff members from institutions who are members of the North America — China Plant Exploration Consortium (NACPEC). For the first time since I had participated in five previous NACPEC-sponsored expeditions, this trip was focused on primarily collecting ash germplasm. Typically there had been too many other *more exciting* species and there was no cause to focus on ash.

Shaanxi Province is located in north-central China. This expedition involved collecting in the north side of the botanically rich Qin Ling mountain range. We collected several thousand seeds of five *Fraxinus* species including Pax's ash (*F. paxiana*), island ash (*F. insularis*), Manchurian ash (*F. mandshurica*), Chinese ash (*F. chinensis*), and Chinese flowering ash (*F. stylosa*) — several of these species are poorly represented in the U.S. For example, Pax's ash and island ash are being grown at only two or three botanical institutions. We made several collections of these species, along with Chinese ash, Manchurian ash, and Chinese flowering ash. Of these, Manchurian ash is probably the best known, as it is a large growing tree with an established landscape value. There is one cultivated selection of Manchurian ash, 'Mancana', and two selections which are hybrids of Manchurian ash and the North American black ash (*F. nigra*). All of these originated at the Morden Research Station, Morden, Manitoba. Of the other species, island ash and Chinese flowering ash are medium-sized trees that may have urban use potential if they prove adaptable. Pax's ash is a shrubby species that possesses extremely large flower clusters, although its landscape potential is unknown.

NEW GERMPLASM SUPPORTING RESEARCH

Efforts to control EAB are occurring via three avenues; research, eradication, and quarantine. Research is being done to develop better ways to detect new infestations, to control *A. planipennis* beetles and larvae, to test *Fraxinus* species for resistance or susceptibility to EAB, and to develop new plants resistant to EAB for landscape and forestry use.

Currently, plants from seed collected in the 2008 expedition are being used by leading researchers, including researchers at The Morton Arboretum to study EAB resistance. The plants are being used in on-going, broad-ranging studies of EAB host range and preference. Chinese, North American, and European ash species are being evaluated in leaf-feeding and longevity trials.

There is evidence of resistance to EAB in some Chinese *Fraxinus*. One study that investigated the EAB infestation history of established ash plantings in China reported that some Manchurian ash trees showed signs of past EAB infestation (old exit holes and calloused larval galleries), but were still alive and no longer showed signs of infestation. This evidence of infestation without mortality shows a certain degree of resistance or tolerance in Manchurian ash compared to North American species. Also, EAB has been shown to exist in Manchurian ash forests in China without reaching outbreak levels. This also would be consistent with the presence of resistance or tolerance genes in Asian ash, which may be a product of the coevolution of Asian ash with EAB (Cappaert et al., 2005).

Another leading researcher, Jennifer Koch from the USDA Forest Service, North Research Station, is using these seedlings to perform genetic sequencing to help understand the taxonomic relationship of the Chinese ash species to other species. The genomics of several of these species have not been previously documented. This information is important to understand the potential for new hybrids, and potentially resistant plants, to be created. Once a range of resistant genotypes is identified, they can go a long way toward preserving the horticultural market for ash in the urban landscape. Identifying appropriate genetic material to create new North American-Asian ash hybrids that combine resistance genes from the Asian species with useful characteristics from the North American species is an important way of maintaining our ability to use ash in the landscape by creating resistance to this EAB without the use of expensive and ineffective pesticides. Additionally, Asian ash may prove to be a useful introduced species if hybrids are not successful. Many of the Asian ash species I observed in China were growing in highly favorable growing conditions. They may not possess the urban tolerance to be considered broadly adaptable on their own. Clonal production of these plants should be relatively easy. *Fraxinus* express a high degree of graft compatibility with different species successfully grafted onto one another. Typically, nearly all cultivated ash selections are grafted onto green ash due to its vigor and environmental tolerance. Whether an EAB-resistant Asian species can be successfully grown for the long-term on an adaptable, yet EAB-susceptible rootstock, like green ash, is an area for future testing.

IN CONCLUSION

It is still too early to understand the full impact EAB has had on North American ashes, but the prospects appear ominous. Considering the resistance demonstrated by Manchurian ash it is highly likely that resistance is held by other Asian ash species as well. Asian ashes are critically important to determine the full range of EAB response and to assess the adaptation of Asian ash species to American conditions and their appropriateness for urban landscapes and U.S. forestry uses.

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Recent Magnolia Exploration in China©

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University of British Columbia (UBC) Botanical Garden is a university botanical garden located in the mild maritime climate of Vancouver. Along with maples, mountain ash, styrax relatives, and woody climbers, magnolias represent one of our more valuable and important collections. Our collections policy states that we should:

- Maintain a balanced and representative collection of global plant diversity, subject to the limitations of site, space, soil, and climate.
- Give priority to plants of known wild origin, recorded provenance, and known pedigree (in the case of cultivated plants), and to maintain their documentation by means of record keeping to a high standard.
- Serve the current scientific needs of researchers at UBC.
- Grow educationally useful plants, principally to serve the needs for live material of UBC undergraduate and postgraduate courses, but also to serve the needs of our community education programs.
- Maintain collections of rare and endangered plants for conservation and education.
- Include in the collections some plants of such aesthetic appeal that they refresh the human spirit, where this is possible without compromising any of the aforementioned principles.

There are about 150 individual magnolias in UBC Botanical Garden's collection, representing about 115 accessions and 90 different taxa. Accessions are represented as individual records in the database. The 90 magnolia taxa consist of species, subspecies, and varieties, and we also grow a number of cultivars, as well. Only about 25 individual specimens are known to be of wild provenance.

Our wild-provenance accessions include the following evergreen and deciduous magnolia taxa:

Evergreen	Deciduous
M. aromatica	*M. campbellii* subsp. *campbellii*
M. cavaleriei	*M. cylindrica*
M. chevalieri	*M. fraseri*
M. fordiana var. *fordiana* (syn. *M. yuyuanensis*)	*M. obovata*
M. maudiae	*M. sieboldii*
M. sinica	*M. wilsonii*
M. yunnanensis	*M. zenii*

Close to 100 species of evergreen magnolia are native to China, the majority to southern China. Obviously, not all Chinese magnolias are cold hardy at UBC, but many are, including some species from surprisingly subtropical areas. We've tried *M. delavayi* on three or four occasions without success. And *M. guangdongensis*, is not your average magnolia foliage. It is not in cultivation in the West.

Last year I had the pleasure of seeing some of the last remaining specimens of *M. sinica* in the wild, growing in a protected area in southern Yunnan. A group of us visited this area following the second Magnoliaceae Symposium that was held at the South China Botanical Garden in Guangzhou, Guangdong Province, China. At the symposium, delegates were introduced to the influence of Liu Yu-Hu, the father of Chinese Magnolia taxonomy. Lui modified and popularized (at least in China) a system originally codified in 1927 by James Dandy of the British Natural History Museum, which describes about a dozen different genera in the Magnolia family. Recent molecular analyses suggest that the segregates (other than *Liriodendron*) don't deserve generic rank; however, most Chinese authors still recognize the Dandy-Liu system. At the symposium, we were treated to vigorous debates between proponents of the Chinese system and the more conservative system of Figlar and Nooteboom. Through his involvement with the Magnolia Society, Dick Figlar has done more to popularize the science of magnolias and to champion the two-genus system than anyone before him.

Increasingly, UBC Botanical Garden has been using the following protocols in the acquisition of seed from wild magnolias in China. The first stage includes the identification of target species, the identification of academic partners in China who are actively doing taxonomic research, and the securing of funding for expeditions. Stage two is mainly springtime reconnaissance. This is primarily finding and recording location and other data on flowering plants, from which seed can be collected later, and assisting of our partners on site in whatever collecting they might be doing, such as tissue for DNA, herbarium specimens, etc. The final stage involves returning to the site in the autumn to collect, or if not possible, to support collecting of seed by partners in China.

Going to China to collect is always an adventure. China is a vast country, with varied terrain and a diverse magnolia flora. Areas such as western Sichuan close to Tibet are typical of the areas that still have deciduous magnolias in the wild: steep and often inaccessible. Andy Hill, curator of the David C. Lam Asian Garden at UBC is following in the footsteps of Peter Wharton, former curator of the Asian Garden at UBC. Peter certainly had the collecting bug. In all, he visited five provinces of China on nine separate occasions. Andy is currently on his fourth trip to China. Magnolia terrain is not always difficult, but because of habitat destruction, over harvesting, and collecting, specimens are getting harder to find.

Locals are enlisted (often encouraged with money or cigarettes) to help find significant, flowering individuals that may be in areas away from roads. Sometimes, the guides are very young. For our collecting, we usually travel with scientists such as Dr. Shouzhou Zhang, Director and Head of Landscapes at Fairylake Botanical Garden, Chinese Academy of Sciences, who are members of the Academy. The Chinese Academy of Sciences is a federal institution and such official work is not generally subject to delays and petty bureaucracies.

Many conservation challenges are likewise, collecting challenges. Some of those collecting challenges include:

- Habitat destruction
- Local over-harvesting
- Over-collecting
- Shrinking genetic diversity
- Access problems
- Lack of expertise

For example, *M. officinalis* is stripped for its bark, which is valuable in Chinese folk medicine. The flower buds of this species are also harvested for medicinal uses. Incredibly, wealthy landowners now pay to have large magnolias dug and moved to their estates. Luckily, DNA can be extracted from frozen flower parts.

Seed of Yulania magnolias can be collected in late summer or fall as soon as the fruits turn red and start to split. Magnolia seeds spoil quickly because of their oily seed coat, but dry out quickly if the seed coat is removed. Before shipping, we remove the seed coat and pack the seeds in slightly damp strips of newspaper. A very mild bleach solution is used on all packing materials. All seed, herbarium material, and tissue for DNA extraction are the property of the Chinese hosts. It is through their work with Chinese regulators as well as their goodwill that any of it arrives in North America. With luck, and by collaborating with our partners both outside and within China, we will continue to share in the wealth of Chinese magnolias and to contribute to their conservation.

The New England Invasive Plant Center©

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INTRODUCTION

The New England Invasive Plant Center was initiated in 2006 through a grant from USDA CSREES (Cooperative State Research, Education, and Extension Service). The University of Connecticut (UConn), the University of Vermont (UVM) and the University of Maine (UMaine) have established a multi-state, interdisciplinary program to develop novel and effective technologies to address problems caused by invasive plants that are economically and environmentally damaging to New England and to the nation as a whole. The Center faculty and staff provide expertise in the areas of horticulture, plant breeding, plant biotechnology, plant ecology, plant physiology, plant biochemistry, agricultural economics, and extension education. The main objectives of the Center are: (1) Development of non-invasive sterile landscape plants; (2) Assessment of the economic impact of invasive species in New England; (3) Development of alternative native crops; and (4) Public education and outreach. More information on the New England Invasive Plant Center can be accessed at: <www. invasivecenter.uconn.edu>.

INVASIVE SHRUB CULTIVAR EXEMPTIONS

As a first step in moving the nursery industry away from the production of invasive ornamental plants, the Center has focused a significant effort on determining if there are meaningful differences in seed production among cultivars of certain invasive species of high economic value. Generally, invasive plant bans have been made at the species level and have included all genotypes, including horticultural forms of the species. Frequently cultivars appear to be significantly different from the species in the manner in which they grow and reproduce. If some cultivars of an invasive species are less reproductively potent than the species, there may be opportunities to create specific cultivar exemptions to plant bans.

We have studied *Berberis thunbergii* and *Euonymus alatus* cultivars to determine if cultivars vary substantially from the species in their seed production. In addition we have compared the seed production of *Buddleja* Lo & Behold® 'Blue Chip' PP #19991 to other standard cultivars to determine its relative seed production. So far, this line of research has resulted in the Connecticut Nursery and Landscape Association successfully establishing a voluntary ban on 25 highly prolific barberry cultivars. The voluntary ban precluded a legislative ban on all barberries and allowed the continued use of some of the more important barberry cultivars for the nursery industry. The 'Blue Chip' butterfly bush data was instrumental in helping to get a cultivar exemption amendment put in place in Oregon's *B. davidii* ban.

DEVELOPMENT OF STERILE FORMS OF INVASIVE SHRUBS

Efforts here have been focused on developing sterile *B. thunbergii*, *B. davidii*, and *E. alatus*. Because *E. alatus* has endospermic seeds, the approach with this species has been to isolate 3n endosperm from seeds and grow triploid callus. Shoot organogenesis can be achieved and then triploid shoots can be rooted, acclimated and grown out for evaluation of horticultural and sterility characteristics. We currently have triploid plantlets of *E. alatus* that are being grown on for evaluation. For barberry, the approach has been to create 4n tetraploid plants using mitotic poisons. The tetraploid plants could then be crossed to 2n diploid plants to create 3n triploid plants that should be sterile. Numerous tetraploid barberries have been produced in both purple-leaved and yellow-leaved plants. To date, tetraploid barberries we have created have exhibited very low fertility, in comparison to diploid controls, or sterility. *B. davidii* is a natural tetraploid (4n), so in order to make crosses to create potentially sterile triploids, our plan was to produce dihaploids (2n) that could be backcrossed to standard tetraploid butterfly bushes. We successfully created dihaploid *Buddleja* by using irradiated pollen to trigger seed development from unfertilized eggs. The dihaploid plants have proven to be completely pollen and egg sterile, so for breeding purposes they represent a dead end. We are still evaluating the plants to determine if they have any horticultural value "as is" as sterile butterfly bushes.

NATIVE SHRUB EVALUATION AND DEVELOPMENT

One aspect of this work is to evaluate native shrubs for use in challenging landscape situations where invasive shrubs, such as Japanese barberry and winged euonymus, have been used. The emphasis is on native shrub species that are currently "not on the radar screen" and for which little information exists about suitability for use in difficult landscape conditions. Species under evaluation are planted in large replicated experiments in parking lot islands, along with barberry and euonymus, and are studied for a minimum of 3 years to evaluate establishment and durability of a few seasons.

Some native shrubs are studied in a more specific way. For example, *Physocarpus opulifolius* has recently experienced a dramatic increase in popularity due to the development of purple-leaved and yellow-leaved cultivars. With increased use, came increased disease problems and powdery mildew is now recognized as a significant limitation for *Physocarpus*. Using replicated and controlled studies we were able to determine that substantial differences exist among ninebark cultivars for resistance to powery mildew infection. Specific recommendations can be made regarding which purple, yellow, and green cultivars are the most resistant to mildew. Furthermore, we were able to recommend specific germplasm that should be used by plant breeders who are attempting to breed mildew-resistant, compact, purple-leaved cultivars.

Our native shrub breeding has targeted *Aronia* as a genus of interest because it produces showy flowers, colorful fruit, and excellent fall color, all on a plant that exhibits wide adapability. We believe that a solid breeding program is most easily achieved when there is access to a large and diverse germplasm base. To achieve this, we have collected over 150 accessions of *A. arbutifolia*, *A. melanocarpa,* and *A.* ×*purpurea* from as far south as Texas, Alabama, and Florida, and as far north as Ontario (Canada), Minnesota, Wisconsin, and Maine. We have also collected diploid, tetraploid, and triploid forms of the various species. When possible, seed collections have been added to the National Germplasm collection in Ames, Iowa. Initial crosses using some of the unique germplasm we have collected appears to have yielded attractive, compact forms of *Aronia* that would make this plant more appealing as a landscape plant.

ECOLOGICAL RESEARCH

One of the questions that we have been trying to answer is "where are specific invasive shrub species most likely to invade." Using demographic modeling, our ecologists have been able to suggest where plants such as winged euonymus, Japanese barberry, and oriental bittersweet are most likely to spread to over the next decades. We are also attempting to use similar demographic models to get a better handle on the consequences of using specific landscape cultivars of barberry that produce limited amounts of fruits.

Amplified fragment length polymorphism (AFLP) fingerprinting has been used to determine to what degree purple-leaved barberry genetics have integrated into populations of invasive barberry found in New England. While it was possible to find wild plants that must have crossed with, or originated from purple barberries, they were not particularly numerous. DNA marker techniques were also useful to document how a barberry invasion could progress from a cultivated purple-leaved cultivar used in a residential landscape.

JAPANESE BARBERRY SYMBIONTS

Little is known about the relationship between invasive plants and their symbiotic partners and any related success/control of plant invasions in natural environments (van der Putten et al., 2007). This is despite finding that symbionts may promote stress tolerance, enhance nutrient uptake, assist with general suppression of pathogens, and potentially serve as natural enemies (Roderiguez and Redman, 2008; Rosenblueth and Martinez-Romero, 2006). Symbiont research is focused on a fruit fly (*Rhagoletis meigenii*) and its potential as a biological control agent as well as soil biotic factors which may contribute to the invasiveness of Japanese barberry, especially in Acadia National Park, Maine.

Tephritid fruit fly larvae of *R. meigenii* consume at least one of the two seeds in Japanese barberry fruits during larval maturation. This relationship is being investigated regarding reductive effects of the fly population on the quantity and viability of seeds produced by infected plants. Fruit infestation rates and fly diversity are currently being studied along with the number of endosymbiotic *Wolbachia* bacterial strains found in the fly populations. *Wolbachia* infections are known to affect fly reproductive rates and population biology and thus, ultimately affect the number of Japanese barberry seeds consumed by the fly, annually. Wolbachia strains may be exploited for these properties.

A broad-scale gene sequencing approach is also being used to identify the fungal and bacterial species found in the root zone soil of Japanese barberry plants in Acadia National Park. Bacterial and fungal species common throughout the different soil types are of particular interest. These data will potentially allow for identification of species that may confer a competitive advantage to the invasive plant relative to native plant species.

CONSUMER EDUCATION AND INDUSTRY OUTREACH

Sharing information developed by the Center's faculty and staff is a primary component that is necessary for achieving the goals of the Center. The Center has sponsored and co-sponsored many conferences on invasive plants, many of which attract hundreds of attendees. We have also sponsored an International Symposium that brought together Asian and North American invasive plant researchers to formulate better ways to create solutions to invasive plants in the East and the West. Additional outreach efforts have involved high school students, Master Gardeners, and the gardening public.

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Development of Seedless Taxa of Popular Invasive Landscape Plants©

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INTRODUCTION

The University of Minnesota Department of Horticultural Sciences has a long tradition of plant breeding and improvement of landscape plants. Our efforts balance the development of new plant introductions with mission-oriented research to solve problems and curiosity-driven discovery. Several publications review the history and productivity of the department's programs (Meyer, 2000; Davis and Gregor, 2008; West, 2009; <http://www.extension.umn.edu/>). This article will focus on our research efforts to produce non-invasive selections of popular plants used in the nursery industry.

Reichard and White (1997) define an invasive plant as "one that has or is likely to spread into native flora and managed plant systems, develop self-sustaining populations, and become dominant or disruptive (or both) to those systems." Invasive species are a primary threat to biodiversity on the planet, second only to habitat destruction, and are one of the least reversible of all human impacts on the environment. An invasive plant is one that is likely to spread to new areas and develop self-sustaining populations, which may disrupt the invaded ecosystem. Many non-native invaders have been intentionally introduced to new areas for cultivation as ornamental plants. The enthusiasm of growers and consumers for novel ornamental plants drives plant breeders and others to develop cultivars from non-native species. Several characteristics contribute to invasive potential; however a major determinant for many invasive plants is seed production. Plants that are sterile, or cannot set seed have a greatly reduced invasive potential. We discuss here two broad strategies to produce non-invasive selections of invasive plants using two approaches: biotechnology and mutagenesis breeding. An essential factor for the application of either strategy is that the aesthetic quality and horticultural characteristics of the plant are maintained or improved.

INVASIVE PLANTS AND THE GREEN INDUSTRY

The harm caused by invasive plants can be economic and ecological. Although many of the non-native invasive species thriving in North America were introduced many years ago, the enthusiasm for novelty by gardeners makes plant collection and introduction profitable for growers of woody and herbaceous plant material. Continued interest in development of novel landscape species of both herbaceous and woody types has led to a dramatic increase in the number of cultivated species offered by the vegetative and seed industries (Janick, 1999). The green industry has historically been a significant contributor of invasive plants (Wells et al., 1986). Many popular invasive landscape plants are still being produced and sold today.

Most cultivated horticultural species lack the ability to compete with native taxa and their continued existence in the landscape depends on remaining in cultivated sites. The majority of important horticultural crops do not develop into noxious weeds, despite worldwide cultivation for centuries. Although only a small proportion of introduced or cultivated plants become invasive, the few that have become established outside cultivation can have significant environmental and economic impacts (Ruessink et al., 1995; Ewel et al., 1999). Examples of ornamental invasives inherently invasive or that have become invasive through adaptation or hybridization are shown in Table 1.

Table 1. Examples of ornamental invasives (inherently invasive or that have become invasive through adaptation or hybridization) [(Amrine and Stasny, 1993; Archibold et al., 1997; Carr and Crisci, 1988; Deering and Vankat, 1999; Egolf, 1970; Goldblatt and Raven, 1997; Hickman, 1993; Lindstrom et al., 2002; Pooler et al., 2002; Pyšek et al., 1995; Randall and Marinelli, 1996; Raven and Gregory, 1972; Westbrooks, 1998)].

butter and eggs	*Linaria vulgaris*
butterfly bush	*Buddleja*
Chinese privet	*Ligustrum sinense*
cleome	*Cleome hassleriana*
fountain grasses	*Pennisetum purpureum, P. polystachion, P. pedicellatum, P. setaceum*
giant hogweed	*Heracleum mantegazzianum*
hibiscus	*Hibiscus syriacus*
honeysuckles	*Lonicera maackii, L. morrowii, L. tatarica, L. japonica*
Hottentot fig	*Carprobrotus edulis*
Japanese knotweed	*Fallopia japonica*
jimson weed	*Datura stramonium*
kochia	*Kochia scoparia*
lantana	*Lantana camara*
Mexican mint	*Agastache rupestris*
oxeye daisy	*Leucanthemum vulgare*
pampas grass	*Cortaderia selloana*
perennial sweet pea	*Lathyrus latifolius*
purple loosestrife	*Lythrum salicaria*
Scotch broom	*Cytisus scoparius*
some maples	*Acer tataricum* subsp. *ginnala, A. platanoides, A. pseudoplatanus, A. negundo*
sunflower	*Helianthus annuus*
tamarix	*Tamarix ramosissima, T. chinensis, T. parviflora*
teasel	*Dipsacus laciniatus*
verbena	*Verbena bonariensis*
wild rose	*Rosa multiflora*

STERILITY TO ELIMINATE INVASIVENESS

Invasive plant species spread via sexual (seed) or asexual (vegetative) propagules. Invasive terrestrial plants are predominantly seed dispersed (Moreira, 1975). *Rhamnus cathartica,* formerly among the most popular landscape ornamentals and now one of the most infamous terrestrial invasive plants, can establish large seed banks with approximately 620 seeds/m^2 beneath mature shrubs (Archibold et al., 1997). It is likely that the high seed set of this and other species contributes greatly to their invasive potential. Seedlessness is therefore a target for reducing or eliminating invasiveness. Sheppard et al. (2002) theorized that a 62% reduction in *Cytisus scoparius* seed set would suppress spread in native grasslands. We are developing methods to minimize or eliminate seed production via genetic mechanisms and thereby prevent invasiveness of valuable landscape plants with invasive potential.

Sterility is also useful in preventing pollen production to reduce allergies (Ogren, 2003). In landscaping, male plants of dioecious crops are used to prevent messy fruit production in gingko (*Ginkgo biloba*) and kiwi [*Actinidia deliciosa* (syn. *A. chinensis*)]. Conventional breeding can create sterility in only a fraction of all crops, sometimes by crossing parents with different ploidy levels (tetraploid × diploid, 4x × 2x) to create sterile triploids (3x). Sterility must not interfere with the ornamental qualities (floral, foliar, etc.) conferring market value. Examples of plants where ornamental quality was not sacrificed in order to achieve non-invasiveness include sterile aspen, cottonwood, and pine trees that maintain their ornamental qualities and may have increased growth rates (Eis et al., 1965; Rishi et al., 2001).

GENETIC MODIFICATION FOR STERILE PLANT PRODUCTION

Genetic engineering of male and female sterility to reduce invasiveness can have broad applicability to many potentially invasive species. Broad applicability is a critical consideration when selecting a strategy to prevent invasive species in an industry where thousands of diverse genera have been introduced and are cultivated (Havey, 2004). Genetic engineering of plants for sterility can be accomplished without greatly altering the inflorescence or flower phenotypes in landscape crops.

Our goal is to use genetic engineering to produce sterile alternatives of well-known cultivars using a strategy to prevent the development of specific tissues in the pistil and the stamen that are required for seed production. This method uses the targeted expression of a cytotoxic gene to specific organs or tissues essential to reproduction. Both RNase-T1 from *Aspergillus oryzae* and barnase from *Bacillus amyloliquefaciens* have been used to prevent the development of specific reproductive tissue to cause sterility (Gardner et al., 2009). The key to producing sterile plants with a cytotoxic gene is targeting the gene to specific reproductive tissue. Fortunately, many reproductive and tissue-specific regulators are available with floral-specific expression. The ability to block the cytotoxicity of barnase using the inhibitor protein barstar (also isolated from *B. amyloliquefaciens*) is very advantageous. In an elegant set of experiments, Mariani et al. (1992) showed that expression of barnase in the tapetum caused male sterility, which could be reversed by hybridizing with plants that carried barstar gene.

Several male- and female-specific regulatory genes with stringent regulation have been isolated. For male sterility, the *Solanum esculentum* (syn. *Lycopersicon esculentum*) stamen-specific regulator from a gene (108-CRP; Aguirre and Smith, 1993; McNeil and Smith, 2005) was selected. Female sterility was accomplished using a pistil-specific regulator in combination with the barnase gene to prevent the development of tissue essential for female reproduction. The SP41-related DNA sequence from *Nicotiana tabacum* 'Samsun' that drives expression specifically in styles (Sessa and Fluhr, 1995; Gardner et al., 2009) was used. The introduction of the male- and female-sterility genes into *N. tabacum* demonstrated that this combination of genes produces sterile plants (Gardner et al., 2009; and Fig. 1). The male-sterility gene inhibits pollen development very early. Introduction of the female-sterility gene resulted in a necrotic stigma that prevents pollen adherence and germination. The introduction of these genes is applicable to decreasing invasiveness through production of sterile plants. These data demonstrated the effectiveness of the strategy that prevents the development of essential tissue for male- and female-sterile plant production.

MUTAGENESIS BREEDING FOR STERILE PLANT PRODUCTION

Mutagenesis breeding is a variation of conventional plant breeding, where whole plants or their propagules are exposed to a mutagenic agent resulting in chromosomal mutations, some of which will result in sterility. In general, mutations provide plant breeders with a diversity of plant phenotypes. Our research tested the efficacy of γ-radiation mutagenesis with previously untested species to induce sterility. Sterility is achieved by exposing cells to high energy radiation and disrupting chromosome structure, or altering the number of chromosomes within cells, thereby preventing homologous pairing during meiosis. Chromosome structure can be altered in the form of deletions, additions, translocations, inversions, and rearrangements (van Harten, 1998).

Many mutagenic agents, including chemical and physical (radiation) agents have been tested and descriptions of their origin and use in plant breeding have been thoroughly reviewed (van Harten, 1998). X-radiation and γ-radiation are highly ionized, penetrating forms of radiation that are similar with respect to inducible mutation frequency, and are the most efficient systems for producing high frequency mutations in plants (Evans, 1960; Gunckel, 1957). Mutations including increased disease resistance, novel variegation, reduced lodging in grain crops, and sterility have been induced in a wide variety of crops using γ-radiation mutagenesis, and over 1800 mutant varieties have been released (Osborne and Lunden, 1961).

The type of propagule used, and the dose of radiation applied in a mutagenesis breeding project depends largely on the specific objectives of the project as well as the plant material and resources available. Seeds, vegetative propagules (dormant buds, stem cuttings, scions), pollen, and tissue culture callus are all suitable targets for irradiation experiments and each have their own advantages and disadvantages; seeds were the propagules selected for this study.

Seeds require very little preparation or space during irradiation, are easily stored, and can be directly sown into the field. These conveniences allow for irradiation of large numbers of seeds leading to a greater chance of finding a desirable mutant. However, in highly heterozygous crops, such as many woody perennials, there is often little chance that seeds will share all of the valuable phenotypes of their cultivated parent, so the selection of a desirable phenotype which carries all of the induced mutations of interest could be onerous.

Choosing efficient radiation doses to induce mutations can be determined systematically. Doses are selected that induce a high frequency of mutations while limiting lethality. A variety of factors including seed moisture content, dormancy stage, physical structure, chromosome size, and chromosome number can affect sensitivity to radiation, which makes *a priori* predictions about the sensitivity of plant material to radiation inexact (Konzak, 1957; Lunden, 1964; Sparrow et al., 1968).

The ornamental horticulture industry would benefit greatly from non-invasive taxa of *A. platanoides* 'Crimson King' and 'Emerald Lustre' and *A. tataricum* subsp. *ginnala* 'Compactum'. The sale of *A. platanoides* is prohibited in Massachusetts and is closely regulated in Connecticut. All of these species are also considered in-

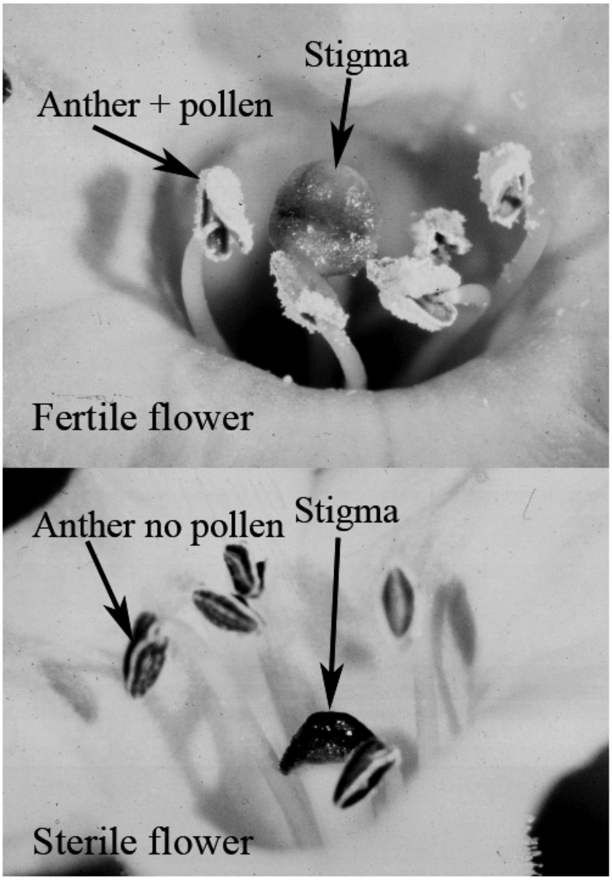

Figure 1. Photograph of a fertile flower (top photo) versus a sterile flower (bottom photo) of *Nicotiana tabacum*. The sterile flower is the result of introducing the male- and female-sterility genes into the plant. The male-sterility gene inhibits pollen development, which prevents pollen production. The female-sterility genes prevent full development of the stigma resulting in necrosis and the inhibition of pollen adherence and germination.

Figure 2. Seedlings with novel leaf shape phenotypes. Seeds were treated with varying doses of gamma radiation. Top Left: *Acer tataricum* subsp. *ginnala*. Top Right and Bottom: *A. platanoides*.

vasive in one or more states (USDA Plants Database, 2011). These plants have high ornamental appeal and are very popular crops, valued at over 7 million dollars per year to the Connecticut horticulture industry alone (Heffernan, 2004). Prohibiting these crops would be economically damaging to the horticulture industry and detrimental to consumers who would lose plant choices. The objective of this study was to assess the radiation sensitivity of specific genotypes based on median lethal dose (LD_{50}) and use that information to produce sterile and novel selections.

All plant material was irradiated in a Mark I ^{137}Cesium irradiator to determine sensitivity to radiation and to determine the LD_{50} of each species. The applied dose rate was 537 rads/min.

Seeds of *A. platanoides* 'Crimson King' and 'Emerald Lustre' and *A. tataricum* subsp. *ginnala* 'Compactum' were collected and irradiated within 2 days. Seeds were sown directly in the field and were subsequently covered with sand and hay. Seedling emergence was measured the following spring and survival rates were calculated as the proportion of plants that emerged throughout the growing season compared to the total number of seeds planted for each treatment/replication. Due to the protracted juvenile phase, sterility will be assessed as plants mature and flower. However, photographs of novel leaf-shape phenotypes generated by mutagenesis treatments show the effectiveness of these treatments (Fig. 2). We found that doses in excess of 50 kR were lethal to both species, and are unnecessary to use during the production of sterile plants. By further assessing survival over several years, the median lethal doses will be determined. The correlations calculated between radiation dose and survival for each species will be used to increase the efficiency of irradiation treatments used during the future production of sterile plants.

CONCLUSIONS

It is unlikely that plant exploration and the cultivation of non-native plants in new locations will be discontinued. However, it is likely that as new plants become problematic because of their invasiveness, there will be self-imposed or legislative restriction on their cultivation and sale. As sexual reproduction is one of the most important factors in determining the invasive potential of ornamental plants, producing sterile cultivars is a practical strategy. After the production of sterile varieties, it will be important to assess fertility levels, reduction in invasive potential, the effects of the introduced genes on plant growth and development, and the stability of the sterility. It is also incumbent on the green industry to educate consumers on the risks of invasive plants and the benefits of using non-invasive alternatives.

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Cincinnati Zoo & Botanical Garden: Native Plant Program©

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The Cincinnati Zoo & Botanical Garden has long had a reputation as being a leader in the conservation of both flora and fauna. The goal of the Native Plant Program is the conservation, education, and promotion of native flora. This is a joint effort between the Horticulture Department and the scientists at the Center for Research of Endangered Wildlife (CREW).

Conservation of critically endangered plant species is primarily the responsibility of CREW. The labs at CREW work with a number of plant species through tissue culture and other means. Tissue can be collected in both in situ and ex situ situations. Tissue can then be placed in culture and developed.

The CREW also oversees the CryoBioBank™. Here, plant tissues are frozen at -320 °F to preserve the genetic material for future use. This genetic material is extremely important when it comes to saving our endangered species. For example, if a particular population of plant would disappear due to development, overgrazing, or other events, the genetic material could have been preserved in the CryBioBank.

The Local Flora Project is an effort to pull together all known plant records in the area and consolidate them into a database. This will allow us to better understand our history of native flora in the region and help us to preserve it in the future.

These records are from old herbarium specimens, universities, verified sightings, and other documents. These records are then inputted into a searchable data base. This consolidation will help to give us a better picture of the history of our native flora in the region.

The Cincinnati Zoo also has many of these critically endangered species on display in order to educate the public on the plight of some of our endangered native flora.

The education component is geared to both the general public as well as the horticulture industry. We educate the public by holding many talks, as well as wildflower hikes, to expose the participants to the vast diversity of native flora that we have here in the Midwest. We hope to build an interest in them of our native flora, and the associated ecosystem they comprise.

We also educate the public on current issues, such as invasive species. If a particular plant seems to be invasive in our region, we try to recommend a comparative substitute. We are also active on the Ohio Invasive Plants Council (OIFC). The OIFC is a coalition of agencies, organizations, and individuals throughout Ohio concerned about the introduction, spread, and control of invasive, non-native plants in Ohio's natural habitats. The OIPC promotes public awareness of invasive species issues and encourages land management and research to detect invasive species and prevent new invasions into natural ecosystems.

The Cincinnati Zoo & Botanical Garden also displays many species of native wildflowers. This is done, as well as to beautify the grounds, to expose our native flora to the gardening public. All species are labeled, and displayed in both naturalized as well as semi-formal gardens. It is hoped that this will encourage the gardening public to seek out these new or little known species and plant them in there home gardens.

As for the horticulture industry, we trial many native species to see which plants that may have cultivated interest that are not currently being grown or propagated in large numbers, as well as growing these plants to check the possible large-scale propagation and production of them.

If a garden worthy plant does indeed propagate well and can be produced in large numbers, we then work on the final aspect of the program promotion. We will attempt to first promote the plant to growers who may want to propagate the plant. As the plant becomes available, we will then promote the plant to the gardening public as a great plant that does need to be used more in the landscape.

One such group of plants is *Trillium*. This genus makes a wonderful garden plant. It is long lived, hardy, and forms an impressive flower display in spring. The challenge is, it is not in large-scale production. We are currently working with this plant to try to unlock some of its secrets to make it better perform in large-scale production, or get the plants to bloom size earlier.

We are looking at both horticulture practices and lab techniques to propagate this plant. Everything from finding plants that rapidly setting offsets for divisions to placing green trillium seed on agar plates in the lab is being trialed.

We hope his program will result in both more garden-worthy plants being grown and becoming available, as well as growing the demand for such plants.

New Plant Forum©

Compiled and Moderated by Jack Alexander

Presenters:

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Physocarpus opulifolius 'Donna May' ppaf First Editiions® Little Devil™ ninebark

Mark Brand
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Buddleja davidii 'Summer Skies'
Panicum virgatum 'RR1', Ruby Ribbons® switchgrass

Allen Bush
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Deschampsia cespitosa 'Pixie Fountain'
Echinacea purpurea 'Magnus Superior'
Alchemilla sericata 'Gold Strike'

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Buddleja Lo & Behold® 'Purple Haze' ppaf, cbraf
Chaenomeles speciosa, Double Take™ Orange Storm flowering quince ppaf, cbraf
Chaenomeles speciosa, Double Take™ Pink Storm flowering quince ppaf, cbraf
Chaenomeles speciosa, Double Take™ Scarlet Storm flowering quince ppaf, cbraf
Hydrangea macrophylla 'Berner', Let's Dance® Big Easy™ bigleaf hydrangea ppaf; pbraf

Brent Horvath
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Geum Cocktails™ Series 'Mai Tai' ppaf
Polemonium 'Heven Scent' pp 20,214
Sedum 'Thundercloud' 21,883

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×*Gordlinia grandiflora* 'Sweet Tea'

***Alchemilla sericata* 'Gold Strike'**

Jelitto's new *Alchemilla sericata* 'Gold Strike' is free-flowering, with grey-green, velvety leaves that are more scalloped than *A. mollis*. 'Gold Strike' has a shorter habit and has been remarkably consistent and more durable in Kentucky's heat and humidity.

Our trials have produced plantings with thick, weed-choking mounds and a lovely profuse constellation of tiny chartreuse flowering stars that have been clearly more abundant than the species. These blooms make lovely cut flowers and are especially useful as fillers, tucked-in around the base of arrangements.

The flower color combines magnificently with most colors and looks particularly lovely planted together with, *Geranium macrorrhizum, Luzula sylvatica* 'Solar Flair', and *Potentilla atrosanguinea* 'Scarlet Starlit'.

'Gold Strike' is adaptable as a groundcover or as an accent plant in sun or partial shade, only requiring evenly moist soils, and is hardy in Zones 3–8. 'Gold Strike' is available in easy-to-germinate Jelitto Gold Nugget Seed®.

Family: Rosaceae

Origin (species): Mediterranean to Caucasus

Special Features: Free flowering, bright chartreuse flowering umbels and velvety gray-green, scalloped foliage. Compact and consistent habit

History: Introduced by Jelitto Perennial Seeds in 2009. Folklore suggests that the dew drops on the leaves of *Alchemilla* could turn ordinary metals to gold

Colour: Greenish-yellow

Natural Flowering Period: June–August

Winter Hardiness Zones: Z3-8

Growth Habit: Thick weed-choking mounds

Foliage: Handsome, velvety gray-green scalloped leaves

Height with Flowers: 35 cm (14 in.)

Spacing between Plants: 40 cm (16 in.)

Soil Requirements: Any good garden soil, pH 5.8–6.8

Location: Full sun to partial shade

Use: Plant in the rock garden, front of the border or containers

Specialities: Lovely small cut flowers; first year flowering and also available as Jelitto Gold Nugget Seed®

Cultural Tips:

Grams per 1,000 Seeds: 0.476

Seeds per Gram: 2,100

Seeding Recommendation: 2 g/1,000 plants

Sowing Rate: 8 seeds per cell

Plug tray recommended size(s): 72, 128

Germination: The sowing must be kept warm (about +18 to 22 °C) [about 64 to 72 °F] and moist for the first 2–4 weeks. After this period the sowing must be kept at a cold temperature (between -4 and +4 °C) [between 25 and 39 °F] for another 4–6 weeks. It is not so important if the temperature is higher or lower during the cooling period, but the cooling period has to be prolonged because the synthesis of the germination inducer, hormone-like acid, slows down or comes to a standstill. After this cooling-period the sowing may not be immediately exposed to high temperatures. The most effective temperatures are between +5 to 12 °C [41 to 54 °F], even if germination has started. The best location for this sowing, even in March, April and May, is the open field, the cold frame, or a cold greenhouse.

Buddleja davidii 'Summer Skies'

This stable periclinal variegated selection was named 'Summer Skies' because of its bright white variegation, which appears cloud-like from a distance, and its pale colored violet-blue flowers that are reminiscent of blue sky. This seedling was selected by William Smith and Mark Brand at the University of Connecticut from a group of *B. davidii* Assorted Colors seedlings that had been exposed to ethylmethane sulfonate to induce mutations. The leaves are distinctly variegated with approximately 60%–80% of the central portion of the leaf a mid-dark green with minor sectoring of a pale green at the marginal interface. The leaf margin is bright yellow under greenhouse conditions, but is creamy white under full sun conditions. There is greater contrast between the green and white portions of the leaves than with 'Thia', Santana™ butterfly bush and the white margin is broader than that of 'Harlequin'. The white leaf margins of 'Summer Skies' have been very resistant to scorch and necrosis even in full sun. 'Summer Skies' panicles are quite long with initial terminal panicles exceeding 45 cm long by 6.5 cm wide and secondary lateral panicles approximately 35 cm × 6 cm. The panicle color is a light violet-blue which complements well with the foliage. Flowering occurs by mid-August in Connecticut and is about 2 weeks later than early blooming butterfly bushes. Plants grow to about 5 ft tall by 5 ft wide, but could grow larger in mild climates. Winter hardiness is similar to most other *B. davidii* cultivars and plants survive well in Zone 5, but with some stem dieback. Propagation by softwood cuttings is very easy and container culture is rapid.

Buddleja Lo & Behold™ 'Purple Haze' ppaf, cbraf

We are pleased to introduce the newest addition to the Lo & Behold series of dwarf, eco-friendly butterfly bush. This gem has a unique, horizontal, low spreading habit with feathery, deep-green leaves, making it an excellent ground covering plant. The dark purple-blue flowers radiate outward and downward like a purple pinwheel. It's continuous blooming and is sterile so you don't get unwanted seedlings in the garden. Developed by Dr. Dennis Werner of North Carolina State University. It is a violation of state and/or federal law to use a trademark without permission. The propagation of and/or the sale of plant parts is prohibited without a license. Patent/trademark tag and container required. USDA 5, AHS 9, 24–36 in. tall × 36 in. wide.

Deschampsia cespitosa 'Pixie Fountain'

Deschampsia 'Pixie Fountain' is a new, lower-growing Jelitto introduction, only one-half the height 60 cm (24 in.) of the ordinary tufted hair grass. It is also a marvelous long-lived, dense clump-forming, consistent seed strain with darker evergreen foliage and slightly wider upright leaves. The lovely cloud-like airy blooms appear in June on sturdy stems, opening a bright light green, and maturing to golden tan by early fall. The prolific flowering effect is noticeably enhanced by backlighting.

'Pixie Fountain' can be extraordinarily effective when it is planted in large groupings, or as an edging plant, in full sun in cooler summer climates. An open woodland setting would be preferred in warmer summer climates. The foliage of *Deschampsia* 'Pixie Fountain' self-cleans and is therefore one of the easiest of all ornamental grasses to maintain.

Mass plantings look outstanding and can be combined with *Euphorbia palustris*, *Luzula sylvatica* 'Solar Flair', and *Primula japonica* 'Appleblossom'. Flowering stems □ fresh or dried □ make nice cut flowers, too.

Deschampsia cespitosa is a species that grows in humus-rich, moist soils, even in bogs, over much of the cooler regions of north temperate portions of Europe, Asia, and North America. Our seeds of this *Deschampsia* originated from the far North, and we estimate it to be hardy in Zones 2–7 — more so than the ordinary species.

Family: Poaceae, Gramineae

Origin (species): Europe, Asia, and North America

Special Features: Brilliant silver-green, followed by golden-brown flower spikes, compact habit. Forms dense evergreen clumps. Especially cold hardy.

History: Introduced by Jelitto Perennial Seeds in 2010

Colour: Silver-green spikes fading to decorative golden-brown

Natural Flowering Period: June–September

Winter Hardiness Zones: Zone 2–7

Growth Habit: Thick clumps

Foliage: Narrow evergreen leaves

Height with Flowers: 60 cm (24 in.)

Spacing between Plants: 45 cm (18 in.)

Soil Requirements: Humus-rich, moist soils — even in bogs — over cooler summer regions, pH 5.8–6.8

Location: Full sun to partial shade

Use: Mass plantings look outstanding

Specialities: Flowering stems — fresh or dried — make nice cut flowers

Cultural Tips:

Grams per 1,000 Seeds: 0,185

Seeds per Gram: 5,400

Seeding Recommendation: 1 g/1,000 plants

Sowing Rate: 5–6 seeds per cell

Plug tray recommended size(s): 128,288

Germination: Rapidly germinating, keep seed in constant moisture (not wet) with temperatures of about +20 °C [68 °F]. Do not cover the seed but tightly press into the earth. Keep in cooler conditions after germination occurs. The germination might be slower and more irregular. This poses no problems.

Scheduling:

Best Sowing Dates: Anytime

Sowing to Germination: 2–3 weeks

Germination to Transplant: 4–6 weeks

Transplanting to Salable Plant: 8–10 weeks

Cutting-Back at Transplanting: Not necessary

Growing on:

Container Size(s): 1–2 plugs per 11/12 cm (4 1/2 in.); 2–3 plugs per 15 cm (6 in.)

Vernalization: There is no current research on vernalization but a prudent recommendation for any perennial would be 6–12 weeks (a few might need 15 weeks!) at an *average* daily temperature of 40 °F (5 °C). Exposure to cold may not be necessary for flowering but might improve quality.

Forcing: An obvious place to experiment — following vernalization — would be raising daytime temperatures to 60–65 °F (15–17 °C). Provide 16 h of continuous lighting. During the short days of winter, provide a night interruption lighting of 4 hours between 10 PM and 2 AM.

Fertilization: Medium (150–200 ppm)

Double Take™ Quince Series

Chaenomeles speciosa, **Double Take™ Orange Storm flowering quince ppaf, cbraf**

Chaenomeles speciosa, **Double Take™ Pink Storm flowering quince ppaf, cbraf**

Chaenomeles speciosa, **Double Take™ Scarlet Storm flowering quince ppaf, cbraf**

A double take is what you'll do when you see these new quince selections. The Double Take™ series gives quince a complete makeover, starting with a spectacular display of big, double, camellia-like flowers in early spring. Look further and you'll also notice these plants are thornless! These drought-tolerant plants are excellent for hedging, mass planting, and flower arranging. They generally do not produce fruit. Develop by Dr. Thomas Ranney and his team at the Mountain Horticultural Crops Research & Extension Center in Asheville, North Carolina, U.S.A. It is a violation of state and/or federal law to use a trademark without permission. The propagation of and/or the sale of plant parts is prohibited without a license. Patent/trademark tag and container required. USDA 5, AHS 9, 4–5 ft tall and wide.

Echinacea purpurea **'Magnus Superior'**

Echinacea purpurea 'Magnus' set the standard for coneflowers. The remarkably affordable, uniform seed strain has been one of the most popular perennials worldwide since Jelitto's 1985 introduction. Named in honor of its originator Magnus B. Nilsson, who spent 10 years of selection work before offering it to Klaus R. Jelitto, it went on to earn the Royal Horticultural Society's Award of Garden Merit (A.G.M.) in 2003 and the Perennial Plant Association's Plant of the Year (1998).

But even the standard can be improved, and now celebrating the Silver Anniversary of 'Magnus', Jelitto marks the milestone with the introduction of 'Magnus Superior'. Darker blooms and stem color, plus more consistent growth, are its finest characteristics. The spiny-looking bold cones, even larger than 'Magnus', are decorative, too. (So decorative that the Genus got its name Echinacea from the Greek *echinos* which means: *hedgehog*.)

How many of you have simply grown nostalgic for a new, truly improved "purple" coneflower? 'Magnus Superior' is cost-effective. It is a reliable garden performer, and it is easy to propagate. Help us celebrate 25 years of making the best, better.

Echinacea purpurea 'Magnus Superior' Coneflower:

Id-Code: RA 181

Family: Asteraceae, Compositae

Origin (species): North America: Ohio and Michigan south to Georgia, west to Oklahoma and northeast Texas

Special Features: 2010 Jelitto introduction to commemorate the 25th anniversary of the award winning 'Magnus'. The result: darker blooms and stems color, plus more consistent growth

History: Introduced by Jelitto Perennial Seeds in 2010

Colour: Dark carmine-red

Natural Flowering Period: July–September

Winter Hardiness Zones: Zone 3–8

Growth Habit: Upright

Foliage: Ovate-lanceolate; 20 × 10 cm (8 × 3 in.)

Height with Flowers: 100 cm (40 in.)

Spacing between Plants: 45 cm (18 in.)

Soil Requirements: Well-drained soils, pH 5.8–6.8

Location: Full Sun

Use: Plant 'Magnus Superior' in mass plantings or can be combined in the border with *Lavatera* 'First Light', *Penstemon* 'Sunburst Colours', and *Eupatorium aromaticum*

Specialities: Cut flowers and decorative seed heads

Cultural Tips:

Grams per 1,000 seeds: 4

Seeds per gram: 250

Seeding recommendation: 10 g/1,000 plants

Sowing rate: 2–3 seeds per cell

Plug tray recommended size(s): 72, 128

Germination: Rapidly germinating, keep seed in constant moisture (not wet) with temperatures of about +20 °C (68 °F). Seeds must be covered thinly. Keep in cooler conditions after germination occurs. The germination might be slower and more irregular. This poses no problems.

Scheduling:

Best sowing dates: Anytime

Sowing to germination: 2–3 weeks

Germination to transplant: 4–8 weeks

Transplanting to salable plant: 6–10 weeks

Cutting-back at transplanting: Not necessary

Growing on:

Container size(s): 1–2 plugs per 11/12 cm (4 1/2 in.)

Vernalization: Some flowering will occur the 1st year without vernalization, but improved flowering will occur the 2nd year; and 3–10 weeks of cool temperatures might benefit fuller flowering in the 1st year.

Forcing: There has been no research on 'Magnus Superior', but an obvious place to experiment — following vernalization — would be raising daytime temperatures to 60–65 °F (15–17 °C). Provide 16 h of continuous lighting. During the short days of winter, provide a night interruption lighting of 4 h between 10 pm and 2 am. Some later flowering species can be forced in 14–16 weeks and perhaps sooner at warmer temperatures. Further experiments are warranted with 'Magnus Superior'.

Fertilization: Medium (150–200 ppm)

***Geum* Cocktails™ Series 'Mai Tai' ppaf**

Heavy blooming plants have single to semi-double blooms of vermillion red fading to peach and then pink starting in May. Clumping mounds are semi-evergreen and reach over 1 ft wide and are topped with burgundy 18-in. stems. Full sun, moist rich to average soils are best.

Propagation of this patented plant is encouraged with a license. Propagate by basal cuttings or division after flowering in June.

×*Gordlinia grandiflora* 'Sweet Tea'

As if ×*Gordlinia grandiflora* (a rare intergeneric hybrid between *Franklinia* and *Gordonia* (see reference by Ranney, T.G., and P.R. Frantz below for more information), wasn't unusual enough, 'Sweet Tea' is a polyploidy form with extra sets of chromosomes. The result…huge (5-in. diameter), showy flowers that look like big fried eggs. Semi-evergreen with large, single, camellia-like flowers from July through September. Why 'Sweet Tea'? Well, it's a member of the tea family, the flowers have a light sweet fragrance, and it comes from the South where sweet tea runs in our veins. Okay, it's not the toughest tree on the planet, so give it a good site. More resistant to *Phytophthora* than *Franklinia* (see reference to article by Meyer et al. below), but it's still a bit persnickety. Best in full sun or a little afternoon shade as long as it's not too dry. Roots from stem cuttings in a matter of minutes, then takes off growing. Mature height is estimated to be 20–30 ft. Zone 7–10. Developed at North Carolina State University. Not patented or trademarked.

Meyer, E.M., T.G. Ranney, T.A. Eaker, and **K. Ivors.** 2009. Differential Resistance of Gordonieae Trees to *Phytophthora cinnamomi*. HortScience 44(5):1484–1486. <http://www.ces.ncsu.edu/fletcher/staff/tranney/meyer_et_al2009.pdf>.

Hydrangea macrophylla 'Berner', Let's Dance® Big Easy™ bigleaf hydrangea ppaf; pbraf

Let's Dance® series just got bigger and better. This reblooming, mop-head hydrangea has the largest in the Let's Dance series or any other series for that matter. The huge blooms go through a wonderful progression of color changes, from pink/green to pink, and often back to green. Color ranges from rich pink to blue. It is a violation of state and/or federal law to use a trademark without permission. The propagation of and/or the sale of plant parts is prohibited without a license. Patent/trademark tag and container required. USDA Zone 5, AHS 9, 2–3 ft.

Panicum virgatum 'RR1' Ruby Ribbons® pp 17,944 switchgrass

This plant resulted from a cross between *P. virgatum* 'Haense Herms' and *P. virgatum* 'Heavy Metal' made by Mark Brand at the University of Connecticut. Plants grow to be 3 ft to 4 ft tall and 2 ft to 3 ft wide. The base foliage color is metallic blue that is similar to 'Heavy Metal'. In Connecticut, foliage tips begin to turn burgundy red around July 1st and the burgundy color progresses down the leaves as the summer continues. The dark red foliage color develops earlier and more fully on Ruby Ribbons® than on other red-leaved *P. virgatum* cultivars. Propagation by division is easy and plants grow well in container culture. Ruby Ribbons® witchgrass exhibits more controlled growth than many other larger-growing *P. virgatum* cultivars.

Physocarpus opulifolius 'Donna May' ppaf, First Editiions® Little Devil™ ninebark

Bred here in Minnesota by Dr. David Zlesak, a young horticulturist who recently got his Ph.D. in horticulture from the University of Minnesota and is currently teaching at the University of Wisconsin-River Falls.

David used Diabolo® and made a number of crosses with *Physocarpus opulifolius* 'Nanus'. The result is Little Devil which is the smallest *Physocarpus* currently on the market.

Reaching a mature height of 4 ft, with a spread of 3 ft, it has the dark, purplish brown leaf color of 'Diabolo', and the small leaf size of 'Nanus'. It has an upright growing habit with slightly arching branches. It blooms in early summer with that classic *Physocarpus* flower of white to pink, contrasting beautifully against the dark foliage.

Propagating easily from softwood cuttings, it is a good grower, and thrives in full sun situations.

Polemonium 'Heven Scent' pp 20, 214

Lacey pinnate foliage emerges red and continues to hold red highlights until summer. Grape-scented blue flowers begin in May and continue into June. Plants top out at 18–24 in. tall. Drought tolerant clumps can grow in full sun to part shade. 'Heaven Scent' makes a nice cut flower.

Propagation of this patented plant is encouraged with a license. Tissue Culture stage III available from Vitro Westland in Holland. Basal cutting divisions including a piece of root in June can also be used in addition to division in August/September.

Sedum 'Thundercloud' 21,833

Unique pointed grey-green foliage emerges in spring on strongly mounding domes. Slowly expanding to 10–12-in. mounds with white spectabile-type flowers the end of August into September. Full sun, well-drained soil are best.

Propagation of this patented plant is encouraged with a license. Propagates like *S. siebodii*. Cuttings should be approximately 2–3 in. and done in spring; keep the cuttings on the dry side. Available as unrooted cuttings.

Propagation of Cuttings Using Foliar-Applied Indolebutyric Acid in Aqueous Solutions at or After Sticking©

Joel Kroin
Hortus USA Corp., PO Box 1956 Old Chelsea Station, New York, New York 10113 U.S.A.
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INTRODUCTION

When propagating plants from cuttings, plant hormones called auxins can be applied to induce root formation. The auxin most used in plant propagation is indolebutyric acid (IBA). Basal application of auxins, done all year, has been done at the time of sticking using dry powders or solutions. Foliar application of auxin in aqueous solutions has been done in the growing season on leafy plant cuttings either before or after sticking. The applied auxin enters the plant's vascular system through open stomata. The auxin solutions travel with the natural auxin indole-3-acetic acid (IAA), by polar transport, to the basal end of cuttings where they can induce root formation.

The present study is to find out if there is a difference in root numbers on cuttings of the annual plant *Begonia* 'Red Wing', if an indole-3-butyric acid (IBA) in aqueous solution is foliar applied at time of sticking or several days later. Commercially, Aris Green Leaf Plants, on perennials, and Bailey Nurseries, on woody ornamentals, both recommend an IBA in aqueous solution foliar treatment within the day after sticking. Using foliar applied IBA in aqueous solutions on the woody plant *Ficus pumila* (creeping ficus) by Dr. Fred T. Davies, all treated cuttings (both mature and juvenile), had higher root numbers than untreated cuttings.

The current study found IBA in aqueous solution foliar treatment to be effective on annual cuttings. Application can be done at time of sticking and up to several days after sticking. Higher root numbers occurred on cuttings when treatment was near the time of sticking. Root numbers diminished when treatment was done on later days.

FOLIAR APPLIED ROOTING HORMONES TO INDUCE ROOT FORMATION ON CUTTINGS

Since the late 1800s, scientists, including Charles Darwin, believed substances produced in the leaves of the plants regulated other parts of the plant (Darwin, 1880). "In 1893 (Julius) Sachs' suggestion was that special stimulating and constructive substances are formed in the metabolic processes in leaves" (Reynolds-Green, 1909). In 1934 Thimann and Went identified this substance as IAA. Produced in the leaves during growth, they called it an "auxin" or "plant hormone." They also identified the bio-simulators of IAA, IBA, and nathaleneacetic acid (NAA), more stable then IAA yet producing similar effects. In their book, *Phytohormones*, they define "a hormone is a substance which, being produced in any one part of the organism, is transferred to another part and thereby influences physiological responses." They found application of auxin to the leaves of plants had a positive effect on basal root formation. They also identified the route of the auxin, from leaves to the basal end of cuttings, as polar (one way) transport (Thimann and Went, 1937).

Auxins in aqueous solution can be applied to the foliage of plants in the growing season. They can enter through open stomata where the leaves capture the solutions under the stomata's guard cells in air spaces. After, they are polar transported to the basal end (Sargent, 1965; Franke, 1967). At the basal end the auxins are stored then regulated by the plant to stimulate root initiation (Thimann and Went, 1937; Epstein and Ludwig-Muller, 1993).

Fred T. Davies foliar applied IBA in aqueous solutions in his rooting trials on cuttings of the woody plant *Ficus pumila*. In one of his trials, application was one time at the time of sticking. Foliar treated cuttings all had higher root numbers compared to untreated control cuttings. Cuttings treated at the time of sticking had the highest numbers. Juvenile cuttings had higher root numbers than mature cuttings. (Davies and Joiner, 1980; Davies et al., 1982; Davies, 1984).

In Holland, Kees Eigenraam, the Senior Researcher of Rhizopon, in 1985 found that foliar applied IBA in aqueous solution improved root formation on chrysanthemum cuttings. Working with the growers at the Dutch company Lyraflor, their greenhouses began using robotic sprayers to apply IBA in aqueous solutions to cuttings soon after sticking (Eigenraam, 2010).

In 1994, Kees Eigenraam and I visited the Yoder Brothers chrysanthemum propagation facilities in Florida, introducing foliar applied IBA in aqueous solution. Since they had large homogenous plant lots, we suggested that they use the total immerse method. By 1996, Yoder (now Aris) Green Leaf Plants greenhouses in Pennsylvania began using foliar application on perennials. They have small production lots; the spray drip down method was more suitable since they did not want to have cross-contamination between lots. They recommend: "apply hormone within 24 h of stick for best results" (Green Leaf, 2010). After 2002, Bailey Nurseries began using foliar applied IBA in aqueous solution on their woody ornamental plant cuttings. "Our results have shown when making these applications within 24 h of sticking is critical for our success" (Drahn, 2007). Dr. Davis said "We would typically apply at dusk at Gainesville, Florida, with the mist turned off for the evening" (Davies, Pers. commun.).

Kees Eigenraam and I have refined two methods to foliar apply auxin in aqueous solutions to leafy cuttings in the growing season. We call these the Spray Drip Down and Total Immerse methods. Rates of application are similar. Application is to be done when the temperature permits stomata to be open. If application is made in cold or hot temperature the stomata would be closed and will not accept the solution. When day temperatures are high then treatment is done early, on cool mornings. Some plants, such as clematis, have their stomata on the bottom of leaves. To assure adequate treatment we found it is best to spray the solution on both sides of the leaves or use the Total Immerse method.

Spray Drip Down Method. The spray drip down method is used after sticking. The solution is used one time resulting in no cross contamination between plant lots. The solution is kept in a tank that does not have cuttings dipped in it. Foliar treatments can be made one time or many times on the same lot. Secondary application can be done on cuttings that had a primary treatment by any other basal or foliar method such as quick dip, basal long soak, or dry dip.

- Stick the cuttings
- Spray leaves of cutting with the solution until drip down
- After treatment, they can resume misting within 30–45 min

Total Immerse Method. The total immerse method is used one time on cuttings before sticking. The cuttings are dipped in a production tank where multiple lots can be processed. It is suitable where cuttings come from a homogenous lot where cross contamination of a used solution is not a problem. The method is useful when getting good coverage of leaves by spray is difficult, such as treating large leaves.

- Totally immerse the cuttings in the solution for about 5 sec then drain
- Stick the cuttings
- After treatment, misting can be resumed within 30–45 min

Plants Can Be Divided into Three Relative Foliar Rate Groups.

A) Annual like plant cuttings: at 80–50 ppm IBA
B) Perennial-like plant cuttings: at 250–1500 ppm IBA
C) Woody ornamental like plant cuttings: at 500–1500 ppm IBA

Growers have asked me if a surfactant (wetting agent) should or could be used with foliar applied solutions made with Hortus IBA Water Soluble Salts. I have never heard of any commercial growers that have added them. In Dr. Davies' studies he added a surfactant to his solutions. It could be the Hortus IBA Water Soluble Salts solution does not need a surfactant due to the composition of the salts. I plan to do a study to find out if surface tension of IBA aqueous solutions is a critical factor in root formation. I want to find out if droplets have a low enough surface tension to enter open stomata.

PRESENT STUDY

The present study was conducted on cuttings of the annual plant *Begonia* 'Red Wing'. IBA in aqueous solutions was foliar applied by the Spray Drip Down Method. The study was to find out differences in root number formed between untreated and one treatment at time of sticking, at the 3rd, 5th, or 7th day after sticking.

Methods and Materials. Annual plant *B.* 'Red Wing' cuttings were used. All cuttings were taken from one mother plant kept in bright daylight for several days. Stem cuttings had 3–5 full leaves. The medium was perlite and peat (1 : 1, v/v). Treatment was by the spray drip down method. The solution was 200 ppm IBA in aqueous solution using Hortus IBA Water Soluble Salts (1.0 g salts per liter water). Fifteen cuttings were in each of five blocks: un-treated control cuttings, treated 1 h after sticking, or at 3, 5, or 7 days after sticking. Application was made at 80 °F to assure the stomata were open to accept the solution. Cuttings were kept in a propagation tunnel at close to 100% humidity for the trial period. Bright sunlight was supplemented with artificial light for 16 h.

After 24 Days (Table 1).

- Compared with the un-treated control cuttings, all cuttings treated with foliar applied IBA in aqueous solution had higher root numbers.
- Cuttings treated 1 h after sticking had the best side root formation.
- Both the untreated control cuttings and those treated 1h after sticking had new leaf shoot formation; untreated controls had more shoots then those treated after sticking.
- Cuttings treated at 3, 5, or 7 days had some leaf loss and no new leaf shoot formation.
- The numbers of rooted cuttings in blocks varied from 92% to 95% (not statistically significant).

Table 1. Number of roots formed on cuttings by Day 24.

Plant: Begonia 'Red Wing'.
Treatment: The spray drip down method.
Solution: At 200 ppm IBA in aqueous solution using Hortus IBA Water Soluble Salts (1.0 g salts/liter water).

	Number of roots formed (averages)					
	Average per cutting	Average at basal cut	Average at sides	Average at nodes	Root quality	Observation
Untreated control	* 18.9	12.3	4.1	2.5	Good	New leaf shoots.
Treat at 1 h	† 27.2	3.9	19.7	3.6	Good	New leaf shoots.
Treat at 3 days	20.7	5.5	8.3	6.9	Poor	Original leaf loss. No new leaf shoots.
Treat at 5 days	22.0	12.4	2.9	6.7	Poor	Original leaf loss. No new leaf shoots.
Treat at 7 days	22.1	6.0	12.4	3.7	Poor	Original leaf loss. No new leaf shoots.

Note: Begonias form new roots on various parts of the cutting. How counts were made for the average number of roots:

Average at basal cut: roots formed at the cut line of the basal end.

Average at sides: roots formed on the stem between basal cut and nodes or between nodes.

Average at nodes: roots formed directly over a node.

* = Lowest value in column.

† = Highest value in column.

Basic Findings. The present study found that auxins applied to leaves translocated to the basal end at the expense of leaf formation. The untreated control cuttings had more leaf shoot formation compared with cuttings treated within an hour. For the untreated control cuttings this was at the expense of root formation. The study found an advantage to treat within the first hour after sticking and perhaps within the same day (Table 1).

DISCUSSION

Rate Determination. Begonia's require very low foliar rates, usually 80–200 ppm IBA. A higher rate on tender annual cuttings may cause leaf curl or leaf spotting where the liquid touches the leaves. Despite these problems, the cuttings develop a good root system with new normal leaves. I have observed the new leaf growth to be normal and the cuttings develop a strong rooting system. The *F. pumila* in Dr. Davies' trials used a high rate, 1,000 ppm IBA for juvenile and 3,000 ppm for mature cuttings. For this specific selection Davies said: "Optimum concentrations for the juvenile and mature *Ficus* were, respectively, 1,000–1,500, and 2,000–3,000 ppm K-IBA" (Pers. commun.). Other ficus family taxa require other rates. In our trials on *F. benjamina*, found 500 ppm IBA to be suitable. I had never heard of other plants that had useful rates higher than 1,500 ppm IBA.

Rooting Quality. The present study, on annual begonias, showed the best root quality are on cuttings treated soon after foliar treatment. The Davies' studies had similar results.

Effects of High Rate. Occasionally I have seen cuttings, such as maples and rhododendrons, that have received too high a foliar treatment rate. Woody plant cuttings may accumulate the auxin at the basal end. The auxins, having no place to go, accumulate at the basal end. This may cause heavier than normal callus formation, and may inhibit root initiation. Growers made the problem more severe when they made a second or third application at the same high rate.

Third Day Observations. I cannot identify why in all the trials there was a slight decrease in root number formation on cuttings treated on the 3rd day after sticking. These cuttings still had more root numbers then the un-treated controls. The root numbers increased on 5th day treated cuttings. I had seen this effect in prior trials using cuttings from the same *B.* 'Red Wing' mother plant and on *F. benjamina.* My initial response was that there were problems with the experiments on the 3rd day. Apparently the trials were accurate.

Secondary Treatment. In another study, Dr. Davies did two foliar applications on *F. pumila.* All treated cuttings were given a treatment at time of sticking. The second application was given on one of several days. The two rates were the same. Juvenile cuttings had more root formation when treated on the 3rd day, for mature cuttings on the 9th day. His study suggests a first application at the time of sticking with a second application a few days later give improved root numbers and quality (Davies, 1980).

Kees Eigenraam did research at Dutch commercial growers of herbaceous plants. He found using a foliar application of rooting solution at the time of sticking, then a second application a week or so later, gave improved root formation. For the grower, the crop is leveled; it may reduce the need for grading (Eigenraam, pers. commun.).

Juvenility. Juvenile cuttings appear to benefit most from foliar application. Dr. Davies found juvenile cuttings of *F. pumila* had higher root numbers than mature cuttings. Growers like Yoder, in commercial propagation of perennials and crops like chrysanthemums, regenerate their stock plants, by taking cuttings from cuttings to make new stock plants. These juvenile cuttings root well when using foliar applied IBA in aqueous solutions.

Timing. Commercial growers must plan their production day to take into account the time of sticking and the time of treatment. The total immerse method has treatment in line with sticking. The spray down method can be done at time of sticking or at a later time. Yoder and Bailey say they have best results when they treat within the day after sticking. To accommodate scheduling, the present study and the Davies studies suggest that after sticking, treatment after a few days produces positive root formation. In addition, rooting numbers are best when treatment is made soon after sticking. I intend to do future studies narrowing the treatment to half days in the first 5 days after sticking. (Tables 1, 2; Fig. 1).

Discussing his *F. pumila* trials, Dr. Davies said: "In terms of our aqueous applications of IBA on juvenile and mature *F. pumila*, the earlier we applied the auxin, the better the response. Auxins were applied at days 3, 5, and 7 for the juvenile and

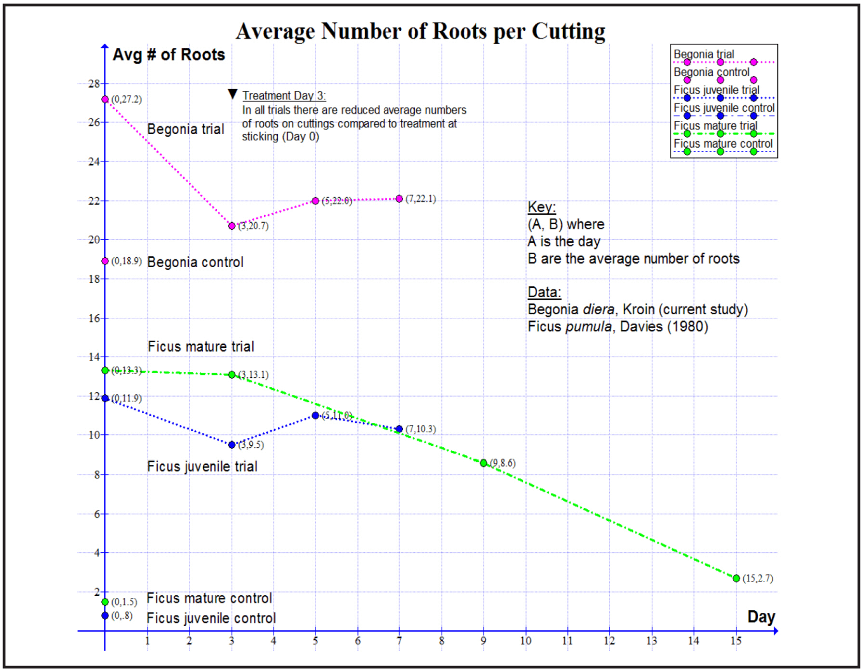

Figure 1. Study comparison: Average number of roots per cutting by day of application. Foliar auxin sprays for rooting of *Begonia* 'Red Wing' and *Ficus pumila* cuttings.

Plants:	Present study Begonia 'Red Wing'
	Davies studies: *Ficus pumila*
Treatment:	The Spray Drip Down Method
Solution:	IBA (ppm) in aqueous solution

Table 2. Study comparison: Timing of foliar auxin sprays for rooting of *Begonia* 'Red Wing' and *Ficus pumila* cuttings.

Plants:	Present study *Begonia* 'Red Wing' Fred Davie's studies: *Ficus pumila*
Treatment:	The spray drip down method
Solution:	IBA (ppm) in aqueous solution

	Begonia 'Red Wing' (Davies)		*Ficus pumila* study (Davies and Joiner, 1980)				
	200 ppm IBA		Juvenile 1000 ppm IBA		Mature 3000 ppm IBA		
Treatment	Average (no.) of roots formed per cutting	Root quality	Average (no.) of roots formed per cutting	Root quality	Day treated	Average (no.) of roots formed per cutting	Root quality
Untreated Control	* 18.9	Good	* 0.8	Poor	Untreated control	* 1.5	Poor
Treat at sticking	† 27.2	Good	† 11.9	Good	Treat at sticking	† 13.3	Good
Treat at 3 days	20.7	Poor	9.5	Good	Treat at 3 days	13.1	Good
Treat at 5 days	22.0	Poor	11.0	Good	Treat at 9 days	8.6	Good
Treat at 7 days	22.1	Poor	10.3	Good	Treat at 15 days	2.7	Poor (See Note 2 below)

Notes:

* Lowest value in the column

† Highest value in the column

Root quality note:

1) For root quality, in this table I have given a subjective value. Dr. Davies gives a numeric value where I have assigned: 1 = poor, 2 = fair, 3 = good.
2) "Application at Day 15 was beyond the "optimum application window", and there was a deterioration of percentage rooting, root numbers, root length, and root quality." (Davies, Pers. commun.)

Days 3, 9, and 15 for the mature since the process of adventitious root formation occurs more rapidly in the juvenile material. When we delayed applying IBA to the easier-to-root juvenile *Ficus* from Days 3, 5, or 7, there was no significant difference in adventitious root formation, including root quality. When we delayed applying IBA to the more-difficult-to-root mature *Ficus* from days 3, 9, to 15, there was no significant difference in adventitious root formation, including root quality at Day 3 or 9, but there was a significant reduction in Day 15" (Davies, pers. commun.).

CONCLUSION

Auxins, natural substances produced primarily in plant leaves, translocate to the basal part of cuttings to induce root formation. Indolebutyric acid, a bio-simulator of the natural auxin, when applied in an aqueous solution by foliar means can be used to propagate plants from leafy plant cuttings in the growing season. The applied auxin solution enters the leaf's stomata and translocates with the natural auxin to the basal end. The plant self regulates auxin use to produce new roots. Application can be done on annual, perennial, and woody plant cuttings. One time application can be done by the total immerse method. One time, or multiple time applications, can be done by the spray drip down method. Studies used IBA in aqueous solutions. Woody plant *Ficus* studies found, compared with untreated control cuttings, juvenile cuttings develop the highest root numbers followed by mature cuttings. The present study on *Begonia*, an annual plant, compared untreated control cuttings with foliar treated cuttings. The highest root numbers were on cuttings treated close to the time of sticking. Positive root numbers were on cuttings treated 3, 5 and 7 days after sticking. Other studies, by Davies, on slower-to-root cuttings have shown positive root numbers when treated beyond 7 days after sticking. Auxins accumulate at the basal end. Root formation is at the expense of leaf formation. Leaf growth resumes after root formation. Cuttings that are foliar treated with IBA in aqueous solution anytime in the trial period have higher root numbers than untreated control cuttings.

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Impact of Lean Flow Techniques on Plant Production©

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INTRODUCTION

Spring Meadow Nursery, a propagation nursery with over 20 acres of greenhouses, is located in Grand Haven, Michigan. All propagation is done asexually, by cuttings, in-house. Much of our production involves direct sticking cuttings in their finish tray sizes of 32 or 18 cells.

In 2009, we had a goal to increase labor efficiency to stick cuttings by 15%. We had a good system with trained, hard-working employees, mechanization that included a flat filler and a dual-line conveyor system that supplied medium-filled trays to workers and transported stuck trays through a watering tunnel. So where was the 15% gain in efficiencies to come from?

Historic average rate for sticking per person for 32-cell trays was 24-cell trays per h. The rate included non-sticking support jobs such as manually loading trays into the flat filler and transferring the finished trays to the greenhouse floor for rooting.

METHODS AND RESULTS

We hired FlowVision, the Lean Business and Supply Chain Consulting Group, to help us reduce our labor costs company-wide. This was a significant investment by Spring Meadow in terms of money and time to learn lean production techniques and to track and quantify improvements on a daily and even hourly basis.

2009 Methods and Results. First year (2009) production improvement resulted from inexpensive changes:

- Standardization of tasks.
- Frequent communication with crew workers on goals. This included feedback from the workers, not just one-way communication.
- Improved work flow with emphasis on material handling. Most important was eliminating any delay for required materials such as cuttings and flats.
- Improved labor tracking. Times to perform each job were measured and recorded, using a stopwatch, to get an average time for every job on the line, including support workers. Exact rates were then determined.
- Attention was paid to flex jobs — jobs involving two or more functions — which have a huge impact on productivity.
- Changed from individual incentive bonus to a group bonus to reward support workers too.

As a result, our 2009 productivity increased 13% for 32-cell trays and 32% for 18-cell trays. Approximately half of the savings for 18-cell trays was due to increased use of sticking multiple cuttings per cell to increase rooting success.

2010 Methods and Results. Lean flow techniques call for continuous improvement:

- We re-configured the work area to allow for improved work flow.
- Purchased overhead conveyors to bring medium to the flat filler so that the cumbersome soil mixer could be removed from the work area.
- Changed from individual sticking stations to progressive sticking, using three people to stick flats in an assembly-line fashion.
- Advantages of progressive sticking:
    - Easy to train new people. Trainees are placed in the center position and receive instruction from workers on both sides.
    - Crew workers like it. They compete as a team and the work is less boring because they are not sticking an entire flat.
    - Slower people are pushed to become faster. The slow person is put in the center and is pushed by the first person and the end person. There is a lot of peer pressure to achieve the goals so that everyone can earn incentive bonus pay.

CONCLUSION

Record of productivity increase from 2008–2010. Quantities are average trays stuck/person/h as a group.

Tray type	2008	2009	2010	Total productivity increase
18 cell	31.4	41.2	44.9	43%
32 cell	24	27	30.7	28%

Seasonal Collection Date of Lingonberry [*Vaccinium vitis-idaea* L. subsp. *minus* (Lodd.) Hultén] Stem Cuttings Influences Rooting and Rootball Size©

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INTRODUCTION

Aficionados of muffins, pancakes, and pies are very familiar with Maine's lowbush blueberry (*Vaccinium angustifolium* Aiton). However, Maine can boast another outstanding *Vaccinium*, the lingonberry. Lingonberry, *Vaccinium vitis-idaea* L. subsp. *minus* (Lodd.) Hultén, also known as mountain cranberry, is found growing in North America from northwestern Greenland, south to Connecticut, and west across Canada to the Aleutian Islands (Vander Kloet, 1988). It has somewhat smaller morphological features than its European counterpart *V. vitis-idaea* subsp. *vitis-idaea* (Ritchie, 1955). Lingonberry grows as a prostrate shrub, spreading by rhizomes. It bears densely arranged small waxy evergreen leaves. Its attractive white to pink bell shaped flowers often appear twice during the year in Maine, late spring and again in the summer. Lingonberry fruit is a bright red tart edible berry, which also provides attractive late season color. These attributes validate its use as a native groundcover.

Holloway (1985) conducted an excellent study assessing the seasonal pattern of rooting of lingonberry stem cuttings of three stages of growth: current season's growth, 1-year wood, and 2-year wood collected from native stands near Fairbanks, Alaska. Interestingly, September cuttings generally rooted at higher percentages after 8 weeks than spring and summer cuttings (with the exceptions of late May 1-year wood, late August 1-year wood, and late June 2-year wood). Holloway cites a study conducted in Finland (Lehmushovi, 1975), which also indicates that early spring and fall cuttings rooted better than summer cuttings for lingonberry in Finland.

The objective of this study was to determine the optimum time to propagate native Maine clones of lingonberry by stem cuttings for optimum rooting and rootball size.

MATERIALS AND METHODS

Greater than 25 terminal cuttings, at least 2.5 cm in length, were collected from a single stand of lingonberry growing in Washington County, Maine, on six dates from mid June 2008 to the end of October 2008. Cuttings were collected and put in sealed plastic bags with moist paper towels and kept in an insulated cooler with ice during transit. Cuttings were stored in the same sealed bags in a refrigerated cooler kept at 7 °C until sticking within 72 h of collection.

Each of the 25 cuttings per treatment date was stuck in its predetermined randomized location within three 50 round cell propagation trays (T.O. Plastics, Clearwater, Minnesota) filled with a moistened peat, vermiculite, and perlite (3 : 2 : 1, by vol.) rooting medium. The six sticking dates were 13 June, 9 July, 7 Aug., 5 Sep., 2 Oct., and 31 Oct., 2008. At each sticking date, the 25 single cuttings (replicates) were arranged in completely randomized design. Cuttings were selected for uniformity and cut with a single-edged razor to 2.5 cm in length with a single 3 mm wound at the base of each cutting before sticking. The leaves were removed from the lower half of the stem and the cutting was buried to half its height (1.25 cm) in the rooting medium. Each of the propagation trays was set in a 1020 tray and covered by a clear plastic propagation dome designed to fit securely over the tray. Each tray and dome was also covered with a 2 mil plastic bag sealed with tape. The sealed propagation trays with stuck cuttings were kept in a culture room maintained at 23 °C with a 16-h photoperiod. Light was provided by a 60 watt fluorescent cool white bulb (Philips, F96T12/CW/EW, Somerset, New Jersey) located approximately 23 cm above the tips of the cuttings. The covered trays were removed from the culture room for each treatment date and returned after sticking of cuttings and resealing the outer plastic bag.

Cuttings from each treatment date were evaluated for rooting and rootball dimensions 8 weeks after sticking. Rootballs were measured in millimeters by the length of the rootball (longest root) and the greatest width of the rootball. Rooting percentage was statistically analyzed using logistic regression (SAS 9.1, SAS Institute Inc., Cary, North Carolina). Rootball dimensions were statistically analyzed using analysis of variance (ANOVA) and mean separation via LSD ($P \leq 0.05$) (SAS 9.1, SAS Institute Inc., Cary, North Carolina).

RESULTS AND DISCUSSION

The rooting percentages for cuttings stuck on 13 June, 5 Sept., 2 Oct., and 31 Oct. were the highest and statistically equivalent (96%, 84%, 92%, and 92% respectively) as shown in Figure 1. The cuttings stuck on 9 July and 7 Aug. had lower rooting percentages than those stuck on the other four treatment dates and were not different from each other (48% and 32%, respectively). The cuttings stuck on the 2 Oct. and 31 Oct. dates had the greatest mean rootball area values and were statistically equivalent (15.3 cm^2 and 16.7 cm^2, respectively) as shown in Figure 2. The cuttings stuck on 13 June, 9 July, 7 Aug., and 5 Sept. had lower mean rootball area values (6.7 cm^2, 2.0 cm^2, 8.9 cm^2, and 9.3 cm^2, respectively) than those stuck on 2 or 31 Oct.

These results support the findings of Holloway (1985), which indicated that fall (24 September) cuttings of current season and 1-year-old wood rooted at greater percentages than summer cuttings. These data also show a spring period of higher rooting potential preceding the summer decline. In Holloway's study, late May 1-year wood rooted at a percentage (80%) statistically equivalent to early and late September (94% and 100%, respectively). In our study, 13-June cuttings rooted at a percentage (96%) statistically equivalent to September, early October, and late October (84%, 92%, and 92%, respectively). Although the calendar dates do not correspond between our two studies, the seasonal rooting trend is similar. Cuttings from spring growth appear to have a high rooting potential followed by a significant decline in rooting potential during the late spring and summer months. Late summer and fall stem cuttings appear to regain higher rooting potential. Holloway also describes a similar seasonal rooting pattern in a study conducted by Lehmushovi (1975), although some variability existed between years. Gustavsson (2000) reports variable seasonal rooting with *V. vitis-idaea* subsp. *vitis-idaea* between 2 years. The author attributed this variability to differences in temperature and precipitation leading to observable differences in the quality of cutting material. Gustavs-

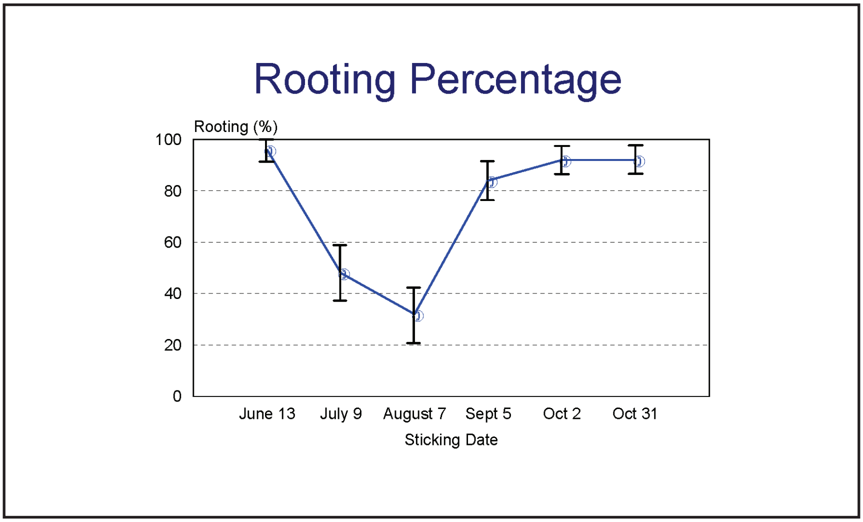

Figure 1. Rooting percentages of a *Vaccinium vitis-idaea* subsp. *minus* clone from Washington County, Maine. Rooting percentage was evaluated 8 weeks after sticking. Error bars represent standard error of the mean (n = 25) of each treatment date.

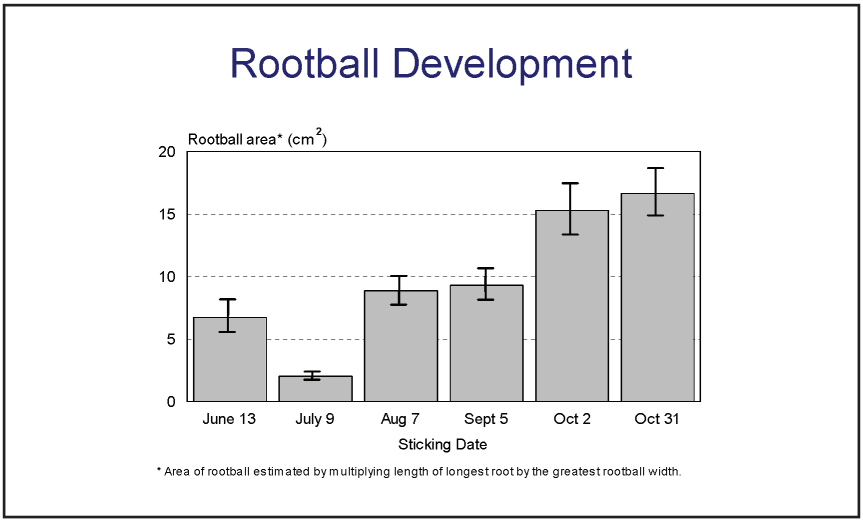

Figure 2. Rootball area estimate of a *Vaccinium vitis-idaea* subsp. *minus* clone from Washington County, Maine. Rootball area was evaluated 8 weeks after sticking. Error bars represent standard error of the mean (n = 25) of each treatment date.

son's study did not include stem cuttings collected later than 25 Aug., and therefore didn't include results of comparable late season stem cuttings.

Holloway also indicated that cuttings produced few but well-branched roots. Root development was reported as average number of roots per cutting. Values ranged from 1.0 to 2.5 and did not differ significantly among collection dates. Actual root or rootball dimensions were not reported. In our study, the quality of the cutting rootballs was determined by estimating the rootball area. Although the cuttings from the 13 June sticking date had a high rooting percentage equivalent to the October dates, the cuttings from the two October dates produced rootballs greater than twice the size of the 13-June cuttings.

These results indicate that the highest rooting percentage and largest rootballs would be obtained from lingonberry stem cuttings of current season's growth collected in the fall.

Acknowledgments. This research was supported by funds provided by the Maine Agricultural and Forest Experiment Station under provision of the Hatch Act. Maine Agricultural and Forest Experiment Station Publication Number 3143.

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Sweet Fern Rhizome Cutting Success Is Influenced by Propagation Medium©

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INTRODUCTION

There is a desire to increase the use of native plants for landscaping as alternatives to exotic species, some of which are invasive. *Comptonia peregrina* (sweet fern), an attractive, low-growing shrub, native to northeastern North America, is a prime candidate for development as a landscape plant due to its adaptability to exposed sites with dry, infertile soil (Dirr, 2009). Stem cuttings and seed are not viable propagation methods (Dirr and Heuser, 1987). Some propagation success has been found using dormant rhizome cuttings (5 cm sections) taken in fall, and provided a cold stratification of 2 to 3 months at 4 °C (Ruchala et al., 2002). Rhizome cutting methods must be optimized if sweet fern is to reach a level of production where it is readily available to landscapers and homeowners. This work looked at media and effect on success of rhizome cuttings. An additional objective was to find out what size plant could be obtained in one growing season from rhizome cuttings.

PROPAGATION AND PRODUCTION METHOD

Fall harvested, dormant rhizomes were cut into 5 cm pieces and planted in 160-ml square pots in four different propagation media: Scotts Metro Mix 510 Growing Medium, horticultural grade perlite, horticultural grade vermiculite, and mason's grade river sand. Two 5-cm cuttings were placed in each pot. Cuttings were placed horizontally in the pot with one crossed over the other. Pots were held in a dark cooler at 5 °C for 90 days and then were moved to a warm greenhouse for forcing. Cuttings were irrigated as needed, and while in the greenhouse, provided a soluble 20–10–20 fertilizer at 200 ppm N every 7 days. Young plants derived from rhizome cuttings were transplanted into 307-ml containers using an aged pine bark : sphagnum peat moss : sand growing medium (4 : 2 : 1, by vol.) and top-dressed with 4 g of Scotts Osmocote Plus 15–9–12 controlled-release fertilizer 8 to 9 month formulation. After 60 days, plants were transplanted by placing two 307-ml square pot plants into a 6-L container using the same (aged pine bark : sphagnum peat moss : sand) growing medium.

RESULTS

Cuttings propagated in vermiculite had 100% survival, while cuttings in Metro Mix 510, perlite, and sand had 81%, 81%, and 6% survival, respectively. Cuttings in vermiculite produced the greatest number of shoots per pot (4.2) and total shoot length per pot (14.8 cm), but were not statistically different from the Metro Mix 510 cuttings. Cuttings in perlite had significantly less total shoot length per pot than vermiculite and Metro Mix 510, and significantly fewer shoots per pot than vermiculite. Cuttings grown in sand performed poorly. Only two of the initial 32 pots survived to produce shoots upon forcing in the greenhouse, and these shoots were severely stunted. One hundred and twenty days of growth in 307-ml and then 6-L containers produced full, well-established sweet fern plants going into dormancy. All 6 L-plants overwintered successfully and after leafing out in spring the average plant height and width was 67 cm and 59 cm, respectively.

CONCLUSION

Of the mediums tested vermiculite was the best for propagating sweet fern from dormant rhizome cuttings. This propagation method can be utilized as part of a production system to produce 6-L plants in one growing season. This work provides evidence that sweet fern can be a successful nursery crop.

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Daylength Affects Rhizome Development and Plant Growth of Two *Achimenes* Cultivars©

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Two recently developed, unnamed cultivars of achimenes (*Achimenes* hybrids) A04 and A16, were grown for 15 weeks in growth chambers at 20 °C (68 °F) at 8- and 16-h daylengths. At harvest, cultivars differed in several growth characteristics. Both cultivars grown in 8-h daylengths developed more rhizomes than plants grown in 16-h daylengths. In addition, cultivar A16 was approximately 4 cm larger and produced more nodes than A04. Cultivar A16 also had greater plant dry weight than A04. When grown in 16-h daylengths, cultivar A16 produced the most flowers. The research presented here provides evidence that a shorter daylengths affect rhizome development in achimenes.

INTRODUCTION

Achimenes are also commonly known as the hot water plant, magic plant, or monkey faced-pansy, and are a member of the Gesneriaceae,. Achimenes were first brought to England (Jungbauer, 1977) and have been cultivated since the end of the 18th century. Popularity of the genus has waned and surged over the last 200 years, with an increased interest in the 1940s after breeding efforts by Michelssen, a German company, C. Broertjes of the Netherlands, and by Paul Arnold, Binghamton, New York, and H.E. Moore of Cornell University in the United States (Vlahos, 1991). Recently there has been a renewed interest.

There is potential for increased greenhouse production and marketing. Achimenes are mainly grown as summer-flowering houseplants but are also well suited for use as pot plants, in mixed containers and for hanging baskets (De Hertogh and Le Nard, 1993; Wilkins, 2005). Plants are available in an array of colors including white, scarlet, salmon, pink, blue, lavender, purple, and yellow and bloom profusely year around indoors and from early summer to fall outdoors. Achimenes are more widely grown and distributed in Europe as compared to the United States of America, where rhizome or cutting availability is limited.

Significant research on environmental factors influencing the induction and initiation of storage organs (bulbs, tubers, corms, etc.) with numerous plant species has been conducted. In many plant species that are affected by photoperiod or daylength, short days (SD) promote storage organ initiation or development and dormancy induction with reduced vegetative growth (Rees, 1992). Achimenes growth and development has not been thoroughly investigated and characterized, including the rhizome formation stimulus (or stimuli) and subsequent dormancy period. Growth and flowering of achimenes occurs throughout the summer, and in autumn, growth begins to decline and flowering decreases or ceases and enters into a dormant phase (Lyon, 1967). An experiment was designed to investigate daylength effects on rhizome development and other growth parameters in two new achimenes selections.

MATERIALS AND METHODS

Rhizomes of recently developed, unnamed achimenes cultivars, A04 and A16, were obtained from Oglevee, Inc. (Connellsville, Pennsylvania). Rhizomes were planted in 128-cell plug trays with Metro Mix 360 (Scott's Company; Marysville, Ohio). Plugs were grown in a glass greenhouse at 42 °N latitude for 10 weeks at 21 °C (70 °F) under natural daylengths (December to February), after which 20 uniform plugs of each cultivar were selected and planted in 10-cm (4-in.) plastic pots using Metro Mix 360. Two weeks after transplanting, 10 plants of each cultivar were placed in each of two growth chambers (Scherer-Gillett Co., Marshall, Michigan) using a complete randomized design. Growth chambers were set at 20 °C (68 °F) with daylengths of 8 h and 16 h with simultaneous florescent and incandescent illumination (approximately 180 $mol{\cdot}m^{-2}{\cdot}s^{-1}$; 900 fc) photosynthetic photon flux (PPF). Plants were subirrigated and fertilized with 21–5–20 ($N–P_2O_5–K_2O$) as needed, typically once a week.

Destructive harvest occurred 15 weeks after transplanting and data were collected on the final number of nodes, flower number, final plant height, plant dry weight, and the number of rhizomes initiated. Data were analyzed using JMP® (SAS Institute, Cary, North Carolina) analysis of variance and means were analyzed using Tukey's honestly significant difference (HSD) test at $P \leq 0.05$.

RESULTS AND DISCUSSION

Rhizome development and plant growth differences were observed between the two achimenes selections (Table 1). The interaction between cultivar and daylength had an effect on the number of flowers produced and plant dry weight. The number of internodes produced ($P = 0.06$) was significant at $P = 0.10$. Significant cultivar and daylength main effects were found for number of rhizomes, dry weight, and number of nodes. Only the cultivar main effect influenced final plant height.

The number of rhizomes significantly increased under the shorter 8-h daylength for each cultivar. Rhizome numbers increased by ~55% and ~350%, for cultivar A04 and A16, respectively. Similar results were reported by Vlahos (1990a), in which the number of rhizomes increased when cultivars 'Schneewittchen' and 'Linda' were grown under 8-h daylengths compared 16-h daylengths. Long days did not inhibit rhizome development in our study, which is in agreement with Vlahos (1990 a,b). It is well known that day length (SD) influence tuberization in potatoes. Short days also promote tuber formation in tuberous begonia (Fonteno and Larson, 1982), dormancy and rhizome formation in several ornamental ginger species (Sarmiento and Kuehny, 2004), and increase tuberous root formation in dahlias (Moser and Hess, 1968; Durso and De Hertogh, 1977). Results from our study suggest shorter day lengths have an influence on rhizome initiation and formation in achimenes.

The number of flowers for cultivar A04 did not differ between daylengths. Contrastingly, cultivar A16 produced significantly more flowers under 16-h daylengths than 8-h daylengths. Vlahos (1990a) found increased flower numbers under 16-h compared to 8-h daylengths and did not observe any cultivar and daylength interac-

Table 1. Daylength effects on plant growth and development of two recently developed achimenes cultivars[z].

Cultivar	Daylength	No. flowers	No. rhizomes	No. nodes	Final height (cm)[y]	Dry weight (g)[x]
A04	8	29 a	7 a	6.9 a	12.5 a	1.43 a
	16	33 ab	4.5 b	7.7 ab	11.8 a	1.62 a
A16	8	38 b	4.6 b	8.2 b	16.1 b	2.08 b
	16	49 c	1.3 c	9.8 c	15.6 b	2.74 c
Significance						
Cultivar (C)		**	*	***	***	***
Daylength (D)		***	***	***	NS	**
C × D		*	NS	NS	NS	*

[z]Values are means of 10 plants. Means followed by different letters within each column are significantly different by Tukey's honestly significant difference test at $P \leq 0.05$.

NS, *, **, *** Nonsignificant or significant at $P \leq 0.05$, 0.001, or <0.0001.

[y]1.0 cm = 0.39 in.

[x]1.0 g = 0.035 oz.

tion in his study of six cultivars. The total number of flowers produced by A16 under both daylengths is likely due to an increased number of nodes produced for both photoperiods, as compared to cultivar A04. Achimenes have three or four whorled leaves present at each node from which a flower (or branch) may be initiated (Zimmer and Junker, 1985). The number of leaves at each node was not recorded for this study and thus, it is not possible to distinguish whether the increase in flower number is due an increased number of nodes or if it is due to cultivar differences with the number of leaves and flowers produced at each node. It is also unclear if the number of leaves developed at each node for any particular cultivar is physiologically stable or if the number of nodes may be affected by PPF and resulting metabolite production.

Plant dry weight was greater for cultivar A16 compared to A04, which can most likely be attributed to cultivar A16 being significantly taller. In this study, the increased PPF for the 16-h daylengths generally increased the number of nodes and dry weight; however it was only significantly different between photoperiods for cultivar A16. Vlahos (1990a) also found increased plant height with 16-h daylengths and found no difference in number of nodes between 8-h and 16-h daylengths.

The research presented here provides more insight into the growth and development of achimenes. Vlahos (1990a,b) showed that growth characteristics vary among older achimenes cultivars. Results presented in this paper and previous published results (Miller, 2005; Miller and Bridgen, 2005) further provide evidence of cultivar differences among newly developed selections. This study provides more evidence that shorter daylengths are involved in rhizome development in achimenes.

Acknowledgement. We thank Oglevee, Inc. (Connellsville, PA) for supplying rhizomes to conduct the experiments. Additional thanks to the Kenneth Post Laboratories greenhouse staff for their assistance.

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Effects of Storage Period and Rhizome Breaking on *Oxalis triangularis* subsp. *popilionacea* Growth and Development©

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***Oxalis triangularis* subsp. *popilionacea* (syn. *regnellii*) (oxalis), a specialty potted bulb crop grown for the St. Patrick's Day holiday in the United States, is asexually propagated using rhizomes. Little information exists regarding oxalis rhizome storage and handling and subsequent greenhouse forcing. This paper describes the effects of storage period and rhizome propagule source on growth and development of oxalis.**

Storage period had a significant effect on several *O. triangularis* subsp. *popilionacea* growth parameters. Days to leaf emergence decreased by nearly a week as storage duration increased from 0 weeks to 5 weeks; while time to flower was unaffected. The number of leaves and flower cymes increased as storage period increased, along with leaf dry weight, more than doubling from 0.33 g with zero storage weeks to 0.85 g after 5 storage weeks.

Whole, intact rhizome propagules produced fuller plants compared to both basal and apical rhizome sections, producing 30% more leaves. Twice as many flower cymes were produced from intact rhizome propagules. Basal rhizome portions emerged between four and six days later than other rhizome propagules and flowered at least eight days later than all other rhizome treatments. Dry weights were greatest from plants grown from whole rhizomes, 0.44 g, but were not different than plants grown from basal rhizome pieces, 0.34 g.

INTRODUCTION

Oxalis triangularis subsp. *popilionacea* (oxalis), also known as the shamrock plant, is a specialty potted bulb crop grown for its clover-like leaves and white flowers. Oxalis is marketed primarily for the St. Patrick's Day holiday in the United States (Dole and Wilkins, 2005; Miller, 1997).

Oxalis is asexually propagated through small, slender rhizomes, comprised of tiny modified leaf scales (Ingram, 1959) and maintains a supply of food reserves (presumably carbohydrates) for perrenation, serving as a survival mechanism. Commercially, rhizomes are produced in the Netherlands and the United States (California and Oregon) (De Hertogh, 1996). In total, there are approximately 6000 to 8000 m^2 (P. Van Leeuwen, pers. commun.) of *O. triangularis* subsp. *popilionacea* (and *O. triangularis*) produced in the Netherlands. There are likely similar production numbers in the United States (M.A. Mellano, pers. commun.). Commercially, rhizomes are harvested from August to October. Oxalis rhizomes can be relatively long and delicate and are easily broken during harvest and processing.

After lifting, rhizomes are separated, graded, and stored in a cool environment at 1–5 °C until shipment in November or December (De Hertogh, 1996; Dole and Wilkins, 2005). Some geophytic species require a dormant period for proper growth and development, whereas others do not require a dormant period. Dole and Wilkins (2005) report that rhizomes can be stored for 10+ months in moist peat, while Mellano (pers. commun.) suggests a much shorter storage period of 1 to 2 months. In our research, we have stored oxalis rhizomes longer than 2 months and up to 4 months, with no ill effects during greenhouse growth.

Because little information exists regarding oxalis rhizome storage and handling, along with subsequent greenhouse forcing, we conducted experiments investigating (1) different storage durations and (2) rhizome propagule breaking effects on subsequent growth and development of *O. triangularis* subsp. *popilionacea* rhizomes.

MATERIALS AND METHODS

Storage Experiment. Oxalis rhizomes were harvested weekly, for 6 weeks, from actively growing oxalis plants in the greenhouse (21 °C). Rhizomes were carefully washed then placed in plastic bags with moist vermiculite and stored in a dark cooler at 3 °C. After the 6th week, rhizomes that had been previously harvested and stored in the cooler were removed. Ten uniform rhizomes (2.15 g ± 0.5) were selected and one rhizome was planted per 10-cm pot using a commercial greenhouse medium substrate (LC1; Sun Gro Horticulture Ltd., Vancouver, Canada). Pots were placed in the greenhouse and grown at 21 °C for 6 weeks. Plants were fertilized at each watering with 250 $mg\cdot L^{-1}$ N 20N–2.2P–16.6K (Jack's Professional LX Water Soluble Fertilizer 21N–$5P_2O_5$–$20K_2O$. All Purpose; J. R. Peter's Inc., Allentown, Pennsylvania).

Breaking Experiment. Oxalis rhizomes that had been stored for 6 weeks in the dark at 3 °C were used in this study. Rhizomes of similar size were selected and gently broken in half to obtain apical and basal portions of ~3 cm. Whole intact rhizomes of ~6 cm were also selected and grown as the control, in addition to whole intact rhizomes that were equal in size to the apical and basal portions (~3 cm). Six rhizomes were planted and grown for 6 weeks in conditions as described for the dormancy experiment.

Data Collection and Statistical Analysis. Data collected for both experiments included days to shoot emergence (DTE) which was recorded when the first leaf was visible above the media surface; the number of days to flower (DTF), recorded when the first flower fully opened; the total number of leaves; and the total number of flower cymes per pot. Plant height was recorded (for the dormancy study only) after 6 weeks and above ground tissues were harvested and oven dried at 70 °C for at least 48 h after which dry weight was determined. One-way analysis of variance tests were conducted to identify differences in the measured parameters in response to storage periods and rhizome propagule portions. General linear or quadratic regression lines were applied as appropriate based on r^2 values.

RESULTS AND DISCUSSION

Rhizome Storage Experiment. Storage period had a significant effect on DTE (Fig. 1). As storage duration increased, DTE decreased. Rhizomes stored for 5 weeks emerged after 10 days compared to 16 days for rhizomes given no storage.

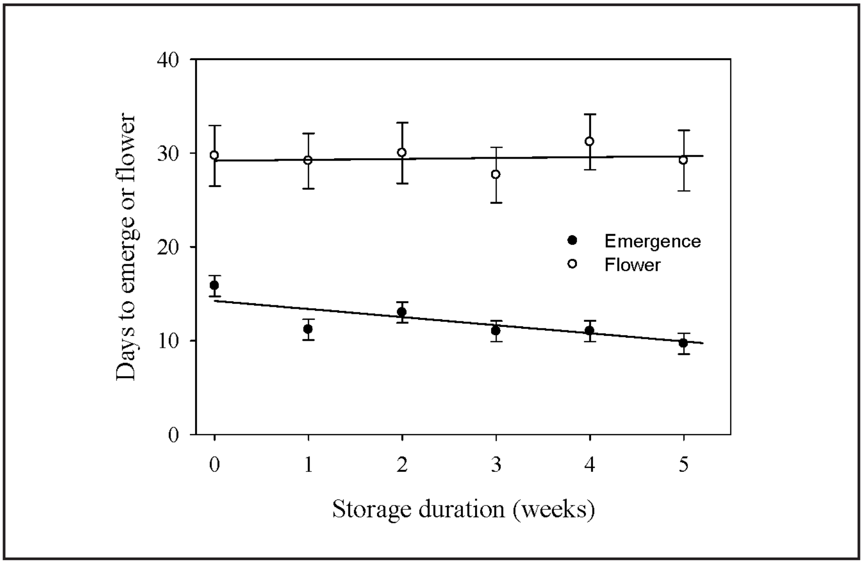

Figure 1. Effects of pre-plant storage at 3 °C on days to shoot emergence and first flower in *Oxalis triangularis* subsp. *popilionacea.* The regression equations, associated *P* values for the associated F statistic, and r^2 values are as follows; emergence: $y = -0.8637x + 14.2401$ ($P = 0.0052$) ($r^2 = 0.21$); flowering: $y = 0.0952x + 29.1846$ ($P = 0.8944$) ($r^2 = 0.00$).

Similar results were observed by Armitage et al. (1996) when *O. adenophylla* was stored at 5 °C (dry or wet) for at least 6 weeks. Storage period had no effect on DTF (Fig. 1). The number of leaves and flowers increased as storage period increased (Fig. 2, 4). Rhizomes stored for 5 weeks produced more than twice as many leaves than rhizomes stored for 0 or 1 week. Leaf dry weight also increased linearly as storage period increased, more than doubling from 0.33 g with 0 weeks to 0.85 g after 5 weeks storage (Fig. 3).

Rhizome Breaking Experiment. Whole, intact rhizomes produced fuller, more marketable plants compared to both basal and apical rhizome sections (Fig. 5). Basal rhizome portions emerged between 4 and 6 days later than other rhizome treatments (Fig. 6). Similarly, basal rhizomes flowered at least 8 days later than all other treatments (Fig. 6). Whole, intact rhizomes produced at least 30% more leaves and twice as many flowers when compared to the short and split rhizome portions (Fig. 7). Decapitation, or removal of the apical meristem, has been used in many plant species to overcome apical dominance and promote lateral bud development. In our study, the basal rhizome propagules produced significantly more dry matter; however, the number of leaves was not significantly different. The number of axillary buds that developed was not recorded. Leaf dry weights were greatest from plants grown from whole rhizomes, 0.44 g, but were not different than plants grown from basal rhizome pieces, 0.34 g (Fig. 8).

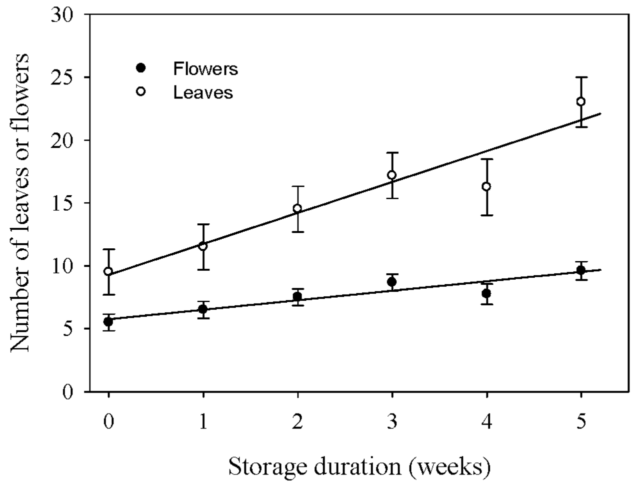

Figure 2. Effects of pre-plant storage at 3 °C on flower and leaf numbers in *Oxalis triangularis* subsp. *popilionacea*. The regression equations, associated *P* values for the associated F statistic, and r^2 values are as follows; flowers: y = 0.7536x +5.757 (P = <0.0001) (r^2 = 0..40); leaves: y = 2.4607x +9.289 (P = <0.0001) (r^2 = 0.49).

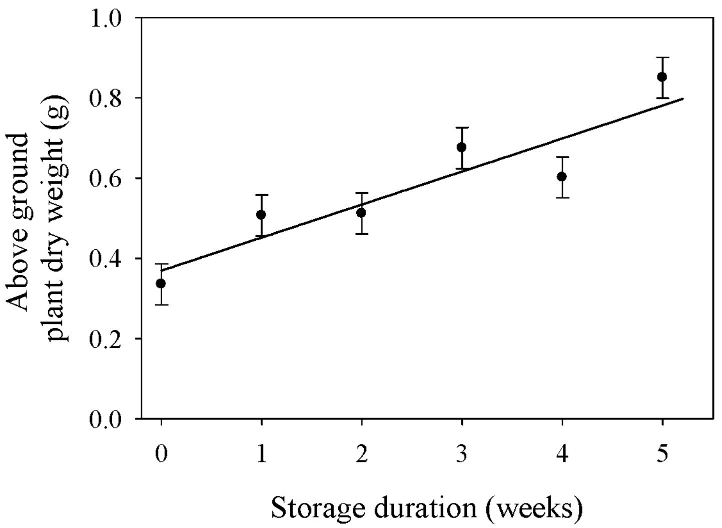

Figure 3. Effects of pre-plant storage at 3 °C on leaf dry weight in *Oxalis triangularis* subsp. *popilionacea*. The regression equation, associated *P* value for the associated F statistic, and r^2 value are as follows: y = 0.0824x +0.369 (P = <0.0001) (r^2 = 0.53).

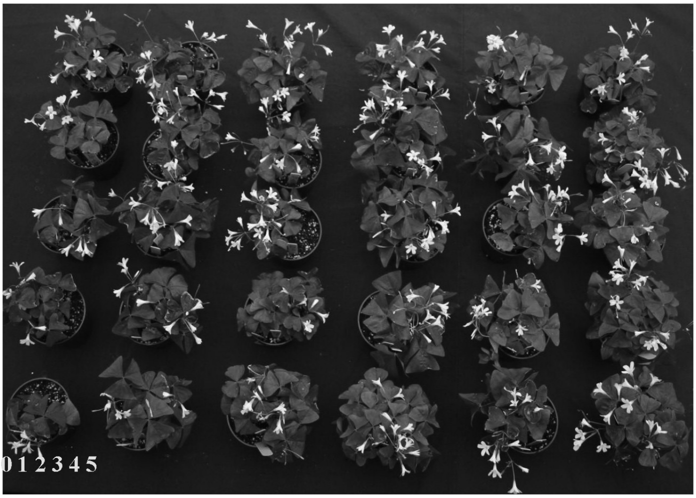

Figure 4. Effects of pre-plant storage at 3 °C on growth and development of *Oxalis triangularis* subsp. *popilionacea* forced in the greenhouse at 21 °C. L to R; 0, 1, 2, 3, 4, and 5 weeks of storage.

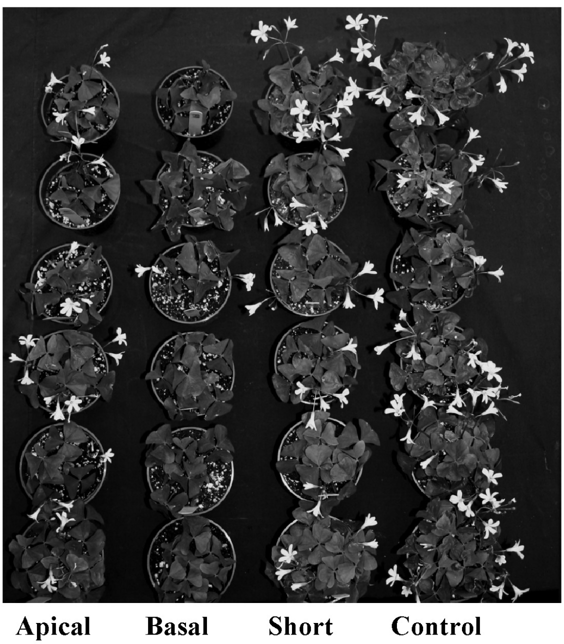

Figure 5. Effects of rhizome propagule type on growth and development of *Oxalis Oxalis triangularis* subsp. *popilionacea* plants after 6 weeks. Control rhizomes were ~6 cm. Apical and basal rhizome propagules were obtained by breaking ~6 cm rhizomes. Short rhizomes (~3 cm) were grown to compare to broken rhizomes.

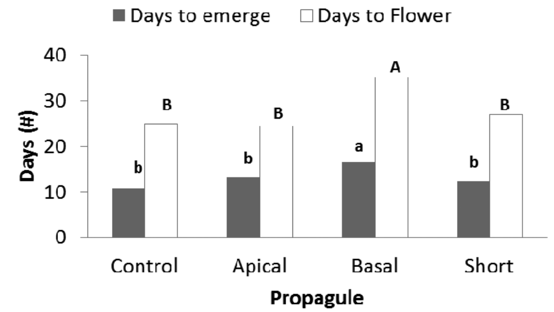

Figure 6. Effects of rhizome propagule type on days to emerge and flower for *Oxalistriangularis* subsp. *popilionacea* plants after 6 weeks of growth. Control rhizomes were ~6 cm. Apical and basal rhizome propagules were obtained by breaking ~6 cm rhizomes. Short rhizomes (~3 cm) were grown to compare to broken rhizomes. Values are means of 6 plants. Means followed by different letters are significantly different by Tukey's honestly significant difference test at $P \leq 0.05$.

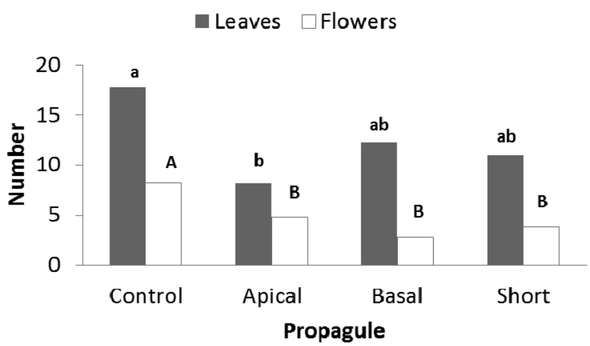

Figure 7. Effects of rhizome propagule type number of leaves and flower cymes for *Oxalis triangularis* subsp. *popilionacea* plants after 6 weeks of growth. Control rhizomes were ~6 cm. Apical and basal rhizome propagules were obtained by breaking ~6 cm rhizomes. Short rhizomes (~3 cm) were grown to compare to broken rhizomes. Values are means of 6 plants. Means followed by different letters are significantly different by Tukey's honestly significant difference test at $P \leq 0.05$.

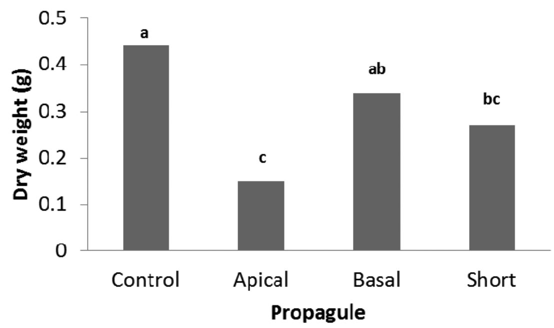

Figure 8. Effects of rhizome propagule type on leaf dry weight for *Oxalis triangularis* subsp. *popilionacea* plants after 6 weeks of growth. Control rhizomes were ~6 cm. Apical and basal rhizome propagules were obtained by breaking ~6 cm rhizomes. Short rhizomes (~3 cm) were grown to compare to broken rhizomes. Values are means of 6 plants. Means followed by different letters are significantly different by Tukey's honestly significant difference test at $P \leq 0.05$.

CONCLUSIONS

Pre-plant storage period had a positive effect on growth and development of oxalis, with more leaves and flowers produced as storage duration increased from 0 to 5 weeks. Careful handling of plant material is always important, as to reduce physical damage and potential pathogen problems. Some oxalis rhizomes can grow to be several centimeters in length and could potentially break during processing. Our results indicate subsequent growth can be achieved from either the apical or basal portion, without significant delay in growth and development. However, because oxalis is primarily marketed as a foliage plant, more leaves are beneficial and the greatest growth, both in terms of leaf number and flower stem production was from intact rhizomes. The value of the flower with oxalis is less important; however more flowers have the potential to attract more customer interest. It is unclear how longer storage periods or storage at other temperatures may affect growth and development of *O. triangularis* subsp. *popilionacea*, and should be investigated in future studies. It is plausible that plant growth hormones have little significant effects on subsequent growth and development of oxalis, namely axillary branching. Carbohydrates and their role in plant development may be more influential and would be interesting to investigate.

Acknowledgement. We gratefully acknowledge Anthos, (Dutch Royal Trade Association for Flowerbulb and Nursery Stock), the Post-Schenkel Memorial Council, and the Fred C. Gloeckner Foundation for financial support of this project. Also thanks to Leo Berbee Co., Marysville, Ohio, for rhizome donations.

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Greenhouse Solarization — An Alternative to Chemical Fumigants©

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Chemical fumigants such as Basamid and methyl bromide are becoming increasingly restricted. Reports of their eventual removal from the tool chest of growers continue to swirl and appears imminent. Their use creates chemical and employee conflicts with lengthy re-entry intervals in greenhouses and concerns about the possible health risks to applicators, employees, and the public alike. Suspicion of the environmental hazards of such material is frequent and concerns can arise quickly when "marine pollutant" is stated on the Basamid label. The use of steamers, while effective, can be expensive and difficult to implement on a large scale. Alternatively, greenhouse growers who propagate in beds may find solarization as an effective, nonchemical means of sterilization.

Capturing the sun's radiant energy to control or suppress weed seeds and soil-borne pathogens has long been a tool by farmers throughout the world. As far back as 1939 farmers in India were trapping the sun's heat to control *Thielaviopsis* in the sand. Other work was presented to the Phytopathological Society of Israel in February 1975. In 1976 California scientists at U.C. Davis reported control of *Verticillium* in cotton with solarization techniques. Many California pistachio farmers relay on solarization to control *Verticillium* today. With an increasing interest in organic production and the shift towards more environmentally conscious farming, solarization has gained popularity and is continuing to pique the interest of many growers.

Bailey Nurseries, Inc., began using solarization or "hydrothermal soil disinfestation" to trap solar radiation in our Minnesota greenhouse beds sufficient for the control or suppression of weed seeds and soil borne diseases. Investigating and employing this method of greenhouse sterilization proactively addresses the issue of chemical fumigant availability, its costs and the concerns of employees, and environmental exposure before EPA restrictions prevent or severely limit their use.

After the greenhouses are emptied following the spring bedding plant season, ground cloth is removed from the sandbeds and prepared for the propagation of softwood cuttings (June, July, and August). Sandbeds are leveled, watered thoroughly, and then covered with a single sheet of transparent, 3-ml infrared polyethylene plastic (AT Films Inc., Edmonton, Alberta, Canada). Placing the plastic as close to the surface of the propagation beds ensures better heating of the bed and not a layer of air in between the bed and the poly. Sufficient moisture within the propagation beds is helpful for two reasons. Heat is transferred more efficiently through wet soil than dry soil, and many weed seeds can be heat resistant when dry. Imbibing these seeds and initiating the germination process can make them more vulnerable to the solarization process. When this has been completed all vents, air intakes, and doors are closed tightly for a minimum of 2 weeks; preferably longer. Successful solarization is achieved by exposing weed seeds and soil-borne pathogens to temperatures and exposure times sufficient for their inactivation. Lengthening the time in which the greenhouses remain closed increases the likelihood of sunny weather and increases cumulative temperatures within the sandbeds. Higher temperatures within the propagation beds are more dependent on bright, sunny days than by warm outside temperatures. When the desired high temperatures and exposure times have been recorded the house is opened and the poly covering the sand beds is rolled and stored for future treatments. We expect a single sheet of poly to be useable for approximately four to five times before light transmission and physical integrity are compromised. Unlike chemical fumigants there is no re-entry interval to observe and planting can begin immediately.

When done correctly the amount of weeds that grow and incidence of soil-borne diseases during the season appears similar to those that escape our Basamid treatments. The most common soil-borne pathogens that we are targeting are *Phytopthora, Rhizoctonia*, and *Pythium*. We have not seen an increase in plant heath problems in houses that have been solarized. The common weeds we are targeting in Minnesota are hairy bittercress (*Cardamine hirsute*), purslane (*Portulaca oleracea*), various grasses, prostrate spurge (*Euphorbia maculata*), and common groundsel (*Senecio vulgaris*). Patterns of weeds growing after solarization have occurred where shadows were cast on the sand beds. Lines of seedlings have been observed below cooling tubes, knee walls, and greenhouse ends. Covering every area within the greenhouse and to removing any cooling tubes and/ or other features inside the house that restrict the transmission of light to the beds has limited these escapes. Effective soil solarization is dependant on the combination of soil temperatures and exposure time. Examples reported by Jarvis (1992) include: Most bacteria 60–70 °C for 10 min, thermotolerant bacteria 90 °C for 30 min, *Phytophthora* 50 °C for 30 min, *Pythium* 53 °C for, 30 min, and most weed seeds 70–80 °C for 15 min.

Using sensors has given us a much better view of the temperatures we are getting underneath the poly. We placed data loggers (Watchdog Data Loggers, Spectrum Technologies, Plainfield, Illinois) directly underneath the poly and approximately 2 in. beneath the surface of the sand. Temperatures were recorded every 6 min for 2 weeks and are presented graphically below (Fig. 1). Because effective soil solarization is dependant on reaching adequate soil temperatures for certain lengths of time, it is important to understand when temperatures sufficient for controlling weed seeds and soil-borne pathogens have been achieved (Fig. 1).

Geography and time of year may reduce the likelihood of successful solarization in the greenhouse. Latitude will affect average daily temperature as well as day length. Local weather, including the percent of days with cloud cover, can be factors that may limit this as a viable technique for growers. Achieving temperatures in a Phoenix greenhouse during the month of April is probably more realistic than during the same time in Seattle.

Bailey Nurseries, Inc. is committed to understanding how solarization fits into the control of weed seeds and soil-borne pathogens in the greenhouses. Following the steps described above has shown us that it is a tool in which we can safely, economically and repeatedly use to control or suppress weed seeds and soil-borne pathogens in our greenhouses during the summer, similar to chemical fumigants. Restrictions on these chemicals are becoming stricter. It is expected that in a short time these tools will no longer be ones that are available to us. There is a great need to develop and refine alternative options for reducing weed seeds and soil-borne diseases in the greenhouse; solarization just may be that option.

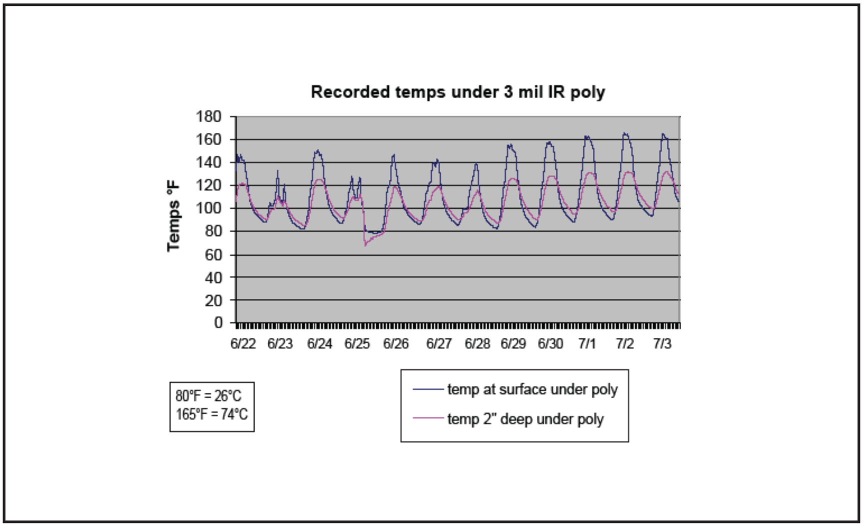

Figure 1. Temperatures recorded over a 2 week period.

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Foliar Application of Rooting Hormone in Softwood Propagation©

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THE PRINCIPLE

Spray Drip-Down Method. Spray solution enters the plant through stomata to the vascular system and the hormone reaches the base of the cutting by mass flow and releases slowly, inducing rooting.

BENEFITS

- Save time on dipping of cuttings into hormone.
- Saves money through minimal use of PPE.
- Workers are not exposed to chemicals all day.
- The hormone is water based and will have zero plant mortality, unlike alcohol based hormones.

METHOD

1) Stick softwood cuttings as usual in media for rooting or lay down flats in the greenhouse.
2) Water the cuttings adequately. Spray rooting hormone at required concentration (1,000 PPM) on completely dried foliage (next day morning, when no direct sunlight).
3) Let the foliage absorb the hormone completely without allowing any chance for dilution of the hormone by misting / watering before drying.

Figure 1. Successfully rooted *Sambucus* cutting.

4) Maintain the proper environment in greenhouse for proper rooting of cuttings [relative humidity 90%, temperature at 28 °C (82 °F)] with adequate light level (diffused).
5) Keep the media moist enough to maintain leaf turgidity without any signs of wilting and stress. Balance hand watering providing allowance for misting coming in line with environment settings.
6) Roots start initiating from 7–8 days after the sticking. Keep same environment until hardening stage.

RESULTS

Over 90% success with *Sambucus, Spiraea, Potentilla, Cornus, Hydrangea, Weigela, Polygonum,* and *Sorbaria* using Hortus IBA Water Soluble Salts. Figure 1 shows a successfully rooted *Sambucus* cutting.

Aronia ×prunifolia 'Viking': Horticultural Enigma With Untapped Potential©

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Aronia, commonly known as chokeberry, is a group of deciduous, multi-stemmed, rosaceous shrubs native to eastern North America. Two primary species compose the genus, *A. arbutifolia* (L.) Pers., red chokeberry and *A. melanocarpa* (Michx.) Ell., black chokeberry. A growing consensus now considers *A. ×prunifolia* (Schneid.) Grabn., or purple chokeberry to be a unique, self-sustaining species of hybrid origin.

Aronia ×prunifolia 'Viking' (syn. *A. melanocarpa* 'Viking') is one of several cultivars that have been selected for their large fruits, robust habits, and cold hardiness. The cultivar and its relatives are a nearly homogenous group possessing a unique phenotype distinct from the wild North American species. 'Viking' was named as a cultivar in Finland in the early 1980s, but can trace its origins to Russian horticulturalist Ivan Michurin nearly a century before. Michurin built his reputation by hybridizing various pome-fruited genera including *Aronia*. After his death the notoriety surrounding his work lead to commercial cultivation of his *Aronia* taxa as a fruit crop within the Soviet Union. By the 1980s 'Viking'-type *Aronia* had become a major crop with 44 thousand acres in cultivation.

The earliest references for *Aronia* cultivation in Europe come from Ukraine in 1816, when it went by the name *Mespilus melanocarpa* (Robertson et al., 1991; Skvortsov, 1983). For the next seven decades references refer to it grown solely as an ornamental, and indistinguishable from wild North American types. By the 1890s, Michurin began working with the shrub, which he considered to be a black-fruited form of mountain-ash. With material he received from German nurseries, Michurin began hybridizing *Aronia* with various pome-fruited species including *Sorbus, Chaenomeles, Malus,* and *Mespilus*. Michurin found that *Aronia* hybridized fairly frequently with many native European *Sorbus*. However, the focus of Michurin's record keeping was primarily on morphological descriptions and less on nomenclature. Given the inconsistencies in his notes, the inclusion of *Aronia* with *Sorbus* in that period, and limited translations of his works, it is not clear Michurin's references to his "black-fruited mountain-ash," refer to one of his hybrid genotypes or to the germplasm he originally received for evaluation. After Michurin's death, his contemporaries, along with the Soviet state, began promoting Michurin's 'Viking'-type *Aronia* as a cold-hardy fruit crop, distributing seed to Siberia, Scandinavia, and other Eastern Bloc countries. Given Michurin's reputation for conducting wide crosses, the propensity for *Aronia* to hybridize with European *Sorbus* and 'Viking's' unique morphology, strong support exists for it to be considered a distinct species. Historically, 'Viking'-type *Aronia* plants have been referred to as *Aronia mitschurinii* Skvortsov et Maitulina.

Scientific interest in *A. ×prunifolia* 'Viking' has surged in recent years because of the polyphenols present in the fruits, in concentrations that are among the highest known (Szajdek and Borowska, 2008). Polyphenols (purple pigments) are potent antioxidants, playing a significant role in reducing oxidative stress in cells. Marketing campaigns highlighting the antioxidant qualities for related fruit juices such grape, cranberry, and *Acai* have proven successful in increasing demand for these products. *Aronia*, with a century of reliable production in Europe, has the potential to be a major competitor in the North American market if it were to receive similar public exposure.

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Propagation of *Hydrangea macrophylla* With Controlled-Release Fertilizer©

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INTRODUCTION

Traditional softwood propagation has generally involved the use of single or blended media components such as peat, perlite, pumice, sand, coir, rice hulls, and liquid fertilizer. Often in greenhouse and propagation settings, conventional growers use liquid fertilizer as a source of nutrition for their crops. The process of rooting a cutting producing a quality liner is as much a science as an art. To create uniform crops, growers generally wait until all cuttings are rooted before making a fertilizer application. However, demand for premium rooted-liners has put pressure on growers to look for innovative ways to produce the same high-quality plants in less time.

Objectives.

1) The primary objective of this study was to incorporate controlled-release fertilizer (CRF) into media of *Hydrangea macrophylla* 'Bailmer', Endless Summer® hydrangea The Original, providing nutrition as required by the liner.
2) Our second objective was to find a CRF product that stops releasing nutrients during the fall and winter, yet provides adequate amounts of nutrients during the following spring.
3) Thirdly, we were looking for a product that provided a consistent rooting and overwintering success rate of at least 90%.

MATERIALS AND METHODS

In the Summer of 2009 we incorporated three homogeneous CRF products at two different rates (Table 1). The media was comprised of coarse perlite, coconut coir, fine bark, and peat (11 : 3 : 3 : 3, by vol.) plus 15.5 lb of a starter package per yard. Rates were calculated according to the label and with assistance from our manufacturing and sales representatives. For each treatment, ¼ yard of medium was mixed by hand with the corresponding fertilizer rate weighed on a digital scale using grams as the unit of measurement. This helped insure the volume and consistency of media and CRF were accurate. Ten flats of 38-cell trays were planted with *H. macrophylla* 'Bailmer', Endless Summer® hydrangea The Original on 29 July 2009 with each CRF treatment and rate.

The hydrangea cuttings were misted for 20 days (August 17) and then weaned accordingly for the next 14 days. On Day 27 a 4.7N–16P_2O_5–3.2K_2O + micronutrients liquid fertilizer was applied to the crop. On Day 34 (31 Aug. 2009), the mist was turned off and the plants were allowed to grow on their own newly developed roots. On Days 37 and 47 a liquid fertilizer blend of 8.1N–4P_2O_5–8K_2O + micronutrients was applied to all cuttings. The control group received only liquid fertilizer, while the test group received both incorporated CRF and supplemental liquid feed.

Media analysis was conducted in-house via the pour-through method on the control and CRF-incorporated treatments. The leachates were tested with a Hanna

Table 1. Controlled-release fertilizer blends, rates, and product information.

Controlled-release fertilizer blend	Rate	Longevity	Micronutrient package
APEX 16N–5P_2O_5–11K_2O Woody Plant	3 lb/yd^3	18 month	No
APEX 16N–5P_2O_5–11K_2O Woody Plant	5 lb/yd^3	18 month	No
APEX 15N–6P_2O_5–11K_2O NPK MAX	3 lb/yd^3	12–13 month	Yes
APEX 15N–6P_2O_5–11K_2O NPK MAX	5 lb/yd^3	12–13 month	Yes
APEX 7N–28P_2O_5–7K_2O Custom Blend	3 lb/yd^3	12 month	No
APEX 7N–28P_2O_5–7K_2O Custom Blend	5 lb/yd^3	12 month	No

Table 2. Controlled-released fertilizer blends with EC, pH, and rooting percentages.

Controlled-released fertilizer blend	10/7/09 EC	10/7/09 pH	3/15/10 EC	3/15/10 pH	4/15/10 EC	4/15/10 pH	4/15/10 rooting (%)
APEX 16N–5P_2O_5–11K_2O @ 3lb/yd^3	0.45	6.8	0.66	7.2	0.72	7.2	97
APEX 16N–5P_2O_5–11K_2O @ 5lb/yd^3	0.61	6.9	0.66	7.1	0.95	7	94
APEX 15N–6P_2O_5–11K_2O @ 3lb/yd^3	0.55	6.9	0.76	7.1	0.93	7.1	92
APEX 15N–6P_2O_5–11K_2O @ 5lb/yd^3	0.49	7.2	0.86	7.1	0.9	7.1	90
APEX 7N–28P_2O_5–7K_2O @ 3lb/yd^3	0.52	6.8	0.64	6.9	1.2	6.7	95
APEX 7N–28P_2O_5–7K_2O @ 5lb/yd^3	0.37	6.8	0.79	6.6	1.02	6.7	89
Control	0.39	7.2	0.55	7.2	0.88	7.1	90

Instruments (HI 9813-6) portable meter. Data was collected once during the fall on 7 Oct. 2009 and twice during Spring 2010 (15 March 2010 and 15 April 2010). Rooted percentages and overwintering success were calculated on 15 April 2010.

RESULTS AND FINDINGS

Of the six treatments, we found the hydrangeas with APEX 16N–5P_2O_5–11K_2O Woody Plant CRF incorporated, had overall higher rooting percentages, better media analysis, and better color than the other treatments, including the control (Table 2). On average, the CRF incorporated media had an accelerated spring flush and a higher rooting and overwintering success than the control.

To be sure the CRF's nutrient release slowed down in the fall and winter, we tested the electrical conductivity (EC) and pH on 7 Oct. 2009 (Table 2). Testing the media in October indicated that all treatments had similar EC and pH levels, all of which were acceptable to our production practices. Pour-through samples were taken and collected on 15 March 2010 and 15 April 2010 (Table 2). Based on our finding no corrections or leaching were necessary for our production cycle.

CONCLUSION AND DISCUSSION

Overall, CRF can assist growers in cutting propagation. Controlled-released fertilizer provides nutrition based on the plant needs rather than solely relying on growers' time to monitor, test, apply, and calculate liquid fertilizer rates. Controlled-released fertilizer has the possibility to create a more consistent uniform crop and in our study it increased rooting percentage and overwintering success. However, none of these claims can be made for all growers in each unique situation. Experimenting with various CRF blends based on climate, plant material, propagation production cycles, and facilities are to the benefit of each grower. Working with local manufacturers can ensure a higher rate of success with CRF in propagation.

Looking forward, we have conducted a similar study during Summer 2010. Since it is still ongoing, results are not available. With the information gathered in 2009 we were better able to select CRFs that fit our crops and production cycle. With the increase in comfort from our 2009 study, we expanded the experiment to more genera in 2010. Areas that need further discussion and evaluation include; a cost study of liquid vs. CRF in propagation. Once blends and rates are better defined, we will draw economic comparisons between the two methods. Another area of interest, will be determining if one process utilities nutrients more efficiently than the other. How much liquid fertilizer is lost between flats and pots? Questions still remain on the role of CRF within propagation; however the success of this trial justifies further investigation.

A Poor Ol' Country Propagator©

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To start a tome of this nature one would naturally ask, "Well since you have been so involved in horticulture, just how did such a process start?" And I would suppose that such a question has merit for like many of us the paths that lead us to our eventual destinations are often derailed and changed along the way.

My earliest exposure to the world of horticulture was brought on by my childhood years growing up in North Florida, inland from the coast and at the logical terminus of the orange grove growing regions. Much of Volusia, Putnam, St. Johns, and Alachua Counties in north Florida are heavily agricultural and horticultural which included such crops as citrus, leatherleaf fern (for the florist trade), peaches, wild collected hearts of palm (known colloquially as swamp cabbage), deer tongue (a wild-collected herb used in the production of tobacco products, $0.50 for a bushel of leaves, I still do not know what it is botanically), pecans, truck farming, beef cattle, chickens, pork production, pulp wood, lumbering, and commercial fishing. In fact, my hometown of Crescent City, Florida owes its very existence to beef cattle ranching. At the turn of the19th century to the 20th it was a shipping point for cattle from Volusia and Putnam counties. Cattle were herded through town, corralled at the town's Eva Lyons Park and loaded onto steam boats at Lake Crescent for a trip up Dunns Creek and the St. Johns River and on to the markets of the upper East Coast.

My father was a part-time farmer aside from his regular job at a grocery store, and the family had a variety of concerns operating at one time including chickens for eggs and meat, pigs, the occasional cow, oranges and other types of citrus, persimmons (*Diospyros kaki*), grapes such as *Vitis rotundifolia*, pecans, leather leaf ferns, asparagus ferns (not really ferns but an ornamental form of asparagus such as *Asparagus densiflorus* Sprengeri Group (syn. *A. springeri*), wild blueberries, and *A. densiflorus* 'Myersii' (syn. *A. meyeri*) for seed production. We never thought to raise the deer tongue herb because it was so abundant in the wild. By the time I was 8 or 9 years old I had a regular active part in maintaining all of these things after school. There was no shortage of work to do before supper and home work and cutting wood for the wood stoves (we had two for heat during winter). Most Northerners would not even consider that heat was a valuable commodity in winter in Florida of all places but let me assure you that it gets cold there. There were massive freezes in 1893 that wiped out most of the Florida Citrus industry, followed by others in 1964 when it dropped to 6 °F and in 1984/85 with cold in the teens which again wiped out much of the Florida citrus production (it has failed to recover from the 1980s freezes). Six hours below 28 °F will kill citrus to the ground.

One of my earliest memories of anything resembling horticulture occurred when I was 4 years old, when my father and grandfather and I a budding horticulturist, went across the road and dug up as bareroot, two water oaks (*Quercus nigra*) and took them back home and replanted them in our front yard. One died and one lived and as far as I know it is still alive today some 52 years later.

From the age of 6 years and on my father would load up the whole family (my sister, step-brother, and step-mother) for a road trip to Massachusetts. There was a dramatic change in plant life and the differences between the Berkshires and lowland Florida were not lost on me. I always managed to bring back a load of plants to Florida only to watch them die in the relentless tropical heat. One of my father's patent sayings was that plants were slaves to their environment and they could not be abruptly moved from one place to the next. He seemed impatient that I did not automatically subscribe to this notion. One of the things that I tried to do later on in life as I learned more was to find tropical substitutes for their more Northern cousins. Having raspberries was a challenge and desire and this was met with the introduction of the Mysore Raspberry from tropical India. Others such as the no-chill-requiring apples from Israel soon found their way onto the farm.

My first tasks were menial such as the ubiquitous pulling of weeds but eventually I graduated to helping to bank orange trees at the beginning of winter to prevent the graft unions from freezing and to running water pumps at night to protect the fern crops from below freezing temperatures. My father often started our own orange trees by t-budding a desired cultivar onto sour orange seedlings.

I thought it was fascinating that by a little bit of surgery and hokus pokus that a bud would take and grow into a desirable tree with delicious fruit, especially since the growing bud resulted in a tree that had but superficial resemblance to the chosen rootstocks which were sour orange or *Poncirus trifoliata*. I used to ask how this could be and another of my father's patent replies was that "it was the nature of the beast." I am not sure that he had an understanding of the physiology, he just knew that it worked. After watching hundreds of such surgical operations I decided to try myself. I bought my first pocket knife with an ultra thin blade at around age 11 and proceeded to try out my skills (I still have that knife). After an uncountable number of flops I finally got the hang of it. From oranges I went to black walnuts, (*Juglans nigra*) (they will graft onto *Carya* with a cleft graft), roses, and persimmons (*Diospyros kaki*). My father maintained that *Ligustrum* was related to *Citrus* (it is not) but I was intrigued by the prospect of this and sought to graft *Ligustrum* to *Citrus*. The grafts all failed and it seemed pretty obvious that if there was a kinship it was a weak one and had no merit. I was set upon the notion that if there was a question about something, try to devise a way to either prove or disprove it. It was about that time I took an interest in plant breeding but not knowing much of the process that endeavor did not take off at that time, but did resurface years later.

When I was around 12 years I started mowing yards and clipping hedges and raking leaves. I would do almost anything to make money as it was genuinely hard to come by. My developing lawn business took me into town where I got to see a great deal many other plants that we did not have. One of the towns' people was a man by the name of Tex Legant (pronounced Lay-Jant).

He had a passion for breeding hibiscus (*Hibiscus rosa-sinensis*) and one day I was astounded to see two of his creations, a bright orange one and a totally brown one — quite a bouquet. I had never seen a brown flower and was completely bowled over at the prospect of plant breeding. When I was 13 years we got our first color TV. I was astounded because with that new marvel I could see what the plants were in the back ground for shows such as Hawaii Five-O and Magnum, P.I. — at the time utterly fascinating.

As news of my lawn mowing capabilities spread around I was approached by a local farmer to raise vegetable seedlings for him. I had quite the enterprise going raising vegetable seedling by the tray for $0.50 a tray. Plugs today of perennials bring $0.50 each or about $30 a tray. Back then it wasn't so much what you got paid by the hour as what the total take was by the end of the week. As an offshoot of that enterprise I got into raising hot peppers for the local supermarket and was paid the astronomical price of $1.00 a pound. That was better than scrap copper which at the time was $0.35 a pound which was considered lucrative enough. Peppers were easier to deal with and did not include toxic fumes from burning wiring to get to the copper.

When I turned 16 years old and had a driver's license I approached my high school guidance counselor with a proposition, either he find something for me to do to interest me at school or I was leaving because I was bored to tears with the whole process (I hated high school). He heard me and got me enrolled in St. Johns River Jr. College and when the next semester rolled around I went to high school for a half of the time and the college for the other half of the time. I came close to graduating both at the same time.

From both of them I went on to the University of South Florida, majoring in Biology. I chose biology because it afforded me a vast repertoire of subjects to take. At that time I was interested in both zoology as well as the plant sciences. Along the way I somehow stumbled into a laboratory that was devoted to elucidation of the chemistry of flower pigments. I spent 2 years as a volunteer lab assistant with several stints as a for-credit student in the lab as an independent study program. During that time I learned about the new science of plant tissue culture, and the influence of breeding (there is that word again) on plant flower color chemistry. I also picked up a great deal of information on analytical chemistry and the use of radioisotopes in tracing applied precursors in plants and how they were transformed into the resultant pigments. I spent many hours during the night running poly acrylamide gel chromotography to extract a specific pigment from a coarse mixture as well as developing extraction procedures for phenolic phytochemicals such as flavones, flavanones, and anthocyanins.

During my junior year at the University I literally ran out of money. I was putting myself through school with minimal help from home, and my savings ran out. I needed work desperately and found a job at Holmes Nurseries in Tampa. I was making all of $2.00 per hour. I worked a 40-h week and went to school when time permitted. After a month I was given a $0.05 raise. I was determined to finish school and I did, but it took 5 years to do so instead of the conventional 4 years total. While at Holmes I learned about many aspects of plant production and plant propagation. I also ran across a copy of *Plant Propagation* by Mahlstede and Haber. I know that I have read that book cover to cover at least four times, maybe more. While at Holmes I was introduced to the art of interior plant maintenance and then on to the merits of conventional landscape maintenance at the Tampa International Airport (TIA). At TIA I did both and had security clearance all over the terminal buildings taking care of the numerous plantings on the cantilevered balconies.

I graduated from South Florida in 1977 and stayed in Tampa for another year. The next summer I wanted to see something different and arranged for a series of job interviews in Denver, Colorado. I was tired of Florida. I loaded up my little truck and headed west. I spent 2 weeks in Colorado and was forever changed with what I saw as I had never seen anything like it. The spectrum of plant material was radically different than anything I had ever seen in Florida. I was smitten. I got a job in a combination re-wholesale/retail nursery and went back to Florida to tie up lose ends and moved to Colorado in time for the spring start up. I left the only life that I knew well behind me and looked forward, even though my father was dead set against it and warned me that there was no future in the nursery business and I would wind up poor and destitute, which I thought was rather odd advice since being poor and destitute was a normal way of life for me and I couldn't see how it could get any worse.

Once in Colorado I had to learn a whole new arena of plants, their culture, and what a severe climate can do to plant production. The occasional cold snaps and hurricanes in Florida were bush league when compared to the vicissitudes of climate change in Colorado. But more importantly is the rapid transformation of ecosystems in Colorado based upon altitude. Whole plant populations can change in a distance of a quarter mile just by going up or down. Microclimate systems abound and many times such things can be encountered merely by crossing the road. While plant communities in Florida changed slowly and the systems in Miami are not the same as in Jacksonville there are similarities. In Colorado the transition is rapid and the similarities can sometimes disappear completely. North facing slopes have entirely different plant communities than those found on south facing slopes. This complexity is often accentuated by those dramatic temperature differentials in very short distances with an accompanying change in water availability. Plants in the high altitude West also have different features to protect themselves from extremes of weather and from the vastly brighter light found there compared to sea level.

I worked many jobs at the now extinct Mountain Meadows Nursery, from production of container plants both woody and perennials, to production, harvesting, and storage of B&B trees and shrubs. As time went by I became more familiar with the range of plants for the trade and served as editor of the nursery's catalogs, trade show representative, and developer of a plant propagation program at the nursery. I had become acquainted with the Denver Botanic Gardens in the process which in turn lead me to learn of the existence of the International Plant Propagators Society. After I had been in Colorado for about a year I discovered a member of the IPPS who would later help me in joining the IPPS and went on to learn that the then secretary of the Eastern Region of the IPPS was one Bill Snyder, who lived in Boulder, Colorado. In 1979 I joined the Western Region of the IPPS with the endorsement of one Clayton Burdge from Montana who was both a member of the Eastern and the Western Regions. At that time there were only two. I attended my first meeting in Vancouver, B.C. that same year. With my head swirling from the vast exposure to a whole new world that was all very new to me even more radically different than the changes in Colorado, I sat down on the bus next to a rather distinguished gentleman who was informative and interesting but at the same time quite mild-mannered and reserved. We talked about viruses in plants. Little did I know that the man I sat next to that day was Dr. Richard Zimmerman, someone who I still like to sit next to on the tour bus.

During the course of my activities in the nursery trade in Colorado I learned of a need for seed collection both for the nursery and for other operations. I soon developed my own seed business collecting native plant seed. One of my favorites was *Rubus deliciosus* (Western thimbleberry) which at the time was bringing $600 per pound and I could collect a pound of seed in one day, which at the time was more than I made in an entire month. What was more important than the sudden fortune of $600 for a day's work was the exposure to the myriad of native plants and the accompanying ecosystems that came along with them. Money was a poor compensation compared to experiencing the grandeur of the Rockies on an early fall day while collecting seed. It must have been an epiphany as I am still in the seed business some 30 years later. One of my key accomplishments from my Colorado days was that on a trip back to Massachusetts I saw for the first time the Eastern form of thimbleberry, *Rubus odoratus*, and brought back seed to the Denver Botanic Gardens. Today there is hardly a garden center or nursery in Colorado and most likely New Mexico and Wyoming that does not have that plant for sale and it was because I wanted to try something different, so much for slaves to the environment.

In the early 1980s, the economic bottom fell out of Colorado and I lost my job. I bounced around a bit, and worked at a range of jobs in the trade from other nurseries to a parks district to the Denver Botanic Gardens. During that time I met my future wife and when both of us were faced with poor and destitute once again, we moved east to Pennsylvania to chase a job as a propagator at a large wholesale nursery. We were married a week before we moved and while I hated leaving Colorado we both needed a change in venue if we were to survive.

We did survive and we had a son some 3 years later. After 5 years I changed jobs and started a propagation program at another nursery. By that time I changed from the Western Region to the Eastern Region and I attended my first Eastern Region meeting in Providence, Rhode Island, in 1985. Once again I felt like a lamb thrown into the wolves' den because here face to face were the giants of the nursery trade and I was just some kid that had stumbled into their midst. I remember seeing Jim Cross, Lenny Savella, Case Hoogendorn, Charles Hess, Peter Vermuellen, Ralph Shugert, and a host of others and stood dumbfounded wondering why I was with this august crowd, what could I possibly contribute to the knowledge base compared to these guys? Another face I saw was none other than Dick Zimmerman. It is amazing how the world travels in concentric circles. It was also there that I met my good friend, Dick Bir who gave a talk on manganese levels of soils in North Carolina. I knew I was in the right place.

One important thing that I realized early on in the IPPS was that in order to get something out of it, you have to give to it. The motto of Seek and Share should be taken literally and one only gets the return of the investment if you have placed as much effort and time into IPPS as you can. I started by just showing up but then developed the courage to say, you know I have something to say about all of this and pretty soon I was part of the proceedings as at least a commentator during the question box secessions, (which by the way was one of the best things about the IPPS which seems to have gone away). From there I gave a talk in 1987 on rooting cutting with IBA dissolved in solvents based upon glycol antifreeze. I caused quite a stir with that because people really questioned who is this guy that has such a different take on things. Others tested my ideas and found that they do work. I now have lost count of the number of articles and posters I have presented but it's sizeable. I do want to set one record straight though. I did not write those papers for the notoriety, I wrote those papers as a pay back to the society that has treated me so very well and introduced me to a host of propagators and plant scientists and, above all, friends that I would not have had any other way had I not joined the IPPS. The IPPS also has offered me a voice and a place to be heard when it comes to horticulture and its advancement. Along the way I have held many committee assignments and progressed to 2nd VP, and then on to 1st VP working with Nevin

Smith of the Western Region for the joint meeting in 2008. Which I would like to think was the pinnacle of accomplishment for me. I am now immediate past president and hopefully still making a contribution to the effort. I would like to think I have made some small contribution to the increase in knowledge in horticulture over the years. I know that the IPPS has been a leader at advancing horticulture both from a knowledge base and from the point of pushing people's careers and I am ever so thankful to be a small part of it.

I left several other jobs during the course of my career and then one day realized that I had a character flaw and that was I had a specific dislike to having a boss. From that time on I forged my own path and started my own business based upon propagation and seed collection. After 16 years I have moved beyond commodity propagation but I do keep a hand in the till working with plant development, breeding, and trialing new varieties. I have also moved on from rooted cuttings to custom grafting and to evaluating seedlings of unusual species to being in the large tree locating and moving business. Large trees are a good fit, as it allows me a fair amount of time in between projects to pursue my life time goal of being a plant breeder (I am finally getting there). I am close to being 56 now and if I can get another 50 years or so to go, I might get to be real good at it.

As always my eternal gratitude is to the IPPS and the members, friends, and colleagues that make it up as one of the best fraternal organizations ever put together.

Use of Expired Plant Patent Numbers Prohibited by U.S. Law: Legal Ramifications©

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Many nurseries sell patented plants and they are required to place plant patent tags on plants with active patent numbers. However, it is has been an industry trend to publish in catalogs, internet ads, print ads, plant descriptions, and listings with not only active plant patent numbers but also plant patent numbers that have expired. It is legitimate and proper to publish active plant patent numbers with the associated plant but according to a Wall Street Journal article (Searcey, 2010) it is not appropriate to do so with expired plant patent numbers. In fact the article points out that it is a violation of U.S. patent law to publish in any form other than information of a plant name with an expired patent number.

United States federal law bars companies from marking products with erroneous or expired patent numbers. A recent federal appellate court upheld a citizen's (read any U.S.A. citizen) right to sue in federal court for the transgression of publishing or printing an expired plant patent number with the plant or plant name. The use of expired plant patent numbers is considered to be a false entity and therefore illegal.

Attorney Raymond E. Stauffer maintains that a plaintiff who brings suit against a company for using expired patent numbers is acting as a "private attorney general on behalf of the people of the United States." The Wall Street Journal article (Searcey, 2010) further states that any person can file a claim on behalf of the U.S.A. government and the plaintiff (person filing the claim) is required to split the settlement proceeds with the U.S.A. government on a 50/50 basis. Violators (defendants) if found liable can be fined up to $500.00 per instance of transgression. An instance of transgression is defined as an expired patent number applied to one product or listing. For simplicity, if there are 500 trees in stock and each has an expired number on it, each tree is considered a separate transgression. This could become a costly fine if fully levied.

The position of the federal courts is that by publishing or marking or printing a package or other object identifiable with the product with an expired patent constitutes fraud and such actions are considered to be a veiled attempt at stemming or inhibiting competition as well as misleading the public and preventing the introduction of new products or varieties that could displace the older product.

From a practical interpretation such a publication of an expired patent number could prevent a plant developer from introducing a new plant or a propagator for pursing an otherwise legitimate plant, which is exactly what the law is designed to protect.

Many large companies in the U.S.A. have been hit with these lawsuits, and most settle out of court to prevent costly legal action. Companies such as Bayer, Johnson and Johnson, and Ames Tools are among those that have been successfully sued by private attorneys trying to cash in on this failure to follow the law. As a practical matter it is best not to use any expired plant patent number unless doing so is legitimate in terms of an informative or educational literature.

As a convenience, plant patents with numbers below PP07341 have expired as of 2 Oct. 2010. Anything higher than PP07341 will still be in force at the time of this paper. A full listing of all plant patents by number can be found at: <http://patft1.uspto.gov/netahtml/PTO/srchnum.htm>.

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Some Fundamental Differences Separating Rooted Cuttings and Seedlings©

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Over the course of my 35 years in commercial horticulture I have noticed that we are far from understanding many of the things that appear obvious or intuitive. To further complicate that is our inability to comprehend what we do not know. This means that there are trends, characteristics, and facets of our jobs that present themselves regularly but we do not know why nor in some cases have even the faintest of idea as to what the fundamental explanations might be. One such case is the observable differences between rooted cuttings and seedlings. It is logical to assume cuttings of *Juniperus* might be different than that of *Cornus*, but they do have similarities. It is also logical to suggest that seedlings of *Pinus strobus* do not behave as seedlings of *Quercus robur*. But again there are similarities that can be subscribed to readily. However, a quandary exits when rooted cuttings of *C. florida* do not behave the same as seedlings of *C. florida*. From a production point of view, rooted cuttings of *C. florida* have more in common with rooted cuttings of *Juniperus* than to seedlings of *C. florida*. After years of study with a range of species it seems clear that a rooted cutting is not physiologically the same as a seedling of the very same species. The purpose here is to delineate some of these differences.

DISCUSSION

As can be seen in the accompanying chart there are a number of differences between rooted cutting and seedling. Much of these differences can be traced to both chemical and morphological differences that can be readily distinguished.

Morphologically seedling roots are derived from cambium tissues along side the xylem in a plant and are under the direct influence of naturally occurring auxins such as indole-3-acetic acid, indole-3-butyric acid, and 4-chloroindole butyric acid. In addition to this, seedling root systems are under the direct influence of gibberellins and cytokinins from the onset of a radicle during seed germination. Such a chemical cocktail is finely tuned to give the normal appearing and growing root system. Altering these chemicals can and does induce changes in the resultant root system.

The very nature of rooted cuttings is that the root systems they possess is not derived from xylem/cambium tissue but originates from undifferentiated parenchyma cells. Undifferentiated parenchyma cells under the influence of auxin and other chemicals related to the wounding response give rise to adventitious roots. These roots do not have the same physiological make up as seedling-derived roots. As with the weeping blue spruce (mentioned in the remarks of the chart), such changes are bordering into the realm of an epigenetic change.

For the sake of clarity an epigenetic change is a change in form or function that is evident but not a genetic change. The transition of *Hedera helix* from juvenile to adult is an epigenetic change as is the transition of the foliage of *Thuja occidentalis* 'Rheingold' from needled form to the more familiar flattened spray form of normal appearing *T. occidentalis*. In some cases such as the formation of adventitious roots the changes occur as a result to exposure to naturally occurring auxins and

Table 1. Some fundamental differences separating rooted cuttings and seedlings.

Rooted Cuttings	Seedlings	Remarks
No suckering	Will sucker in varying degrees	Seedlings of different species vary considerably with respect to suckering unless they are gymnosperms which rarely sucker. Ferns and related genera do not count as they are not seedlings.
Decapitation of apical tips will rarely if ever result in the formation of adventitious buds but will promote growth of axillary buds	Seedlings will form adventitious buds as a result of decapitation as well as promoting growth of epicormic shoots and protobuds buried at the stem-root union.	
Cuttings will rarely form adventitious buds when physically wounded along the main stem	Seedlings will often form adventitious buds when wounded along the main stem, such buds usually occur along the wound edge	
Cuttings exhibit an increased sensitivity to applied fertilizers, especially during the first year of growth post rooting	Generally will tolerate doses of applied fertilizer that would injure or kill rooted cuttings.	Applied fertilizer will also disrupt the physiological balance of rooted cuttings and could lead to toxicity or death of cuttings during winter storage.
Rooted cuttings will not readily tolerate drowning or water saturation of soils	Seedling will often be impervious to water saturation of soils	Rooted cuttings of *Ilex verticillata*, normally as a seedling quite water tolerant, will suffer damage if placed back into the normal environment where a seedling is found.
Will carry the same degree of maturation as its mother plant	The physiological age of a seedling can be kept stable by cutting back to near the root -stem interface and will only change if allowed to grow out of it	There are differences in the “age” of a plant based upon chronological age (actual age) and physiological age known as juvenility. A seedling can be kept in the limbo land of physiological juvenility even though the chronological age increases. Rooted cuttings cannot be made to do this.
Cuttings in general are less heat drought or cold tolerant than seedlings	Seedlings are not as sensitive to environmental changes as cuttings are	

Table 1. Continued.

Rooted Cuttings	Seedlings	Remarks
Cuttings take longer to establish mycorrhizal associations than seedlings	Seedlings seem to inherently able to connect to the symbiotic mycorrhizal fungi	While there is scant evidence it seems logical to assume that the mycorrhizal fungi in seedlings could well be different than those of cuttings.
Cuttings can be brought to flower in much shorter periods of time than seedlings	Seedlings cannot be readily induced to flower unless sophisticated grafting techniques are used	A 2-year-old seedling *Hibiscus syriacus* will just begin to flower if at all, whereas a 2-year old *Hibiscus syriacus* cutting marketed as part of the Proven Winners program will flower.
Some plants if produced from rooted cuttings will not grow or will grow extremely slow	Generally speaking seedlings will always grow unless they are the result of some hybrids which exhibit chromosomal mismatches or other types of genetic incompatibilities	*Acer griseum* grown from cuttings will not grow, although they make leaves, most often they will eventually die. Sometimes a plant from a cutting will grow but far from a normal rate and will exhibit cutting induced dwarfism.
Cuttings will sometimes not regrow after going through the first winter even though they are not dead	Seedlings do not exhibit this phenomenon	The onset of permanent dormancy is usually attributable to hormonal imbalances due to exogenously applied root hormones or as a result of excessive ethylene formation during the rooting process. Other factors could include the use of synthetic auxins such as alpha naphthylene acetic acid or dichlorophenoxyacetic acid.
Cutting derived plants will not regrow if cut to the ground in fall or winter	Seedlings do not exhibit this phenomenon	One certain way to kill an undesirable plant if it is cutting grown is to cut it back in late fall or winter. In some cases even a cut back in summer will result in the plant's death as well. Cuttings generally lose the regenerative capability which is inherent in seedlings.

Some rooted cuttings will develop distorted and unbalanced root systems which are detrimental in the long term	Seedlings rarely develop aberrant root systems	Rooted cuttings of conifers are especially prone to this phenomenon. In some cases the root system is limited to one or two primary roots and nothing else. Such sparse primary roots can lead the phenomenon known as "hinge root" which can lead to wind throw or toppling in harsh winds.
Troposis or the ability of a plant to grow normally with respect to gravity. However some rooted cuttings will exhibit a troposis based upon their original orientation on the mother plant and will not change the growth pattern	Seedlings can sometimes exhibit a troposis that is different than the norm but such occurrences are rare and represent a true weeping or crawling characteristic This at the very least an epigenetic change or in some cases a genetic change	The so called *Picea pungens* 'Glauca Pendula' (there is no genetic basis for this name) is an example of troposis response where a lateral shoot is rooted or grafted and it maintains its growth form that it had while on the mother plant. This could loosely be called an epigenetic change but it is far from the true meaning of an epigenetic change and it is definitely far removed from any kind of a genetic change.
Rooted cuttings will often tolerate pre-emergence herbicides	Seedlings have a poor ability to tolerate pre-emergence herbicides	This appears to be related to the mode of action of This appears to be related to the mode of action of pre-emergence herbicides where a vapor barrier exists at air soil interface and the toxic gases affect the sprouting of latent buds at the root /stem junction. Since rooted cuttings do not have this morphological feature they are immune to the pre-emergent chemical.

some synthetic chemicals such as acetylene and carbon monoxide. Other man-made chemicals that mimic this response are the dichlorophenoxy auxins and the naphthylene aliphatic acids, such as NAA. Synthetic here means chemicals not naturally formed by plants. It should also be noted that while exogenously applied auxins will lead to adventitious root formation, the continued presence of such chemicals will inhibit root growth for the long term.

Naturally occurring roots are also responsible for the formation of a range of gibberellins and cytokinins and they too have a direct affect on the structure and formation of a root system. Aberrations in cytokinin balances are often manifested by odd growth patterns in plants such as dwarfism and troposis changes such as weeping characteristics. Evidence of such changes can be found by grafting experiments and in rooted cutting experiments where the overall structure of a plant can be changed by changing the root system. I know of a dwarf *Metasequoia glyptostroboides* that when rooted or grafted reverts back to normal. Handsome plant but remains as a one of a kind because it cannot be propagated. Also tissue-culture-derived plants (actually an exaggerated form of rooted cuttings) can exhibit unusual growth changes due to the cytokinins used during the tissue culture process. Such changes are known as somalclonal variations and are evidence of epigenetic changes due to the disruption of normal chemical balances. Grafting experiments with two-needled pines grafted onto five-needled pines show no problem, but a five-needled pine grafted onto a two-needled pine will fail. This points to a potential root to shoot chemical imbalance that cannot be tolerated by the five-needled scion.

All of these things point indirectly to why there are noticeable changes in rooted cuttings compared to seedlings of the same species. Grafting of a given clone to a seedling of the same species or even one of close speciation such as *C. florida* onto *C. kousa* results in plants that in general behave like seedlings as the introduced scion adopts the biochemical systems of the rootstock. However when a scion is grafted onto a rooted cutting of the same or similar species the graft combination then behaves like a rooted cutting. For instance grafting of *Viburnum carlesii* 'Compactum' onto seedlings of another viburnum creates suckers on the rootstock, but by grafting onto rooted cuttings of another viburnum suckering is eliminated. Grafting seedling on to chronologically mature rootstocks (meaning the rootstock has the capacity to flower) the seedlings can be induced to flower at a much earlier age than if allowed to just grow under normal circumstances.

Where does this lead us? We know that overdosing cuttings with auxin for rooting can result in a number of maladies, including poor rooting, poor overwintering, rooting but followed by no subsequent root growth, excessive callus formation and no rooting or sparse rooting known as callus roots which are inferior to normal adventitious roots. For all practical purposes a callus root should be considered another class of root along with adventitious roots and normal seedling roots. In some cases overdosing with auxin can cause basal burning and necrosis of cutting tissue, leaf abscission, and death of the cutting. It is also well known that synthetic auxins such as NAA can be used as sprout inhibitors and applications of 2,4-dichlorophenoxyacetic acid and 2,4,5-trichlorophenoxyacetic acid are used as herbicides. Could then an inference be made that auxin contributes to a range of physiological changes in cuttings such as tolerance to pre-emergent herbicides or sensitivity to fertilizers when compared to seedlings? The answer unequivocally is yes and these various manifestations are often coupled with the changes in gibberellins and cytokinins as a result of adventitious roots being physiologically different than seedling roots.

In some plants, treatment with triazine herbicides shows no visible clues to the triazine's presence. However, when cuttings are taken from those plants and subsequently treated with auxins in preparation for rooting, they will often turn black and die out right within days of being stuck into the rooting bench. Obviously there is an effect on the cutting precipitated by the combination of the triazine herbicide and the auxin. Just what is exactly occurring is not understood or even known. While the mode of action of auxins is generally understood the ramifications of secondary auxin metabolism is not so clear and how it reacts with triazine herbicides is certainly not known.

Research should be centered on developing protocols for use of the least amount of auxin for the rooting of cuttings. Something that is currently not generally considered. Lower doses of auxin translate into smaller changes in the biochemical pathways in the cuttings and thereby possibly limiting the potential harmful side effects of the use of the auxins. By comparing cuttings rooted with low doses of auxin with those of high doses of auxins and looking at the degree of sensitivity to known stress inducing agents such as fertilizers or overwintering survival could lead to important clues as to the mechanisms of the sensitivity issues. It would be interesting to compare the water tolerance of rooted cuttings of *C. florida* with seedlings of *C. florida*. Theory would suggest that the seedlings would be more tolerant than the rooted cuttings. *Cornus florida* would be a good choice since it is well known to be water intolerant and a small difference between the two types of plants might be evident.

A take home message would be to pursue the use of the lowest amount of auxin possible to get acceptable rooting percentages and quality, thereby limiting deleterious side effects and ensuring some degree of success perhaps better than the norm.

Progress Developing Non-invasive Nursery Crops©

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BACKGROUND

Invasive plants are an important issue for the nursery industry. Although the vast majority of plants sold by the nursery industry are not invasive, some of these economically important crops can be weedy and naturalize to the point where they can cause environmental harm. Considering that many of these plants are economically, aesthetically, and environmentally important, development of seedless/non-invasive cultivars is an ideal solution whereby these valuable plants can be grown and utilized without detriment.

There are a number of approaches that can be used to develop seedless cultivars. One of the most effective means for developing seedless plants is to create triploids — plants with three complete sets of chromosomes. Although triploids typically grow and function normally, they have an inherent reproductive barrier in that the three sets of chromosomes cannot be divided evenly during meiosis yielding unequal chromosome segregation (aneuploids) or complete meiotic failure. Triploids have been developed for many crops including seedless bananas, seedless watermelons, grapes, and althea. Natural polyploids frequently occur in nature. Triploids can also occur naturally or can be bred by hybridizing tetraploids with diploids to create seedless triploids. Additional attributes of triploids include enhanced flowering and re-blooming, reduced fruit litter, and reduced pollen allergens.

GOALS AND OBJECTIVES

The overall goal of this work is to develop techniques and methods that will allow for the development of seedless cultivars of invasive or potentially invasive nursery crops. Related projects will work towards improving pest resistance, adaptability, and commercial potential of these crops. Specific objectives include:

- Further develop and improve methods and technologies for the induction of polyploids using mitotic inhibitors and tissue culture techniques.
- Identify/induce polyploids of key taxa as breeding lines.
- Develop triploid cultivars through controlled crosses between tetraploid and diploid parents including the development and use of embryo culture techniques.
- Develop new technologies and procedures for developing triploids through somatic embryogenesis from endosperm tissue.
- Develop and implement protocols to evaluate fertility and commercial merit.
- Make new non-invasive cultivars available to the nursery industry.

TECHNOLOGY TRANSFER/IMPACT

We have successfully developed methods and technology for manipulating ploidy levels of important nursery crops. These methods include techniques for somatic embryogenesis, in vitro and ex vitro chromosome doubling, and embryo and endosperm culture to facilitate the development of triploids. New seedless, triploid cultivars of *Hypericum androsaemum* have been introduced and other introductions will follow.

ACCOMPLISHMENTS

We have initiated work on developing a broad range of new seedless cultivars of important nursery crops with improved commercial traits. We have successfully developed new triploid forms of *Campsis* sp. (trumpet vine), *Elaeagnus* spp. (elaeagnus), *Euonymus alatus* (winged euonymus), *Hypericum androsaemum* (tutsan St. Johnswort), *Ligustrum* spp. (privet), *Miscanthus* spp. (maiden grass), *Pyrus calleryana* (callery pear), and *Spiraea japonica* (Japanese spiraea). These plants are currently being evaluated for commercial merit and fertility. Additional efforts are underway and have been successful in developing tetraploids of *Acer tataricum* subsp. *ginnala* (amur maple), *Albizia julibrissin* (mimosa), *Berberis thunbergii* (Japanese barberry), *Cytisus* spp. (Scotch broom), *Koelreuteria paniculata* (goldenraintree), and *Ulmus parvifolia* (lacebark elm). Once these plants reach reproductive age, we will complete interploid crosses to develop triploids. We have initiated *Acer platanoides* (Norway maple) into tissue culture for in-vitro chromosome doubling.

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Breeding Ornamental Hazelnuts (*Corylus*)©

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INTRODUCTION

Hazelnuts are a highly underutilized plant in the U.S.A. primarily due to the presence of eastern filbert blight (EFB), a disease caused by the fungus *Anisogramma anomala*. Eastern filbert blight is a native North American disease that is tolerated by *Corylus americana*, the wild American hazel, but is lethal to *C. avellana*, the European hazel grown for nut production and ornamental use. Eastern filbert blight causes cankers with conspicuous stromata to form along stems, causing dieback from the tips and eventual girdling of the stem (Fig. 1). Eastern filbert blight can kill susceptible plants in 2–5 years, although some possess various degrees of tolerance.

Figure 1. Eastern filbert blight on 'Contorta' (Harry Lauder's Walking Stick).

Breeding at Rutgers University began in 1996, when Dr. C. Reed Funk and Thomas Molnar began a genetic improvement program for underutilized perennial crops. Hazelnuts were chosen for their hardiness, wide adaptive range, valuable nut crop, and ornamental value, among other characteristics (Fig. 2). After establishing hazelnuts as the primary focus of the program in 2000, the search for disease resistant germplasm began. Collection efforts ranged throughout Europe and Asia, while still obtaining native germplasm from the U.S.A. and Canada. These collections have enabled us to acquire over 15 unique sources of genetic resistance to EFB for use in our breeding program.

Figure 2. Eastern filbert blight resistant, high-yielding hazelnut selection from the Rutgers breeding program.

DISEASE SCREENING

Our seedlings undergo intensive greenhouse inoculations in a mist chamber designed to simulate optimal environmental conditions for infection by *A. anomala* (Fig. 3a, 3b) (Molnar et al., 2005; 2007). In addition, each spring, every plant that makes it to the field evaluation stage is further inoculated with diseased wood (Fig. 4) to create artificially high disease pressure, ensuring that resistant plants hold up under extreme conditions.

***Corylus avellana* 'Contorta'.** The contorted hazelnut, better known as Harry Lauder's walking stick, has been the most popular and well known ornamental hazelnut since its introduction in the mid 1800s (Fig. 5). The contorted habit is controlled by a single recessive gene (Smith and Mehlenbacher, 1996), making breeding efforts to recover contorted seedlings difficult and requires multiple generations. Unfortunately, 'Contorta' and the new purple-leaf release 'Red Majestic'[PBR] have both shown high susceptibility to EFB in our disease resistance trials at Rutgers (Figs. 6a and b). Our goal is to release both purple- and green-leaf contorted plants carrying complete EFB resistance.

We recovered green-leaf contorted seedlings for the first time in 2007, and purple-leaf contorted seedlings in 2008, and have been exposing them to severe disease pressure ever since. We are currently evaluating a number of new contorted hazelnut seedlings from our breeding program in the field that have undergone our greenhouse disease screening procedure and show no sign of infection (Figs. 7a, b, and c). Our EFB-resistant purple- and green-leaf contorted hazels are selected for vigor and hardiness, along with other ornamental traits, including leaf color and texture, degree of "contortedness," catkin, and nut cluster proliferation, etc. A new purple-leaf contorted hazel 'Red Dragon' PP20694 from Oregon State University

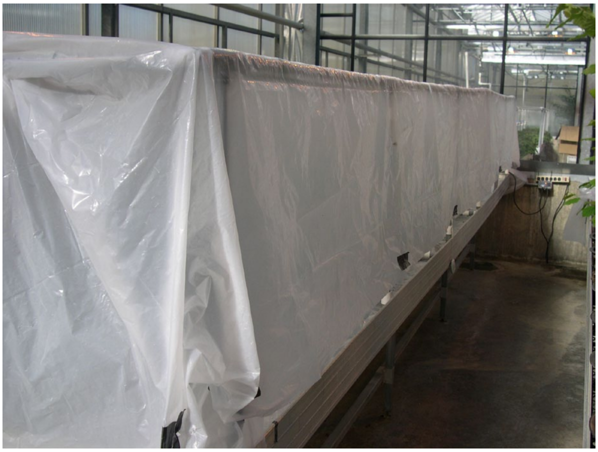

Figure 3a. Outer view of greenhouse inoculation chamber.

Figure 3b. Inner view of inoculation chamber.

Figure 4. Field inoculations of hazelnuts with diseased wood.

Figure 5. 'Contorta' at King Estate Winery, August 2011.

Figure 6a. Three-year-old 'Contorta' plant with EFB.

Figure 6b. Close-up view of eastern filbert blight on 'Red Majestic'[PBR]. Both 'Contorta' and 'Red Majestic' plants showed significant eastern filbert blight growth after disease screening at Rutgers.

Figure 7a. Three-year-old EFB-resistant contorted hazelnut in the field at Rutgers.

Figure 7b. New contorted seedlings in the greenhouse.

Figure 7c. Our first generation of red contorted seedlings were recovered in 2008.

contains a promising gene for EFB resistance, but the cultivar has not undergone testing at Rutgers yet (Mehlenbacher and Smith, 2009).

PURPLE-LEAF HAZELS

In addition to the standard green color, hazelnuts also come in purple. The purple color is vibrant in the spring and will fade to dark green during the hot summer months, with the duration depending on the genotype and weather conditions. We are presently testing several purple-leaf hazel clones with highly ornamental nut clusters for performance in multiple sites (Fig. 8a, 8b). These plants have undergone extensive disease screening and should be EFB resistant under any conditions. The nut clusters of these purple-leaf plants are also very striking and maintain their vibrant color throughout the entire season. Purple-leaf plants also have purple catkins in the fall and winter and they produce edible nuts.

We are currently screening a population of over 800 hybrid purple-leaf seedlings for a new trait, fall color (Fig. 9a, 9b). Fall color, which is derived from *C. americana*, shows up in late summer/early fall and can produce a striking array of colors for up to several weeks before leaves drop.

FUTURE POSSIBILITIES

We have begun breeding for several other ornamental *Corylus* traits to combine with strong EFB resistance. This includes cutleaf (Fig. 10a), weeping (Fig. 10b) (Mehlenbacher and Smith, 1995), and combinations of these with 'Contorta' and fall color, including weeping/cutleaf, contorted/cutleaf, and contorted, weeping, and cutleaf, all with fall color, among others. Tree forms also exist in *C. colurna*, *C. chi-*

Figure 8a. Purple-leaf selections in the field at Rutgers University.

Figure 8b. Ornamental, purple-leaf nut clusters.

Figure 9a and b. Fall color comes in shades of pink, orange, yellow, and red. These plants also have dark purple leaves in the spring. We are working to select the plants with superior fall color, persistent purple spring and summer color, attractive nut husks, and resistance to EFB.

Figure 10a. *Corylus avellana* 'Cutleaf'.

Figure 10b. *Corylus avellana* 'Pendula'.

nensis, and *C. fargesii*. We have bred hybrid seedlings of all 3, with the peeling bark trait *of C. fargesii,* corky bark of *C. colurna*, and single-stemmed growth habit of *C. chinensis* being of particular interest.

CONCLUSIONS

Eastern filbert blight is a lethal disease that takes several years to kill susceptible trees, while causing them to look increasingly blighted. At Rutgers University we have developed a diverse collection of EFB-resistant germplasm and have been using this in breeding ornamental hazelnuts for over 10 years. Eastern filbert blight resistance will help increase the market value and shelf life of ornamental hazels while decreasing loss due to disease. Upcoming, novel, widely adapted, and attractive cultivars will be released from Rutgers that contain stable EFB resistance from various sources across the world.

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Cutting Propagtion of *Ilex angulata*©

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***Ilex angulata* Merr. et Chun, a small tree or shrub, is an important and popular landscape plant in China. The market demand is high because of its round habit, zigzag branches, pink flowers, and brilliant red fruits. To introduce this wild species for cultivation, semi-hardwood stem cuttings were collected in June 2009 and treated with liquid KIBA, KNAA, and Hormodin at 1,000 and 3,000 mg·L^{-1}. Rooting hormones significantly increased root percentages and root quality, regardless of cuttings with or without heels. The highest rooting rate, 91.7%, was obtained under KNAA at 1,000 mg·L^{-1}. The effect of hormone types on rooting of *Ilex angulata* was not significant. As rooting hormone concentrations increased from 1000 to 3,000 mg·L^{-1}, the rooting percentages of heeled cuttings with all hormone treatments decreased significantly from 66.7 to 50.0% (Hormodin), 75.0% to 50.0% (KIBA), and 75.0% to 25.0% (KNAA), respectively. Cuttings treated with KIBA produced better root systems. The largest root ball, 250.1 cm^3, was observed from cuttings treated with KIBA at 1,000 mg·L^{-1}. Cuttings treated with KIBA had root ball volumes of 39.4–250.1 cm^3, while those with Hormodin and KNAA had root ball volumes of 33.8–107.2 cm^3 and 53.5–167 cm^3, respectively. For the propagation of *Ilex angulata*, semi-hardwood cuttings treated with KNAA and KIBA at 1,000 mg·L^{-1} were recommended.**

INTRODUCTION

Ilex angulata (*lengzhi dongqing* in Chinese), a member of Aquifoliaceae, is a newly introduced evergreen woody ornamental plant. Although it was discovered in 1935 (Chen et al., 1999), this small evergreen tree had not been cultivated until recent years. It had attracted gardeners by its dense, glossy green and elliptical foliage, slender zigzag, vertical ridge branches, and rounded habit. Its pink flowers and bright red fruits also contributed to its popularity in the ornamental world. Flowers bloom in April and fruits are persistent from July to October. The plant is indigenous to China and mainly distributed in Guangxi and Hainan province (Chen et al., 1999). This plant naturally occurs at an elevation of 350–600 m (1,000–2,000 ft) in the mountainous jungles or woodlands. The specimens and seeds were collected and brought into the U.S.A. in 1932 (Chun and Tso, 1935). Later, *I. angulata* Merr. et Chun var. *longipedunculata* S.Y. Hu was collected by How (1949) from Po-ting, Hainan, China. However, only a few reports about this plant (and its variety) were published in the U.S.A., especially its application in landscape and propagation. *Ilex* species can be reproduced by seed germination; however, seed germination of holly species is a very slow procedure and often requires 1–3 years. This is due to the immature embryos of most species and to complicated seed coverings from stony to woody to leathery

(Galle, 1997). Cutting propagation is the most popular method to reproduce plants clonally (Dirr and Heuser, 1987) and many *Ilex* species, especially its cultivars, had been regenerated from rooting of stem cuttings (Galle, 1997). *Ilex angulata* is an excellent landscaping plant with great market potential. However, no research on clonal propagation about this plant was reported, which limited its popularity. Cutting propagation and its commercial application were investigated in this paper.

MATERIALS AND METHODS

Materials. Semi-hardwood cuttings of *I. angulata* were collected from the campus of Central South University of Forestry and Technology in Changsha, Hunan, China (U.S.D.A. Zone 7–8) on the 9 June 2009. All cuttings were divided into two groups: with heel and without heel. The propagation medium was a mixture of peat moss and perlite (1 : 3, v/v). The rooting hormones were potassium salt of indole-3-butyric acid (K-IBA), potassium salt of naphthaleneacetic acid (K-NAA), and talc indole-3-butyric acid (Hormodin #1 and Hormodin #2) (Table 1).

Table 1. Treatments of rooting hormones on semi-hardwood cuttings of *Ilex angulata*.

Treatment	Rooting hormones ($mg \cdot L^{-1}$)
1	Control (CK)
2	Hormodin #1 (1,000) powder
3	Hormodin #2 (3,000) powder
4	K-IBA (1,000) liquid
5	K-IBA (3,000) liquid
6	K-NAA (1,000) liquid
7	K-NAA (3,000) liquid

Methods. This study was conducted from June to November 2009 in the propagation greenhouses at Central South University of Forestry and Technology. Terminal stem cuttings were taken in the early morning on the 9 June. All cuttings were placed into black plastic bags, immediately sprayed with water, and then transported to the greenhouses. Each cutting was pruned from the base to an approximate length of 15 cm (5–6 in.) with 3–4 top leaves maintained. To reduce respiration and energy loss, leaf area of each remaining leaf was reduced by two-thirds on the cuttings. The bottom portion was stripped and received a slight double wound. Stem cuttings were treated with distilled water (as the control) and six rooting hormones listed in Table 1. The basal 3–4 cm of each cutting was dipped into the liquid solution for 15 sec, and then air-dried for at least 15 min. Some cuttings were dipped into water first, and then dusted with talc hormone (Hormodin #1 and Hormodin #2). All treated cuttings were stuck into a $6 \times 6 \times 8$ cm^3 cell in 32-cell flat trays filled with the propagation medium. All cuttings were randomly placed on a mist bench in the greenhouse. The mist system was set for 20 sec every 10 min in the first week, then 20 sec every 20 min thereafter during daylight hours.

A randomized complete block design was applied in this experiment. There were three replicates per treatment and eight cuttings per replicate per treatment. Rooting percentage and root quality, which measured by root ball volume (rooting ball

Table 2. Rooting rates and root quality (root ball volume) of *Ilex angulata* by semi-hardwood stem cuttings under various rooting hormones and concentrations.

Hormone type and concentration (mg·L^{-1})	Cuttings with heel		Cuttings without heel	
	Rooting rate (%)	Root-ball volume (cm^3)	Rooting rate (%)	Root-ball volume (cm^3)
Control (CK)	25.0 c	8.0 d	33.3 e	11.6 e
Hormodin #1 (1,000)	66.7 a	107.2 b	58.3 c	76.7 d
Hormodin #3 (3,000)	50.0 b	33.8 cd	66.7 bc	69.7 d
K-IBA (1,000)	75.0 a	118.2 b	66.7 bc	250.1 a
K-IBA (3,000)	50.0 b	39.4 c	75.0 b	206.7 b
K-NAA (1,000)	75.0 a	167.0 a	91.7 a	139.1 c
K-NAA (3,000)	25.0 c	53.5 c	41.7 de	65.1 d

Note: Mean rooting rate and root-ball volume within the column followed by the same letter are not significantly different using LSD at $\alpha \leq 0.5$.

length, width, and height) were recorded after 4 months. All data were analyzed using SAS software. Mean separation was carried out using the least significant difference method with alpha at 0.05 level.

RESULTS AND DISCUSSION

Ilex angulata could be commercially propagated by semihardwood stem cuttings with rooting hormones. Compared to the control, rooting hormones had significant effects on rooting of *I. angulata* stem cuttings, regardless of the presence or absence of a heel (Table 2). Cuttings without any rooting hormone (control) produced a rooting percentage of 25% (with heel) and 33.3% (without heel) and all treated cuttings produced significantly higher rooting rates up to 91.7%, which was the highest rooting percentage under the treatment of 1,000 mg·L^{-1} K-NAA without a heel. Cuttings without heel generally rooted better, but no significant difference was observed. Our results did not support that cuttings with a heel usually rooted better than that without a heel by Hartmann et al. (2002). The type of rooting hormones did not show any significant effect either. Hormone concentrations had the greatest influences on rooting rates and root quality (indicated by root-ball volume). Low concentration (1,000 mg·L^{-1}) yielded significant higher rooting percentages and better root quality. The highest root ball volume (250.1 cm^3) was recorded under the treatment of 1,000 mg·L^{-1} K-IBA quick dip. It is possible that hormone concentration at 3,000 mg·L^{-1} may be too high for *I. angulata*, which caused stem "burn" and resulted in a reduction of rooting percentages and root quality (Table 2). Application methods (powder vs. quick dip) did not have significant effect on either rooting rates or root quality.

CONCLUSION

As an important small ornamental tree, *I. angulata* could be clonally propagated by semi-hardwood stem cuttings. Cuttings should be collected in early to middle June in U.S.D.A. Zone 7–8 and prepared with 1,000 mg·L^{-1} rooting hormones and rooted with peat : perlit (1 : 3, v/v) medium under mist systems. Hormone types and application method had no significant effect and only newly sprouted stem cutting should be collected (no old wood).

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Improving the Preservation and Promotion of Underutilized Crop Species in Southeast Asia©

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BACKGROUND

Seed is a fundamental agriculture input and access to locally adapted, quality seed is an essential component of sustainable crop production. In much of the developing world, informal seed systems are important sources of seed for small farmers (Almekinders et al., 1994). Indeed, planted seed in many regions of the world are not improved varieties, but come from farmer-to-farmer seed exchanges or from farmer self-saved seed and often comprise the majority of planted acreage. This local seed production and distribution facilitates maintenance of crop bio-diversity by preserving in situ locally adapted varieties and by broadening the genetic base of production with multiple varieties adapted to specific production systems and microclimates. These informal seed systems are also critical for seed and food security during periods of instability or natural disaster, including changing environmental conditions (Chapman et al., 1997).

A rich diversity of indigenous germplasm exists in Southeast Asia and represents a valuable resource for the development and improvement of crop species locally, regionally, and globally. Annual and perennial vegetables in this region are grown primarily in mixed home gardens and used abundantly, both raw and cooked in local dishes (Fig. 1). Local vegetable varieties are mostly grown for home consumption, but increasingly over the past decade are also found in urban markets. The high diversity of ethnic groups within a small region has produced extraordinary

Figure 1. Typical northern Thailand hilltribe dwelling utilizing a diverse mix of perennial and annual vegetable species. Little effort has been made to improve upon these locally important species and develop value chains around them to enhance local farmer income.

diversity in indigenous vegetables in northern Thailand, as different groups favor specific culinary and agronomic qualities. The mechanisms and pathways of this informal seed system by which farmers acquire new varieties is not well documented or well understood. This knowledge would facilitate increased exchange and opportunities for indigenous crop improvement. Improved understanding of the local, existing germplasm systems will enable horticultural scientists and extension workers to have more effective collaboration with farmers, as they will be able to identify and work alongside these farmer leaders or "germplasm gatekeepers" in communities. Much of the indigenous germplasm represented in the local informal seed system also has not been sufficiently characterized, improved, preserved, or widely distributed (Sperling and McGuire, 2010). For example, a great deal of genetic variability exists in the perennial vegetable species *Lablab purpureus* and *Psophocarpus tetragonolobus*, but little effort has been made to improve upon these locally important species and develop value chains around them to enhance local farmer income. The local informal seed systems also usually lack the means to disseminate these resources regionally, thus limiting the reach of their benefit. The opportunity to characterize these crops for traits of interest such as drought tolerance or disease resistance, are decreasing as these landraces are lost or replaced in farmer fields and in local diets. It is well documented that current efforts to identify, conserve, improve, and disseminate local, traditional varieties are insufficient (Mazhar, 2000).

PROJECT PREMISE AND APPROACH

This project is premised on four well-established facts:

- Informal seed systems, such as farmer-to-farmer exchanges and farmer self-saved seed, are critical components of resource-poor farming systems.

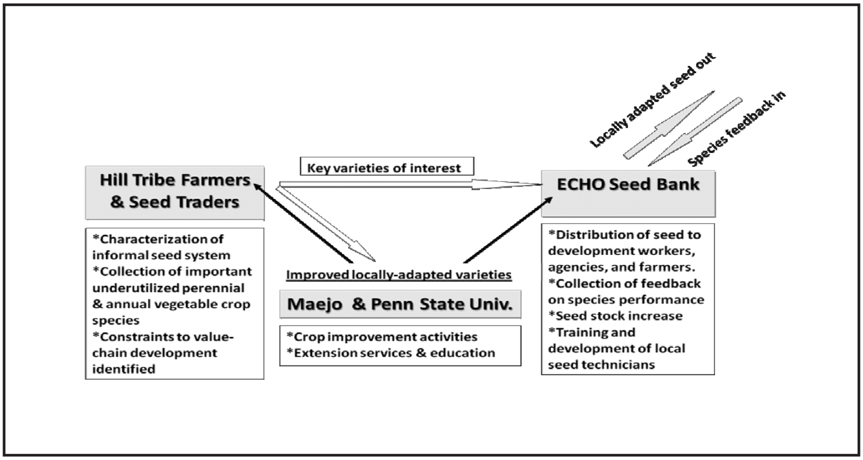

Figure 2. Conceptual framework of seed system linkages, designed to improve preservation and distribution of underutilized locally adapted crop species.

- A rich diversity of underutilized species function within these systems.
- Current efforts to conserve, improve, and disseminate indigenous species are failing.
- To optimize these informal seed systems we need to better understand their germplasm characteristics, pathways, and gatekeepers — and we need to improve local stakeholder access to seed information.

Our approach to this project was to demonstrate the value of investing in local, indigenous informal seed systems. This was accomplished through the development of an innovative seed bank system linking local farmers and noncommercial seed traders with developing markets, and supported by accessible information made available through a local outreach network (Fig. 2).

OUTCOMES AND IMPACTS

This United States Agency for International Development (USAID) Horticulture Collaborative Research Support Program (CRSP) project, administered through the University of California, Davis, is realizing immediate impact during the current 12-month implementation phase, but it is also paving the way for longer term benefits which will be regional in scope and could address USAID Feed the Future focus countries in the region. The formation of a partnership between Maejo University, the Educational Concerns for Hunger Organization (ECHO) Asia Regional Office, and Penn State University is resulting in a cohesive strategy to enhance the effectiveness, impact, and reach of Southeast Asia's informal seed system through institutional capacity building and training. Impacts realized within the first year of this project include:

- Identification of key seed traders and farmers functioning within northern Thailand's hilltribe informal seed system.
- Initial inventory of important indigenous crop species.
- Documentation of specific indigenous knowledge surrounding the culture of these key crop species.

- Training of ECHO seed bank manager and key Maejo University and ECHO personnel.
- Seed drying and storage surveys and seed storage trials.
- Village-based seed exchanges and training conferences.

Longer term benefits include:

- Formation of ECHO seed bank-farmer linkages that allow non-commercial seed producers to access new varieties, hybrids, and high-value seed resources not available from traditional sources.
- Development of value chains around key indigenous species.
- Regional distribution of important seed resources to the neighbor nations of Cambodia, Laos, and Vietnam.

By characterizing these indigenous informal seed systems, farmer-to-farmer exchanges can be improved, and researchers can identify more effective ways to communicate with and distribute promising germplasm through these individuals, and thus on to their existing networks. Non-commercial seed traders and farmers in the informal seed markets can also partner with seed banks and universities to improve the seed system in ways not being currently exploited by the formal seed market. This may include the dissemination of new or underutilized species or maintenance of specific regionally valued crops and the indigenous knowledge surrounding these genetic resources.

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Alternatives to Pesticides: Recent Advances in Fruit Crop Protection That Could Be Transferred to Ornamentals©

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INTRODUCTION

Research into alternatives to pesticides has been extensive over many decades, numerous and diverse alternative control methods have been developed and there is a vast literature. Biological control, including the use of introduced predators and parasites and the use of microbial biocontrol agents and nematodes, is perhaps the most widely exploited.

There are several well known and important established uses of introduced natural enemies to control pests of soft fruit crops in the U.K. — such as use of the predatory mite *Phytoseiulus persimilis* to control two spotted spider mite (*Tetranychus urticae*) and the predatory mite *Amblyseius cucumeris* to control strawberry mite (*Phytonemus pallidus* subsp. *fragariae*) and western flower thrips (*Frankliniella occidentalis*) — and the number and extent of use of these has increased in recent years in response to the increase in protected cropping, the development of pesticide resistance, loss of pesticides, and other factors.

There have been very few instances where natural enemies have been introduced to regulate an invasive pest in tree fruit crops. On apple, the best known is the introduction in the 1920s of the parasitoid *Aphelinus mali* to control woolly aphid, an invasive pest from America. *Aphelinus mali* is now an important natural enemy of woolly aphid present in most places where the pest occurs. It certainly greatly helps to regulate woolly aphid outbreaks, but is often not quite good enough on its own, requiring the assistance of earwigs. Inundative releases of arthropod predators or parasites as biocontrol agents to orchards are generally too costly and are often not successful because of climatic instability.

There are a small number of significant success stories of the use of microbial agents and nematodes for pest control in fruit growing. The widespread use of codling moth granulovirus is the most important. Formulations of the virus are approved in most European countries and are applied to the foliage as sprays. The virus is highly selective and virulent. In orchards, only codling moth can be infected. A single virus particle is sufficient to kill a first instar codling moth larva. The virus is safe to humans, plants, and the environment. It has to be ingested by the newly hatched larva when feeding on the skin of the apple before it penetrates the flesh.

Strains of the codling moth resistant to the virus have developed in some regions in continental Europe where the virus has been relied upon for control for many years. The problem has been overcome by using a different strain of the virus. However, this development highlights the need to use multiple suppressive control tactics to minimise the risk of resistance.

However, the subject is clearly too vast to cover in any depth here so for the purposes of this paper, I have concentrated on semiochemical-based control methods as these have been the subject of intensive ongoing collaborative research between East Malling Research (EMR) and the Chemical Ecology Group of the Natural Resources Institute (NRI) at the University of Greenwich. Semiochemicals are compounds such as pheromones which insects and other animals use to signal their presence to each other; and chemicals emitted by plants which influence the behaviour of specific insects and other animals.

SEMIOCHEMICAL-BASED CONTROL METHODS

Although numerous sex pheromones, aggregation pheromones and other semiochemicals of insect pests have been identified there have to date been relatively few commercially viable products and techniques to control only a limited number of pest species, mainly moths, though this number is now starting to increase.

There are three principle means of using sex pheromones, aggregation pheromones, and other semiochemicals for control of insect pests:

1) Mating disruption (MD)
2) Attract and kill (A&K)
3) Mass trapping (MT)

Semiochemical control methods usually have to be deployed on a large, preferably area-wide, scale and initial pest populations generally have to be low for control to be effective. Below are described two examples of ongoing work at EMR and NRI to exploit for control some of the non-lepidopteran semiochemicals we have discovered.

Mating Disruption and Attract and Kill. The use of sex pheromones for mating disruption or attract and kill are potentially very powerful tools in IPM. Most sex pheromones are produced by female insects and only attract males of the same species. The mating disruption (MD) technique is based on the premise that male insects are unable to locate females if the environment around the females is permeated with sex pheromone.

Three factors may act alone or in combination to produce mating disruption; sensory adaptation, habituation, and direct competition.

In theory, mating disruption may be accomplished in two principle ways: false trail following or confusion. False trail following results from placing many more point sources of pheromone per unit area than the anticipated numbers of females in the crop. The chances of males finding females at the end of the pheromone trail must therefore be greatly reduced. Males following these trails are thought to spend their mating energies in pursuit of artificial pheromone sources. In contrast, male confusion is thought to be the result of ambient pheromone concentrations sufficient to hide the trails of calling females (large doses from point or diffuse sources).

Attract and kill (A&K) is an extension of the false trail MD method, and is closely related to the mass trapping method described below. In false trail following, the males come in close vicinity of the artificial pheromone sources and may try to mate with them. In A&K formulations, the pheromone dispensers or the target devices on which they are held are coated with a contact insecticide, often formulated in a sticky carrier. The males become contaminated with insecticide and die. Females are thus less likely to encounter males by chance. However, in many cases the effectiveness and benefits of the added insecticide is largely unknown under field conditions.

A further combination of pheromones and insecticides is occasionally encountered. Dual applications of pheromone and insecticides (either separately or, in the case of sprayable pheromone formulations, in tank mixes) are applied, sometimes with the idea of increasing insect flight activity and thus increasing the chance of insecticide exposure.

The MD technique is widely used for control of a number of economically important lepidopteran pests including codling moth (*Cydia pomonella*), the oriental fruit moth (*C. molesta*) and the vine moth (*Eupoecilia ambiguella*). In comparison, there have been very few investigations of the use of sex pheromones of non-lepidopteran pests for MD or A&K. Our discovery of the sex pheromones of many of the midge pests of U.K. fruit crops has presented an important opportunity to attempt to exploit these for control. The midge pheromones were active at very low doses, several orders of magnitude lower than those of most Lepidoptera.

Experiments on Use of Pheromones in Orchards. We first attempted to exploit the female sex pheromone of apple leaf midge (*Dasineura mali*) for control in newly planted versus established apple orchards in 2004 and 2005 (Cross and Hall, 2007). This pheromone was present at less than 20 pg per female (Hall and Cross, 2006). The pheromone is extraordinarily active. Rubber septa lures containing 1 μg and emitting only a few pg of pheromone per hour are highly attractive. An experimental permit was obtained from the Pesticides Safety Directorate to conduct large-scale field trials of the pheromone without the need to destroy the crop from fruiting trees. By analogy with similar compounds, the sex pheromone was considered to be comparatively safe to humans and the environment but because no data was available, the experimental permit restricted the dose applied to 1 g per ha per season on the basis that the local concentration of the pheromone would not exceed the maximum concentration that occurs naturally.

In July 2004, a preliminary field experiment was done at EMR to investigate use of the apple leaf midge sex pheromone for control of apple leaf midge using an A&K strategy. The A&K devices were 20 cm × 20 cm squares of plastic laminated cardboard surface coated on both sides with a microencapsulated formulation of the insecticide lambda-cyhalothrin, developed for control of olive fly (AgriSense, BCS Ltd.). These were positioned 5 cm above ground level and baited with a rubber septum lure impregnated with 100 μg of apple leaf midge pheromone fixed centrally.

Four small heavily infested apple orchards at EMR were selected for the experiment. On 5 July, a single standard white delta trap baited with a standard 3-μg rubber-septum lure was deployed in the centre of each plot. Catches of males were counted on six occasions between 7–27 July 2004. On 7 July, 28 and 12 A&K devices respectively were deployed in lattices in two of the plots to give a density of approximately 100/ha.

On 27 July, 100-shoot terminals in the centre of each plot were examined for ovipositing females and presence of apple leaf midge galls.

The two orchards where the A&K treatment was deployed had considerably lower trap catches than the untreated plots, but the treatments failed to shut down catches completely. The shoots assessment on 27 July revealed that 100% of shoots were galled on three of the plots, with 84% galled on the other. Small numbers of ovipositing females were also recorded. The results showed the treatment was not able to adequately suppress mating and that a much higher dosage of pheromone would be required, probably with many more devices per ha.

Bioassays of the effect of contact of apple leaf midge adult males with the lambda-cyhalothrin target devices were conducted on 1 and 2 Sept. 2004. The A&K devices were observed in the field and at intervals. Ten attracted male midges were taken from the surface of the device or shortly after they had made contact, and held in tubes. Midges were taken in a similar way from the surface of a similar device not treated with lambda-cyhalothrin. After 1 h, all the midges that had been exposed to the lambda-cyhalothrin card, even for 5 min, were severely affected by the insecticide. After 3 h, all were dead. Similar results were obtained with cards from A&K devices that had previously been exposed for 2 months in the field.

A very large-scale field trial was carried out in commercial apple orchards in Kent during 2005 to evaluate the use of the apple leaf midge sex pheromone for control of apple leaf midge by MD or A&K approaches. The MD devices were polythene caps each initially loaded with 500 µg of the apple-leaf-midge sex pheromone. These caps each released the pheromone at approximately 10 ng/h at 27 °C. The A&K target devices were 10 cm × 6.7 cm oblongs of the microencapsulated lambda cyhalothrin surface treated cardboard with a polythene cap lure containing 100 µg of the apple leaf midge sex pheromone fixed to the centre with a drawing pin. These caps each released the pheromone at approximately 2 ng/h at 27 °C. Both MD and A&K devices were deployed at 500 devices/ha or 2000 devices/ha, fixed to tree stakes so that the lure was at a height of approximately 15 cm above the ground in a regularly spaced lattice.

Thus for the MD treatments, pheromone application rates were 0.25 $g{\cdot}ha^{-1}$ or 1 $g{\cdot}ha^{-1}$ respectively and release rates were approximately 5 $\mu g{\cdot}ha^{-1}$ per h and 20 $\mu g{\cdot}ha^{-1}$ per h. For the A&K treatments, pheromone application rates were 0.05 $g{\cdot}ha^{-1}$ or 0.2 $g{\cdot}ha^{-1}$ respectively and release rates were approximately 1 $\mu g{\cdot}ha^{-1}$ per hour and 4 $\mu g{\cdot}ha^{-1}$ per hour.

A fully randomised experimental design was used with six replicate 1-ha plots of each treatment, requiring 30 plots of 1 ha in 11 orchards on six different fruit farms in Kent. Three of the plots for each treatment were in newly planted orchards where leaf midge populations were low and three were in established orchards where leaf midge populations were high. Untreated plots were well separated from those which had MD or A&K treatments which themselves were adjacent. The effectiveness of the treatments was assessed by weekly monitoring of catches of adult male midges in a delta trap baited with a 3-µg rubber-septum lure in the centre of each plot and by counting the number of galls present in 200 shoots in the centre of each plot for each of the three main generations, at the peak of damage expression on 17–23 May, 20–25 June, 4–6 July, and 30–31 August 2005.

The only differences of significance were whether or not any "treatment" had been applied, with no differences between type and number of lures. All the MD and A&K treatments suppressed the catches of males in the traps in the centres of the plots compared to the untreated control. In the established orchards with higher populations, catches were decreased by >98% in April–May, by >99% in June–July, but by only >91% in August–September. In the newly planted orchards with very low populations of the midge, trap catches were zero in April–May in all plots, were very low but suppressed by 90% by the MD and A&K treatments in June–July, but rose somewhat in August September being suppressed by about 80% in the treated plots.

There was no evidence that either the MD or A&K treatments were suppressing numbers of galls in shoots in the established orchards. In the newly planted orchards, it appeared that the MD and A&K treatments were failing in July and certainly by August, no suppression of galling damage was evident.

Measurement of release of pheromone from the open polyethylene caps used in these trials for both MD and A&K treatments showed relatively uniform release for at least 270 days under laboratory conditions. However, lures recovered from the field at the end of the above experiments were found to contain no detectable pheromone.

This has subsequently been shown to be due to degradation of the pheromone, the lures being unprotected from direct sunlight in both MD and A&K treatments.

Why did these first attempts at exploiting the pheromone fail? In the Cecidomyiidae, unmated females are evidently not able to lay viable eggs (Gagne, 1984; 1989) though monogeny often occurs in some species (Murchie and Hume, 2003). The bioassays indicated the A&K devices did kill the males, albeit only after a few hours. Males are known to be able to mate several times, though females only need to be mated once to be fertilised. Clearly, sufficient mating was still occurring to provide enough fertilised females to oviposit in the shoots that were present.

There are several possible explanations for the failure:

- The dose (1 g·ha^{-1}) was too small
- An insufficient number of dispensers/devices was deployed per ha
- There was rapid UV degradation of the pheromone
- The 1-ha scale of deployment of treatments was insufficient and there was ingress of mated females into the plots from the edges
- The initial populations of the midge were too high to prevent some mating from occurring

Experiments on Use of Pheromones in Raspberry Plantations. Unfortunately, our funding for working on exploiting the apple-leaf-midge sex pheromone was not continued to allow us to investigate further, but, as part of Horticulture LINK project HL0175, we did start work on exploiting for control the raspberry cane-midge (*Resseliella theobaldi*) sex pheromone, which we had already identified (Hall et al., 2009).

To date we have conducted 4 years of field trials testing a wide range of formulations of the raspberry cane-midge pheromone. At the outset, we determined the effect of the release rate of pheromone from rubber septum lures on attractiveness to male raspberry cane midge. The results were surprising.

Lures which released 600 pg of pheromone/h (in the NRI laboratory wind tunnel at 27 °C and 8 km/h wind speed) and initially loaded with 0.1 µg of the pheromone racemate were significantly attractive. Maximum attraction occurred at 600 ng/h though 60 ng/h (initial loading 10 µg) performed nearly as well. Attraction was significantly reduced at greater release rates. Two alternative control strategies were apparent:

1) MD or A&K using false trail following using large numbers of devices with release rates of ~60 ng/h.
2) Male confusion using high ambient pheromone concentrations sufficient to hide the trails of calling females using smaller numbers of devices with high release rates (>6 µg/h).

Each year for 4 years to date, large-scale (~1-ha plots) field experiments have been done in commercial raspberry plantations in southeast and east England to evaluate the efficacy of MD and A&K treatments in comparison with an untreated control for control of raspberry cane midge.

In 2006, we evaluated a MD treatment with 2,000 polythene cap dispensers per ha, each initially loaded with 1 mg of raspberry cane-midge sex pheromone racemate, deployed in a regular lattice through the crop at a height of 15 cm. The A&K treatment tested comprised 2,000 plastic laminated cards surface coated with a microencapsulated formulation of the SP insecticide lambda-cyhalothrin and which had a polythene cap dispenser (initially loaded with 100 µg of the pheromone) fixed to the centre per ha.

The MD and A&K treatments were effective outdoors where a high degree of trap suppression was achieved but were ineffective in the polytunnel crops where trap suppression was less effective. Possible explanations for this difference in efficacy are that pheromone release was too rapid from the dispensers when they were deployed in the polytunnels where temperatures were much higher than outdoors and/or that the pheromone did not disperse so effectively in the enclosed polytunnel environment.

In 2007, we tested 200 polythene sachet MD devices and 200 mass trapping (MT) devices per ha. The sachets were each initially loaded with 50 mg of the midge sex pheromone racemate released at rates of approximately 0.5 mg/d at 28 °C. The MT devices were Lynfield traps each baited with a rubber septa lure initially loaded with 200 µg of the pheromone racemate and released 60 ng pheromone/h at 28 °C.

The traps contained 50 ml of water + 50% glycol, and were suspended at a height of 15 cm from the ground. The MT rather than A&K devices were used because they gave records of whether or not attracted midges were killed (by drowning). Although the MD treatment gave fairly good suppression of trap catches the MT treatment was less effective in this respect and neither treatment prevented larval attack in artificial splits in the canes. It was concluded that 200 devices per ha was probably too small a number.

In 2008, a new MD treatment comprising 3 kg·ha^{-1} of 0.5% w/w pheromone racemate EVA granules (~150,000 granules/ha) broadcast by hand to the soil surface between the rows was tested in comparison an A&K treatment comprising 2,000 plastic laminated lambda cyhalothrin cards (similar to those tested in 2006) each with a rubber septum dispenser loaded with 200 µg of the pheromone racemate and an untreated control.

Although both the MD and A&K treatments failed at one site, very good control was achieved at another and intermediate results at a third. The reasons for the different results at the different sites are unclear. There was evidence that the MD treatment was losing its efficacy as the season progressed with better results for the first generation pests. Lab measurements of release rate indicated that the EVA granules used for the MD treatment released 60% of their pheromone in the first 31 days at 27 °C. One explanation of the decline in trap-catch reduction may be that the pheromone release rate from the EVA granules declined steeply through the season. Another possible explanation is that the granules progressively worked themselves into the soil surface, some being trampled by pickers as they walked through the tunnels. The trap-catch reductions achieved by the A&K treatments remained consistent through the season

The trial MD/A&K/MT formulations were either impractical for use by growers or were ineffective. In 2009, we developed and tested a new *R. theobaldi* sex pheromone MD/A&K method which we thought would be practical for use by growers, would not get lost in soil, and would have a large number of pheromone sources per ha so having a better chance of success. We also used the method in conjunction with a directed spray of a contact acting insecticide, deltamethrin. The aim was to use a competitive MD approach to attract the male midges with the sex pheromone to numerous artificial pheromone sources where they would then be killed by a surface deposit of insecticide, to be applied subsequently. The insecticide chosen was deltamethrin (Decis®), a product already approved for use in raspberry. It is a light stable synthetic pyrethroid with excellent knock down properties and good persistence. It was used as a separate spray to avoid registration difficulties.

A new “SPLAT” formulation of the cane midge pheromone was produced in the laboratory at NRI by mixing 4 g of the raspberry cane midge sex pheromone racemate per kg of SPLAT-base formulation supplied by ISCA technologies, California. The formulation was then transferred to caulking guns. The integrated pest and disease management (IPDM) plots were then treated with 2.5 kg of SPLAT containing 10 g of raspberry cane-midge pheromone racemate per ha. The SPLAT was applied in 5,000 0.5 g, 7-cm-long strings per ha to the polythene mulch or lay flat polythene irrigation pipe. Depending on the row spacing, approximately one SPLAT string was dispensed per metre of row. One to three days after SPLAT application, Decis was applied by the grower to the polythene at 600 ml of product in 200 L of water per ha to polythene mulch on which SPLAT has been applied.

Regrettably, the SPLAT plus deltamethrin treatment was unsuccessful in suppressing pheromone trap catches of males and at the one site where they were found, the treatment was ineffective in controlling larvae.

The weekly pheromone trap catches did show that the SPLAT formulation gave a very high degree of trap shut down for the first 2–3 weeks, but thereafter the suppression of catches declined sharply. Measurements of the amount of pheromone remaining in the formulation also showed a sharp decline in the first few weeks, which may be at least in part the explanation for the poor results.

So to date, despite much effort, we have not managed to produce a successful formulation for exploiting the *R. theobaldi* sex pheromone for control. The reasons for this are unclear but appear to be a combination of an inadequate sustained release rate and deployment where populations are too high initially. In 2010, we hope to test the SPLAT formulation again but at higher doses and possibly with repeated applications, and in fields with low to moderate *R. theobaldi* populations. We will devote more attention to behavioural observations of the effect of the formulation on the midges.

Mass Trapping. In MT, traps are deployed with the objective of destroying insects for population control. As stated above, most sex pheromones are female produced and attract males only. For mass trapping to be effective using female produced sex pheromones, enough traps have to be deployed to catch enough males to leave the females of the species without mates. But it is difficult to get good results because any untrapped males simply mate more frequently. Large numbers of traps ($>50 \cdot ha^{-1}$) are likely to be too costly.

However, aggregation pheromones often attract both sexes and are therefore better suited for MT applications. The strawberry blossom weevil (*Anthonomus rubi*) aggregation pheromone is male produced and attracts both males and females. We evaluated the aggregation pheromone in sticky stake traps for MT of *A. rubi* but achieved poor results (Cross et al., 2006b). Importantly, its attractiveness can be greatly enhanced by addition of host volatiles, especially the host volatile from wild strawberry flowers. Furthermore, bucket traps with white cross vanes are far superior to sticky stake traps used in our previous work and the combination of these factors has enabled us to develop a supertrap for this pest.

In 2010, we will start large-scale field trials to evaluate the use of this supertrap for control of *A. rubi* by MT.

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The Benefits of Cross-Sector Research©

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INTRODUCTION

The Horticulture Development Company (HDC) is a levy funded body that serves the commercial horticultural industry in England, Scotland, and Wales. The levy is based on sales value and is currently set at 0.5%. It is collected to fund "near market" — that is, applied — research, development, and technology transfer and encompasses more than 300 different crops.

The research projects are set by the members of eight grower panels which cover field vegetables, soft fruit, tree fruit, mushrooms, protected edible crops, protected ornamentals, bulbs and outdoor flowers, and hardy nursery stock. "Cross-sector" projects are also funded to give members access to research that can be used on a wide range of crops in topic areas such as biological control; lighting; developments in crop hygiene; pest and disease identification, forecasting, and the use of appropriate controls; translation of European research; alternatives to revoked pesticides and the use of novel pesticide active ingredients; biopesticides; photoselective plastics; winter protection; and peat alternatives.

Traditionally each sector has tended to carry out work on its own crops, which means that work on problems common to more than one sector is sometimes duplicated or that growers in other sectors do not always realise there has been a project that could be of real value to them. For example, research into the cultural, biological, and chemical controls of pests and diseases — particularly in field vegetables, soft fruit, tree fruit, mushrooms and protected crops — has been significant and could provide hardy nursery stock (HNS) growers with valuable information.

Publicly funded horticultural R&D currently only targets edible crops which means in the ornamentals sectors the only R&D under way is that which growers themselves fund, and the bulk of that is work undertaken by HDC. So, in the current financial climate any opportunity for HNS growers to reduce their research costs of by "sharing" work with other sectors would, in effect, increase the value of the HNS research budget.

This paper provides a brief review of recent HDC work in other sectors that are of significance to HNS growers. Through this, the author hopes to encourage growers to look more widely at the research work carried out across the horticultural industry, and think about how it could be adapted to nursery stock crops. Project reports for all of the work mentioned below is available to levy-payers and voluntary members in any sector, via the HDC website <www.hdc.org.uk>.

RESEARCH IN OTHER SECTORS

Field Vegetables. Work on diseases has included crown-rot, damping-off, downy mildew, chocolate spot, club-root, stemphylium leaf spot, xanthomonas bacterial infections, ring spot, white blister, sclerotinia, fusarium, septoria leaf spot, botrytis, scab, pythium, canker, and rusts.

[1]The author is a member of the board of the Horticultural Development Company, a sector company of the Agricultural and Horticultural Development Board

Pest control has been developed for free-living and stem nematodes, leaf miner, aphid, cutworm, thrips, cabbage root fly, slugs, flea beetles, caterpillars, two-spotted spider mite, midges, wood pigeons, and rabbits.

Soft Fruit. Nursery stock growers can gain advantages from research on diseases such as botrytis, *Phytophthora* spp., crown rot, powdery mildew, *Xanthomonas*, black spot, and *Colletotrichum*.

Pest control work has included vine weevil, aphids, midge, capsid, tarsonemid mite, and two-spotted spider mite.

Tree Fruit. Particular tree fruit diseases that can also affect nursery stock and have been investigated by this sector include scab, fireblight, canker, botrytis, and powdery mildew.

Focus on pests such as codling moth, sawfly, mussel scale, light brown apple moth, aphid, leafhopper, and midge has also helped nursery stock growers to selecting the most appropriate controls.

Mushrooms. Of particular concern to this sector are verticillium diseases as well as sciarid and shore flies, which also affect a range of ornamental crops.

Protected Edible and Ornamental Crops. Diseases such as botrytis, bacteria, white rust, tomato spotted wilt virus, pansy mottle syndrome, fusarium, verticillium wilt, rhizoctonia, sclerotinia, downy mildew, thielaviopsis, *Phytophthora* spp., and *Colletotrichum* have been the focus here.

Recent work on pests that are notifiable in the U.K. such as *Tuta absoluta* (South American tomato moth, a leaf miner) and *Bemesia tabaci* (tobacco whitefly), as well as leafhopper, aphid, two-spotted spider mite, capsid, Western flower thrips (WFT), sciarid and shore flies, lily beetle, mealybug, whitefly, and caterpillars has produced useful information for the nursery stock sector.

Cross Sector Projects. Examples of some of the research relevant to all sectors is listed below:

- A website to provide current information on pesticide approvals for ornamental crops.
- Thermal and visual analysis for crop scanning and disease monitoring.
- Ground sink refrigeration.
- Development of a pre-selection system for seasonal horticultural labour.
- Champion supervisor model and training programme to improve selection and training of key staff.
- The use of "sterile insect technique" to increase the success of IPM in horticultural crops.
- The implications of "carbon foot-printing" for U.K. horticulture.
- Commercial production of rosemary to provide the raw ingredients for developing a new genre of bio-based antioxidants for industry.
- A review of peat alternatives for U.K. commercial plant production.

- The use of potassium bicarbonate for powdery mildew control.
- The effect of spectral modified tunnel cladding materials on invertebrate pest populations.
- The technical and economic benefits of spectral modified plastic crop covers for horticultural crops.
- Sex pheromone ecology of some important U.K. midge pests.
- The application of trap plants for pest control in field vegetables.
- The activity patterns of WFT and their manipulation to enhance control measures.

Biological Control in a Propagation Unit©

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INTRODUCTION

The Guernsey Clematis Nursery Ltd (GCN) is a wholesale nursery that specialises in propagating and raising young clematis plants for export to other wholesale nurseries. Production is exported to 18 countries worldwide although a large proportion of the market is in the U.K., E.U., and North America. Typically a GCN customer will buy either a 13-week-old "rooted cutting" or a 9-month-old 7-cm liner that will be potted and grown on for another 9 to 12 months before being ready for retail sale.

Over the last 10 to 12 years, GCN has modernised its propagation facility from traditional floor-level sand beds with constant manual input to control the environment, to a fully computer-controlled, purpose-built facility with ebb-and-flow benches, a re-circulated water system, top and bottom heat, assimilation lighting, and both shade and blackout screens. The unit allows for good heat and humidity control, while the use of lights and screens enables the nursery to dictate the daylength, shortening the days in the summer to keep the plants vegetative and lengthening in the "shoulder months" to extend the propagation season. The propagation season for GCN now extends from February to October.

Current Propagation Process. Trays are pre-filled and prepared with medium by machine, or Elleguard pots manufactured on site, 24 h prior to use. They are watered up by passing under a boom at a set speed ensuring a uniform quantity of water is applied to each. Cutting material is collected from the liner crop and stored at 3 °C until processed (usually the same day).

Nodal cuttings are made, dipped in rooting hormone and stuck into the pre-made trays or Ellepots. The cuttings are then misted over with clear water, placed on a bench, and sealed under a white polythene tent before being moved into the propagation zone at 21 °C. The polythene maintains a very high humidity (>90%) and shades from direct sunlight.

The cuttings remain in the propagation zone for 4 to 5 weeks, until rooted. From there they are moved to a weaning zone where they will remain for a further 4 weeks, during which time the polythene is gradually cut and opened up before being replaced with green netting and finally no cover at all.

After a final 4 weeks at ambient temperatures in a well-ventilated zone, the cuttings are rooted, fully weaned, and mature enough for either sales or potting on. This three-stage process is completed in a total of 13 weeks. Once rooted (after 5 weeks) the cuttings are generally sub-irrigated with liquid feed included.

BIOLOGICAL CONTROL

While the more modern facility has greatly increased the throughput of plants and improved both labour and heating efficiencies, the challenges of propagating under a new regime have meant a steep learning curve — not least with the approach to pest and disease management.

Re-circulating the water has led to the potential re-circulation of any root disease that might be present, such as *Phytophthora* and *Pythium*. Optimal growing conditions with high heat and humidity also create ideal conditions for foliage diseases such as *Botrytis* to flourish. And by extending the season, pests such as western flower thrips (WFT) have the opportunity to establish early and multiply to numbers that are hard to control by mid-summer and can remain active in the crop until late in the year.

While developing the propagation facility, GCN has been working with crop protection supplier BCP Certis to produce an integrated pest management system with a heavy reliance on biological controls, and a move away from chemical pesticides, to satisfy environmental demands, and because of the reduction in availability of effective chemicals.

A significant proportion of the crop is sold in North America where there are very strict conditions imposed at the port of entry and zero tolerance of pest and disease. Previously, GCN would have used a pesticide at the point of export to ensure that there were no live insects in a consignment. But following a rejected consignment after the discovery of two dead WFT at the U.S.A. border, GCN had to change its procedures to ensure that the pests were controlled to a much lower level on the nursery so that few if any pests (dead or alive) could be discovered during the export process.

These three factors — the change of facility, reduction of pesticides, and low pest tolerance levels — have influenced the development of pest and disease management on the nursery over the last decade.

Early Experiences with Biological Controls. Initially, when embarking on a biological programme, WFT control was left to the predators. This included the introduction of *Amblyseius cucumeris* and *Hypoaspis miles*. The amblyseius — predatory mites that feed on the immature larval stages of the thrips — is introduced in a breeder pack, with two placed on each propagation table at the time of sticking (two packs per 3.5 m^2 table) and remaining in place for the 8-week period that the cuttings are in propagation and weaning. Once all the polythene and net covers have been removed, further applications of amblyseius from shaker packs can be added weekly to the crop (introduced at $50/m^2$). Hypoaspis are also sprinkled over the prepared cutting trays just before the cuttings are inserted at a rate of $250/m^2$. These are aimed at controlling any thrips that may drop to the soil to pupate during their life cycle.

Success of these two agents on their own was very limited. Although the temperature and humidity were thought to be ideal for amblyseius to thrive, in reality the life cycle of thrips in these conditions was quicker than expected and the number of eggs laid meant that the thrips appeared to be out-doing the predators.

At the same time GCN was still relying on a number of fungicides to control *Botrytis*. The installation of a U.V. filter that processed all used and stored water in the re-circulation system eliminated the need to fungicide-drench the cuttings in propagation to control soil-borne root diseases, though the use of foliar fungicide sprays was still necessary. Although no physical evidence could be found to back up the claim, our observations suggested that some of the fungicides being used could have been reducing the effectiveness of the predators — such as Switch (cyprodinil + fludioxonil) on amblyseius.

With reliance on just these two bio-control agents against WFT and the possible effects of the fungicides, chemical back up was often required: Conserve® (spinosad) was applied quite regularly throughout propagation.

Further Development of IPM. In 2005, in addition to use of the predators, GCN started applying weekly sprays of Nemasys-F® (*Steinernema feltiae* nematodes) throughout the propagation period at a rate of 250 million per 1000 m^2. Conditions in the propagation unit are ideal for these nematodes as the foliage should remain wet for at least 2 h after application, enabling the nematodes to move around and find the pests. The nematodes should not be applied in direct sunlight, so the white polythene and the shade screens ensured optimum conditions. This had an immediate impact on the control of WFT, with far fewer applications of Conserve being required over a season.

A further reduction in the use of chemical fungicides came with the introduction of Serenade ASO® (*Bacillus subtilis*). Regular applications of this biological fungicide (a naturally occurring bacterium) have reduced applications of chemical fungicides significantly while controlling *Botrytis* to an acceptable level throughout propagation. There are no known negative effects of Serenade ASO on beneficials. Any impact of fungicide treatments on bio-control agents in the propagation house is now minimal.

Most recently the use of the bio-pesticide Naturalis-L® (*Beauveria bassiana,* an insect pathogenic fungus) as an addition to the other biological agents, has achieved complete control of WFT and incidental control of other pests (applied at a rate of 300 ml in 100 L of water). The warm humid conditions are ideal for this pathogenic fungus to infect both adult and larval stages of thrips species. Recommended conditions for Naturalis-L are a temperature between 15 to 30 °C and humidity greater than 60% RH, again already achieved in a propagation unit.

Current IPM Programme. Throughout the 13-week propagation cycle at GCN, a programme is now in place where weekly sprays alternate between Naturalis-L, Nemasys-F, and Serenade ASO. This is in addition to the hypoaspis mites that target the pupating thrips and the amblyseius parasitic wasps which target the thrips larvae. This programme has led to almost complete control of the major pest and disease problems that used to be an issue in propagation.

The use of chemicals has reduced, mainly a result of the introduction of Nemasys-F in 2005. Before this as many as 20 chemical applications per year were being used to control thrips. Since Nemasys-F became a regular part of the programme the number of chemical pesticide applications has reduced to five over the course of each propagation season to control WFT.

During the 32 weeks of propagation so far in the 2010 season, no chemical insecticide has been used and only three applications of a chemical fungicide have been made. Botrytis control is very acceptable and control of WFT is complete. Even when material has arrived heavily infected with thrips at the propagation house, cuttings have emerged after 13 weeks, rooted, weaned, and matured, and a live thrip is almost impossible to find. Incidental control has also been shown on sciarid larvae — dead larvae were collected and taken to the local pathology laboratory where spores of the fungus *B. bassiana* were identified as the cause of death.

FUTURE DEVELOPMENT FOR IPM ON THE NURSERY

The bio-control programme does now involve high input levels of predators and very frequent applications of biological sprays, some of which are quite costly. However, good control has now been achieved and the benefits are starting to show with increased yields and improved quality.

Having reached this stage in the pest and disease control programme at GCN it is now thought that some of the inputs can be reduced to save cost while continuing to maintain control. For example, it may be that the number of predators introduced at the beginning of the process can be limited or the number of spray applications reduced. Perhaps the biological sprays are now good enough to control the pests without the predators.

Generally it is expected that the predators will be able to control the background levels of thrips with little interference from chemical fungicides, with Nemasys-F and Naturalis-L used as a reactive treatment to an increase in thrips population.

Research on a cucumber crop (Jacobson et al., 2001) showed that *B. bassiana* and *A. cucumeris* were completely compatible with no evidence that control of WFT was impaired by application of Naturalis-L onto plants already treated with *A. cucumeris*. The study suggests that a mycopesticide could be used as a second line of defence to support preventative pest management with *A. cucumeris*. Work for GCN over the next few years will look at ways of reducing the cost while maintaining good control so that pest and disease levels can be maintained at a suitable economic threshold.

Other trial work at GCN involves the use of *A. swirskii*, another predatory mite that feeds on the first larval stage of the thrips but can build up a population with much greater speed to give more effective control. Minimum glasshouse temperatures are required to ensure good activity of this predator.

CONCLUSION

Overall, while the cost of pest and disease management at GCN, including cultural, biological, and chemical control, has remained fairly static over the last 10 years, the cost of chemicals has been reduced dramatically, while the control of pests and disease has improved in the propagation unit. The environmental conditions in the propagation unit now lend themselves to the more recent developments of biological control including nematodes and pathogenic fungi and bacteria. It is now thought that with a little experience, some of the costs of bio-control might even be reduced. Good pest and disease management is now being achieved with very little, if any, input from chemical control, with biological agents proving successful in a propagation unit.

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Experiences With Biological Control in Outdoor Container-Grown Nursery Stock©

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INTRODUCTION

Gunnar Christensens' nursery was started on farmland more than 40 years ago by Nina and Gunnar Christensen. It is now run by the second generation of the family, Lotte and Henrik. The nursery covers 11 ha and has 25 employees during the season. Production is approximately 600,000 flowering shrubs and perennials in containers ranging from 2 L to 10 L and the main market is garden centres in Denmark and southern Sweden.

Production has been streamlined in the last few years, including the use of Visser's potting and spacing systems. The dispatch systems are currently being developed with the aim of reducing labour input by at least 30% and to improve the working environment significantly, with less harmful lifting and poor posture.

Reducing the environmental impact of production is an important consideration in the Danish market. During 2010 the area of the standing beds has been expanded and the area of roads and paths reduced so that productivity can be increased without necessarily increasing use of water or fertiliser. It also means there is less space to keep free of weeds and the opportunity to either produce more plants or produce a better quality by increasing plant spacing — we have chosen the latter.

We use re-circulated water from our new container beds and greenhouse roofs. All pots are covered with bark to prevent weeds and to reduce evaporation and water consumption. And following the experiences described below, all the plants are grown with the use of biological control as the primary means of crop protection.

EXPERIMENTS ON THE USE OF BIOLOGICAL CONTROL OUTDOORS

For over 20 years, biological control has been used with great success on the nursery, in both propagation and the production greenhouses. Initially the nursery was forced into using biological control, because of the lack of effective chemical agents available in Denmark. The nursery has continued to work with biological control, in addition to chemical pest control, to provide a better working environment.

Because of our experience we offered to host a study of biological control in outdoor container plant production. The trials are being organised by the Danish Nursery Owners Association.

The trials began in 2008 with a small study in which we examined whether it was realistic to use biological control in open-field production. The following year we hosted a larger scale experiment, in which 10%–15% of our production was grown with the use of biological control. In 2010 we hosted further trials with biological control, including the use of air-assisted knapsacks to apply the biological agents. All the plants in the trials, which included a range of shrubs and perennials, are watered by drip lines to prevent over-watering. Predators work best with a RH of 60%, or more.

The trials have shown that it is possible to use biological control in open-field production. The 2009 trials showed that it cost almost twice as much to produce the plants with biological control as with chemical control.

However, since the beginning of the 2010 season, our thinking has changed from asking "which plants we should grow with biological control" to "which of the plants should not be grown with the primary use of biological control" for reasons which will be explained below.

BIOLOGICAL CONTROL IN PRACTICE

Preparation. During the winter we plan the following season's production and crop protection. We assess each crop, what pests and diseases they typically can get and at what time of year. Planning is informed by our records from previous years which we keep as a knowledge base in a Microsoft Excel document.

Propagation. We run a fixed programme of biological control in our propagation. We start our propagation in early April and biological control starts in the propagation houses in early May. We put predators out weekly onto the new planted cuttings until mid August.

Production. We start biological control in the outdoor container beds at the end of May when night temperatures should be above 10 °C when the predators will perform well. Typically, there are very few major pest attacks until night temperatures are above this level.

Pest Management Outdoors. Crop inspections begin in early May. We go through the entire crop once a week with a primary focus on the subjects that are likely to see the first attacks by pests, guided by our knowledge base. We also get regular reports from the staff who are working in the crop. When pests are found we decide whether we should control at this stage or wait and observe.

Small attacks will be observed but major attacks will be addressed using predators. If an attack is detected late — that is, immediately before marketing — we can either put out many predators and wait 2 or 3 weeks for them to work, or we can choose to use pesticides. We only resort to pesticides if the plant quality will be significantly impaired without them and the chemicals we choose are compatible with biological control. Against aphids we use flonicamid as Teppeki®. It works on aphids via ingestion and they stop feeding after about 2 days. Against spider mites we use hexythiazox as Nisserun®. It also works via ingestion and reduces the spider mites' ability to reproduce.

Biological control cannot usually be used to prevent pest attacks. The exception we have found, by experience, is that we can prevent spider mite attacks with the release of the predatory mite *Amblyseius cucumeris*. Predatory mites eat spider mite eggs and therefore are able to restrict spider mite infestations. They will never be able to handle a major outbreak however.

Application. From the time of ordering predators it will typically take 2 to 3 days until we receive them. It is possible to keep them for up to a couple of days in cool storage but, unlike chemicals, they cannot be stored long-term on the nursery. It is best to use them as soon as possible after delivery, while they are still in the best condition. They can be put out on the crop at any time of day. However, it is best in the morning when there is dew on the plants, which catches the predators so they do not fall off. They also acclimatise better at this time — midday sun can burn very brightly and makes for a sharp transition from storage for the predators.

All control agents except nematodes and *Hypoaspis miles* can either be spread directly from the container onto leaves, in branch angles and onto shoot tips, or spread with an air-assisted knapsack applicator. This piece of equipment is best described as a modified leaf blower. It has a tank mounted on top into which the predators are put. From there they are blown through the machine and out onto the crop through a large diameter hose. It takes some practice to dose the crop correctly. Effective distribution is achieved using the fan at a faster speed.

Hypoaspis miles is spread directly from their container onto the ground. Nematodes are applied through the irrigation in the spring when the soil temperature reaches 12 °C. This will be repeated in early September.

At the end of August we stop releasing predators. Night temperatures in Denmark are too low after this time and both pest and predator activity decreases.

Table 1 shows the predators used on the nursery. We also use the biopesticides Spruzit® (plant extracted pyrethrum) against caterpillars, beetle larvae, and leaf wasp larvae; and Dipel® (*Bacillus thuringiensis*) against butterfly larvae.

Table 1. Predators used in biological control at Gunnar Christensens Planteskole during the 2010 season.

Common name	Scientific name	Activity
Predatory mite	*Amblyseius cucumeris*	Nymphs and adults eat first instar thrips; larvae eat spider mite eggs
Common flower bug	*Anthocoris nemoralis*	Nymphs and adults feed on all stages of beech aphids
Parasitic wasp	*Aphidius colemani*	Parasitizes around 40 species of aphids
Parasitic wasp	*Aphidius ervi*	Parasitize aphids, including potato aphid
Gall midge	*Aphidoletes aphidimysa*	Feed on aphids
Parasitic wasp	*Encarsia formosa*	Parasitizes whiteflies
Nematodes	*Heterorhabditis bacteriophora*	Parasitizes black vine weevil larvae
Ground-living predatory mites	*Hypoaspis miles*	Feed on ground-living organisms including springtails, mites, the larvae of fungus gnats, beetles, flies. Its nymphs and adults feed on thrips pupae
Predatory bug	*Orius majuscules*	Nymphs and adults feed on all stages of thrips, aphids, mites, and other small arthropods
Spider mite predator	*Phytoseiulus persimilis*	Nymphs and adults feed on all stage of spider mites

THE RELATIONSHIP WITH CHEMICAL PESTICIDES

We have significantly reduced the numbers of fungal sprays since we stopped using chemical insecticides. Chemical insecticides are formulated with organic solvents that break down the wax layer on the crop leaves to help them penetrate into the tissues the pest feeds on. However this wax layer is part of the plant's defence against fungal diseases. We believe reduced use of chemical insecticides has therefore helped to preserve the crop's natural defence against disease, which is why we have seen a reduced need to apply chemical fungicides.

In Denmark we have unpredictable weather and the likelihood of wind and rain is always a consideration when spraying. As we have to rely less on chemical sprays, we are more able to choose to apply them at the optimum times in relation to weather, wind, and workflow. Thus, they become more efficient and this also means fewer applications are needed.

We can spray with most fungicides without an effect on predators. The ones currently in regular use are Folicur® (tebuconazole), Amistar® (azoxystrobin), Tilt™ (propiconazole), Proplant™ (propamocarb hydrochloride), and Teldor® (fenhexamid).

Bugs and leafhopper are harmful pests for which there are no biological controls yet. However, they have not posed a problem for us. Against slugs and snails we use Ferramol (ferric phosphate), which is approved for organic food crops.

LABOUR INPUT FOR BIOLOGICAL PEST CONTROL

The time spent per week managing biological control breaks down as 2 or 3 h for inspection and record keeping; and 1 or 2 h for spreading of predators. Our nursery records have shown us that the hours spent spraying chemical versus the time spent distributing biological control over the season are very similar.

To make a proper comparison, the time spent on chemical control is not just operating the sprayer. It must include setting up and dismantling warning signs and barriers to keep staff out of the treatment area; distributing information for affected employees and departments; putting on and taking off personal protective equipment; preparation of spray equipment and the disruption of the workforce in the affected departments.

Most spraying is done outside of normal working hours which means expensive overtime costs while for biological control the crop inspections and applications of predators typically take place within normal working hours.

In Denmark a spray certificate is required for any operator who applies chemical agents. It must be renewed every 2 years. No certification is required for use of biological control.

INFORMATION AND MARKETING

Our aim at Gunnar Christensen's Nursery is to provide all our employees with a knowledge and understanding of biological control. We know it is at the busy times when pest damage occurs and this is why it makes sense for all employees to know how to recognise damage and learn what the pests and predators look like and how they behave. When we see damage in the crop, we try to show it to all staff members and explain the strategy to be used. Most people know what a badly infested plant looks like, what is important is to teach them all what the earliest stages looks like and how the attack will evolve.

Knowledge about our strategy is just as important for our sales team. For example, there may be times when we have to withhold a consignment of plants, because biological control has not yet cleared up the problem. When customers are informed that they will have to wait for delivery due to the biological control, there is a very good understanding. None of our customers have said: "Then use chemical spraying instead!" They also have employees and customers to consider. We explain to our customers that there is a natural balance in the plants, which lasts all the way to the final customer's garden, and we find this is a good selling point. A plant which has just been cleaned up chemically is very receptive to many kinds of pests and diseases after it has been transplanted into a garden.

STARTING FOR YOURSELF

Before starting you need to make an assessment of whether biological control can work on your nursery. It is important that you really want to succeed. It requires good nerves and a strong will as it is still so easy to resort back to chemicals at the first sign of a problem.

Start by listing your crops and your known historic pest and disease issues and their typical times for attack. It is useful to put this into a spreadsheet such as Excel which makes it easy to search for historic data. Your records can then help you to develop a suitable strategy for your own range of crops.

It helps if you have an employee with an interest in and desire to use biological control, to whom you can give this responsibility. But you also need to find a serious and experienced supplier who will come to advise and also use an experienced horticulture consultant.

Expect to devote time to crop inspections and start them earlier in the season than for chemical control. Be very aware of the possible impacts on your biological agents of any chemicals that you do use. Record in detail all that is done over the season. Evaluate the process. Use the experience to plan next year's strategy.

Start with a small part of nursery. It's better with a little success than a big failure

Inform clients and their customers about your use of biological control. It will be a good selling point.

CONCLUSION

Our biggest lessons have been in how to observe and how to be patient — knowing your enemy. Some pests are very dependent on your crop management.

The philosophy with chemical controls was to prevent attacks rather than cure but this destroys a natural balance. When we were using chemical sprays, we had no major fluctuations from year to year. There were always some aphids, spider mites, larvae, etc. Now we have aphids one year, next year spider mites, and so on. It is easier to deal with one problem at a time.

A bonus effect of not using insecticides is the very high incidence on the nursery of natural predators such as ladybirds, lacewings, all kind of spiders, gall midges, hoverflies, and wasps.

Liverwort Control Using Novel Techniques©

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INTRODUCTION

Liverwort growing on the surface of growing media is a major problem in nursery stock production, affecting both protected and outdoor-grown crops: removal has been estimated at 4% of total annual production costs (Scott and Hutchinson, 2001), equivalent to £1,763 per hectare based on Horticultural Business Data 2008–9 figures (Crane and Vaughan, 2009). Zero tolerance of liverwort in certification schemes and a lack of approved chemical products make its control a technical priority for growers. This paper reports on a project funded by the Horticultural Development Company (HDC) to investigate the herbicidal effect on liverwort of glucosinolate hydrolysis products found in oil seeds, and the suppression of liverwort growth by unknown biological or physical factors within certain growing media components.

Seed Meal Suppressive Effect. Glucosinolates (GSLs) and their hydrolysis products (isothiocyanates, ITCs) are responsible for the distinctive pungent smell and hot taste of cabbages, mustards, and other brassicas and have shown toxicity against root knot nematodes, fungal species, and plants (Bialy et al., 1990). Such GSLs could potentially be used to control liverwort — each brassica species has a distinctive profile of one or more glucosinolates, each of which could have a different effect.

These GSLs are nontoxic thioglucosides with a common core comprised of a β-d-thioglucose group with a sulphonated oxime and a variable side chain ("R" group) that largely determines the biological activities of the degradation products (Brown and Morra, 1999). The hydrolysis of GSL is catalysed by a myrosinase enzyme released following mechanical damage in the presence of water; GSLs and myrosinase are stored separately within the plant and come into contact only following mechanical damage. The products of this reaction are primarily ITCs, thiocyanates, nitriles, or epithionitriles, depending on the "R" group present and environmental conditions (Vaughn et al., 2006). These ITCs are the most bioactive products of GSL hydrolysis and have been shown to exhibit a herbicidal effect on liverwort: ITCs adversely affected liverwort gemmae (vegetative propagules produced by gemma cups on the liverwort surface) comparable to two herbicides (lenacil and metazachlor) when tested under laboratory conditions in a previous HDC project (Jeger, 2008); *Limnanthes alba* seed meal provided short-term liverwort control when incorporated into growing media (HDC project HNS 93c); and *Sinapis alba* 'Ida Gold' applied as a mulch has been found to control established liverwort (Boydston et al., 2008).

Growing Media Suppressive Effect. Observations made by ADAS (formerly Agricultural Development and Advisory Service) consultants during an earlier HDC-funded project (HNS 93c) suggested a suppressive effect on liverwort growth where the growing media was amended with loam or the proprietary wood-fibre-based growing media ingredient Sylvafibre® (Melcourt Industries), possibly indicating natural microbial suppression in addition to any physical effect (Atwood, 2005). Work carried out for the U.K. government-funded "Peatering Out" project also suggested a suppressive effect of green compost on liverwort growth (Adlam and Rainbow, 2002).

Two trials were completed in Year 1 (2009–2010) of the project, sited on commercial nurseries, investigating the effect of brassica seed meal species and application method, and the effect of growing medium amendments on liverwort infestation.

MATERIALS AND METHODS

Seed Meal Suppressive Effect. Five seed meals were selected: *Camelina sativa* (false flax), *Brassica carinata* (Abyssinian mustard), *Sinapis alba* 'Albatross' (white mustard), and *Brassica napus* (oilseed rape) from two different sources. The seed meals were ground to fine meal and analysed for glucosinolate content (undertaken at NIAB [formerly National Institute of Agricultural Botany], Table 1). Each was applied both as a mulch (M) and incorporated (I) into the growing media. Irrigation was applied via overhead sprinklers and by hand during the winter. The potting mix was 100% Sinclair Professional Peat®, with Osmocote® Exact 11N-11P-18K + 2 MgO + trace elements, 8–9 months formulation (3 kg·m^{-3}) and the pH adjusted to 5.5 with lime. The trial was set up on 21 Sept. 2009.

Growing Media Suppressive Effect. Five products were included in this trial (Melcourt Sylvafibre®, Melcourt Growbark®, perlite, Vital Earth® green compost,

Table 1. Seed meal glucosinolate analysis.

Glucosinolate (µmol·g^{-1})	*Brassica carinata*	*Sinapis alba* 'Albatross'	*Brassica napus* '00'	*Brassica napus* RMF	*Camelina sativa*
Sinigrin	95.4	0	-	-	-
Glucosinalbin	33.9	187.8	-	-	-
4OH glucobrassicin	2.8	0	0.19	2.12	-
Glucoberin	-	-	0.15	0.89	-
Progoitrin	-	-	6.26	6.32	-
Epi Progoitrin	-	-	0.17	0	-
Glucoraphanin	-	-	0.53	0.54	-
Glucoalyssin	-	-	0.7	0.37	-
Gluconapin	-	-	2.49	2.64	-
Glucobrassinapin	-	-	0.76	1.13	-
Gluconasturtiin	-	-	0.15	0.26	-
Glucocamelinin	-	-	-	-	19.75
9-methylsulfinylnonyl-GLS	-	-	-	-	5.57
11-methylsulfinylundecyl-GLS	-	-	-	-	4.62
Total content	132.2	187.8	11.4	14.3	29.9

and sterilised loam). Sinclair Professional Peat was used as a base with added nutrients (Osmocote Exact Mini, 16N-8P-11K + 2 MgO + trace elements, 3–4 month formulation, 1.0 kg·m^{-3}, and Dolomitic lime, 500 g·m^{-3}). Lime was added to the Sylvafibre® treatment at 1.0 kg·m^{-3} as per the manufacturer's instructions. No lime was added to the green compost. Treatments were incorporated into the peat at a standard rate of 50%, except for the sterilised loam (20%). Irrigation was applied by hand in addition to overhead irrigation to maintain high water levels, excluding any effects caused by improved drainage due to the amendments increasing liverwort pressure. The trial was set up on 27 July 2009.

Both trials were carried out under protection, with treatments arranged in randomised block designs with 4-fold replication. Each plot consisted of a tray of 17 liners (9-cm pots), with one additional pot containing liverwort to introduce inoculum; no plants were used in the trials.

RESULTS AND DISCUSSION

Seed Meal Suppressive Effect. Over the whole trial, the least liverwort established in the *S. alba* (incorporated), *C. sativa* (mulch), and *B. napus* '00' (incorporated) treatments, and most liverwort established in the control pots (Fig. 1). Of the two *B. napus* seed meals ('00' and RMF), *B. napus* '00' had less liverwort infestation. After 22 weeks many of the pots were extremely dry, and this contributed to the decreased liverwort across the trial after 26 weeks.

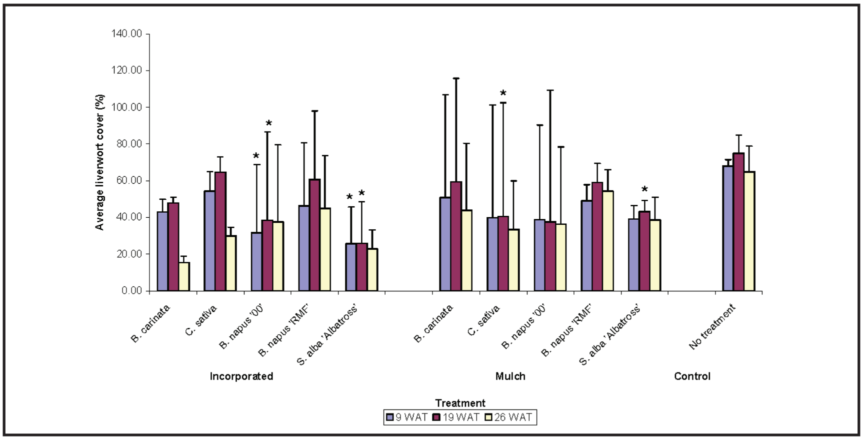

Figure 1. Seed meal suppressive effect (WAT = weeks after treatment). Least significant differences: 9 WAT = 10.35, 19 WAT = 13.75, 26 WAT = 26.12. *Average liverwort cover differs significantly from other treatments.

Data collected after 26 weeks was not found to be significant. However, data collected after 19 weeks, analysed using analysis of variance, showed a highly significant difference in liverwort cover between treatments ($F4,27 = 5.06$, $P<0.05$). Closer inspection of the data indicated that liverwort cover in the *S. alba* (incorporated and mulch), *B. napus* '00' (incorporated and mulch), and *C. sativa* (mulch) treatments was significantly less than in other treatments and the control. However, liverwort cover was highly variable in the majority of treatments. The most consistent results were within the *S. alba* plots.

Although statistical analysis using data gathered after 19 weeks did not identify a significant difference due to application method ($F_{4,27} = 2.71$, $p = 0.051$) it did suggest a trend towards less liverwort establishment where treatments were applied as a mulch (Fig. 2). After 19 weeks there was less liverwort cover in the mulch rather than incorporated *B. napus* RMF, *B. napus* '00', and *B. napus* '00' treatments; however even less liverwort cover developed in the incorporated *S. alba* and *B. carinata* treatments.

Growing Media Suppressive Effect. Peat treatments had a high level of liverwort infestation from early in the trial, as expected. Average pot cover in excess of

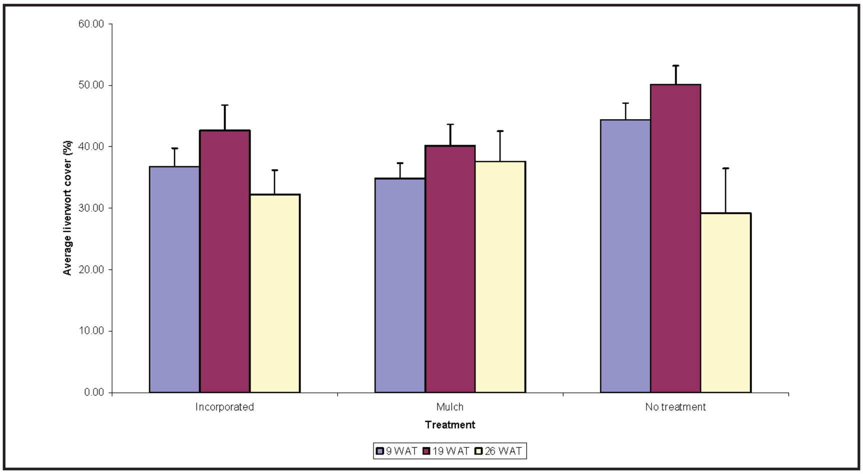

Figure 2. Comparison of application method (WAT = weeks after treatment). Least significant difference = 8.89.

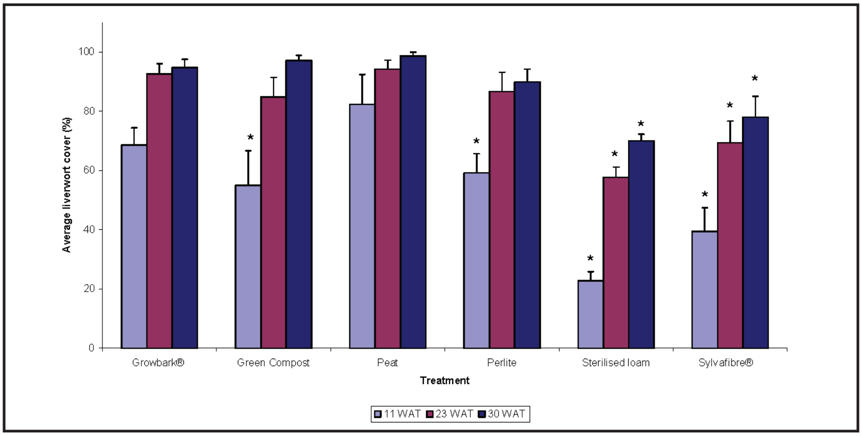

Figure 3. Growing media suppressive effect (WAT = weeks after treatment). Least significant differences: 11 WAT = 19.51, 23 WAT = 14.49, 30 WAT = 10.28. *Average liverwort cover differs significantly from the respective peat treatment.

82% was recorded after 11 weeks and 99% after 30 weeks. Liverwort growth was strong and healthy in this trial and the liverwort inoculant had spread into adjacent pots across all treatments after 4 weeks. Liverwort was slow to establish in the Vital Earth green compost treatments early in the trial, but 100% pot coverage was recorded in some plots after 30 weeks. Small black snails (*Oxyloma pfeifferi)* infested these treatments after 4 weeks, and the growing media slumped by approximately 10 mm in the pots.

Growbark® and perlite increase drainage and one would expect this to reduce liverwort infestation. However, under the moist conditions provided for this trial, after 30 weeks liverwort infestation was approaching that recorded in the peat and Vital Earth green compost treatments. Liverwort was also slow to establish in the Sylvafibre treatments although 78% pot cover was recorded after 30 weeks. Throughout the trial the sterilised loam showed least liverwort establishment. While this may show promise in reducing liverwort infestation, the weight and cost of loam may restrict the proportion that could be included in commercial growing media.

Statistical analysis using analysis of variance showed a very highly significant difference in liverwort cover between treatments ($F_{5,15} = 11.54$, $P<0.05$) after 30 weeks. The data indicated that liverwort cover in both the sterilised loam and Sylvafibre treatments was significantly less than in the Vital Earth green waste, perlite, Growbark and peat treatments.

CONCLUSIONS

The dry conditions of the seed meal trial meant the final results after 26 weeks were not reliable. The *S. alba, B. napus* '00', and *C. sativa* treatments all showed promise, and merit further investigation. The seed meals had individual GSL profiles (Table 1), although the two *B. napus* seed meals had similar profiles the proportions of each differed and this could be responsible for the different effects on liverwort infestation. Overall *S. alba* and *B. carinata* had the greatest GSL content, but this did not translate into greatest liverwort control in both cases, suggesting a greater influence of individual GSL characteristics than GSL quantity.

For short-term crops, or those potted up and due for sale within a short time frame, use of Sylvafibre may reduce the amount of liverwort herbicides applied or pre-sale pot cleaning. The Sylvafibre treatment produced promising results, maintaining liverwort cover less than 40% for 11 weeks. The most promising results were obtained using sterilised loam where liverwort cover was less than 23% after 11 weeks.

Acknowledgements. Funding for the project was provided by the Horticultural Development Company (HDC project HNS 175). The assistance of Oakover Nurseries, Palmstead Nurseries, Statfold Seed Oils Ltd, Plant Solutions Ltd, ADM Ingredients Ltd, Romney Marsh Farms, Melcourt Industries Ltd, and Vital Earth Ltd are gratefully acknowledged.

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Herbicide Screening for U.K. Ornamental Plant Production: a Cross Sector Approach©

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INTRODUCTION

A programme of herbicide screening is important for the ornamentals sector in the U.K. to replace withdrawn herbicides and tackle resistant weeds. Over the last 5 years the number of herbicide active ingredients available to the ornamentals sector has been considerably reduced (Table 1). Many of these have been lost or their use restricted as a result of the review process within European Council Directive 91/414/EEC. Further restrictions will occur as the criteria for E.U. approval switch from risk management to hazard based. Meeting the requirements of the Water Framework Directive (2000/60/E) for water quality by 2015 will also affect pesticide use with particular implications for residual herbicides.

Table 1. Recent herbicide losses for the ornamentals sector

Herbicides lost		
Active ingredient	Product	Use
Chorthal-dimethyl	Dacthal W-75	Residual herbicide, field and container
Dichlobenil	Casoron G	Residual herbicide, field
Diuron	Diuron	Residual herbicide, field
Paraquat	Gramoxone	Contact herbicide, field
Simazine	Gesatop	Residual herbicide, field
Trifluralin	Axit GR Ardent	Residual herbicide, containers Standing bed herbicide
Herbicides restricted		
Active ingredient	Product	Use
Metazachlor	Butisan S	Residual herbicide, field and container
Propyzamide	Kerb Flow	Residual herbicide, field and container

In addition, new weed problems continue to emerge. For container nurseries the distribution of bittercress species has changed in recent years. Hairy bittercress (*Cardamine hirsuta* L.) used to be the predominant species, but it is increasingly being replaced by flexuous bittercress (*C. flexuosa* With.) and New Zealand bittercress (*C. corymbosa* Hook. f.), the former being more prevalent. This change has also been reported in Belgium where Eelden and Bulcke (1998) showed that flexuous bittercress was less susceptible than hairy bittercress to isoxaben when applied post emergence. In field-grown crops, cockspur grass (*Echinochloa crus-galli* (L.) P. Beauv.) is another non-indigenous species causing problems in nursery stock in the southern counties of England. It can rapidly shade-out field crops leading to loss of quality and difficulty in lifting.

SOURCES OF ORNAMENTAL HERBICIDES

The ideal herbicide characteristics for container production are:

- Good residual activity for key weeds
- Minimal contact activity
- Not mobile, liable to leaching or root uptake
- Good mammalian safety data

It is unusual for herbicides to be developed specifically for the ornamentals market in the U.K. so herbicides are selected from those developed for larger scale crops. These can be for broad-leaved drilled crops (e.g., soy beans, oil seed rape, and sugar beet), perennial crops (e.g., fruit, vines, and olives), maize, and vegetables. There are several problems that have to be addressed in considering products' suitability for ornamental crops: the range of weeds controlled can be limited (e.g., oil seed rape herbicides can be weak on bittercress); there can be limited data on spring-germinating weeds for herbicides designed for autumn-drilled crops; and herbicides for vegetable crops only have to be of relatively short persistence. In all cases, unexpected phytotoxicity can be a problem because of the range of ornamental crops that are grown. In the U.K. there is a strong link between the researchers working in vegetables, fruit, and nursery sectors as the majority of R&D on these crops is grower-funded through a single organisation, the Horticultural Development Company.

HERBICIDE SCREENING FOR CONTAINER SHRUBS

In a series of trials carried out from 2007–09 (Atwood, 2009) a range of herbicides were tested on key weeds of container nursery stock production including hairy, New Zealand, and flexuous bittercress (*C. hirsuta, C. corymbosa*, and *C. flexuosa*); pearlwort (*Sagina procumbens* L.); mouse ear (*Cerastium fontanum* Baumg. subsp. *triviale* (Link) Jalas); groundsel (*Senecio vulgaris* L.); willowherb (*Epilobium ciliatum* L.); and goat and grey willow (*Salix caprea* L. and *S. cinerea* L.). Herbicides (Table 2) were tested in nursery trials on 18 species (Table 3), in most cases following successful results in pot experiments pre- and post emergence of the weeds. The results of the pot experiments confirmed that both New Zealand and flexuous bittercress were more resistant to control once germinated compared with hairy bittercress although Skirmish® (terbuthylazine + isoxaben) and Sumimax® (flumioxazine) were relatively effective even post emergence.

Table 2. Herbicides used in the 2007–9 screening.

Active ingredient	Product	Main usage / approval
Dimethachlor	Teridox	Oil seed rape (not U.K.)
Flazasulfuron	Chikara	Total weed control
Flumioxazine	Sumimax	Winter wheat, oats
Metazachlor + Dimethenamid –p	Springbok	Oil seed rape
Metosulam + flufenacet	Terano	Maize (not U.K.)
S – metolachlor	Dual Gold	Maize
Terbuthylazine + isoxaben	Skirmish	Peas and beans
Undisclosed	Code HDC H2	

Table 3. Nursery stock species used in the 2007–9 screening.

Berberis	*Kolkwitzia*	*Rosmarinus*
Buddleja	*Lavandula*	*Santolina*
Chamaecyparis	*Lonicera*	*Sambucus*
Choisya	*Philadelphus*	*Spiraea*
Escallonia	*Potentilla*	*Veronica*
Hebe	*Pyracantha*	*Vinca*

The main herbicides shown to have potential for use on nurseries were Dual Gold® (s–metolachlor), Sumimax (flumioxazine), and Skirmish (terbuthylazine + isoxaben). Dual Gold gave effective control of mouse ear, annual meadow grass, and willowherb. Control of groundsel was partial and control of all three bittercress species was unsatisfactory. Dual Gold has potential for use in U.K. nurseries as a supplement to the commonly used isoxaben product Flexidor 125 which gives unsatisfactory control of grasses, willowherb, and groundsel. Dual Gold was safe to use on a range of shrub species tested but caused slight foliar bleaching to *Hebe*. Sumimax controlled all of the key weeds tested but has a contact action so it was only tested as a dormant season treatment on shrub species. All deciduous species were unaffected following treatment but evergreen species *Escallonia, Hebe*, and *Vinca* were slightly damaged. Further work is required to quantify crop safety in other evergreen species. Skirmish was only tested as a dormant season treatment and proved safe to all except *Buddleia*, *Escallonia*, and *Hebe*. Skirmish was the only treatment tested that controlled established pearlwort and larger seedlings of all three bittercress species.

Although Teridox, Chikara, Springbok, Terano, and HDC H2 had potential for use in crops in container nurseries, lack of availability in the U.K. or approval restrictions preclude their use at present.

HERBICIDE SCREENING FOR CONTAINER-GROWN HERBACEOUS PLANTS

In a series of trials started in 2008 (Atwood, 2010) a range of herbicides including Dual Gold, Teridox, and Springbok were tested alongside standards Flexidor 125 and Ronstar 2G (oxadiazon) for crop safety on 50 herbaceous species (Table 4).

Dual Gold was safe to most of the subjects tested. Only *Campanula, Rudbeckia,* and *Stachys* suffered a temporary growth check following treatment. Dual Gold in particular could be a useful herbicide for herbaceous growers. Although there are gaps in the weed control spectrum, notably bittercress species, it could be a useful supplement to Flexidor 125 which gives poor control of willowherb and grasses. Springbok was damaging to more subjects, particularly *Bergenia, Brunnera, Campanula, Leucanthemum, Pulmonaria*, and *Rudbeckia*. Flexidor 125 was safe to use on all species except for *Brunnera* and *Rudbeckia* and in one trial *Hemerocallis* and *Penstemon* were damaged.

Table 4. Herbaceous species used in the 2009–2010 screening.

Acanthus	*Geranium*	*Paeonia*
Achillea	*Hakonechloa*	*Phlox*
Agapanthus	*Helenium*	*Polypodium*
Ajuga	*Helleborus*	*Polystichum*
Alstroemeria	*Hemerocallis*	*Pulmonaria*
Artemisia	*Heuchera*	*Rudbeckia*
Bergenia	*Hosta*	*Salvia*
Brunnera	*Iris*	*Schizostylis*
Campanula	*Kniphofia*	*Sedum*
Centaurea	*Leucanthemum*	*Sisyrinchium*
Centranthus	*Leymus*	*Stachys*
Coreopsis	*Liriope*	*Symphytum*
Crambe	*Lobelia*	*Teucrium*
Crocosmia	*Lupinus*	*Tradescantia*
Dicentra	*Matteuccia*	*Verbena*
Dryopteris	*Ophiopogon*	*Zantedeschia*
Fragaria	*Penstemon*	

Teridox is relatively unknown as a herbicide for ornamentals. Initial crop safety results from 2008 were encouraging but more damage occurred in 2009 indicating that it may have more limited application. Ronstar 2G is widely used on herbaceous crops particularly after potting. Some species suffer temporary foliage damage from Ronstar 2G however. Ronstar 2G was safe to use on all but *Penstemon* and *Crocosmia* in 2008 and *Campanula* in 2009.

PREVENTION OF ROOTING THROUGH AND WEED CONTROL ON SANDBEDS

Rooting through on sandbeds can be a problem when lifting plants for sale. Following earlier trial results (Rowell, 1996) U.K. growers have applied a trifluralin + diflufenican product, Ardent®, to the sandbed prior for standing down for prevention of rooting through and weed control. Following the withdrawal of trifluralin in 2009 an alternative was sought. Trials on heathers (*Erica* ×*darleyensis*) and shrub species showed that Stomp® and Chikara® applied to the sandbed had some activity in preventing rooting through (Atwood, 2009). For heathers Stomp was fully effective and did not reduce rooting within the pot. Chikara reduced the root development of heathers at the bottom of the pot. A limited number of shrub species were tested and Chikara was found to reduce rooting through of *Buddleia* and *Spiraea* but no effect was found on *Vinca* or *Weigela*.

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Approaches to Herbicide Selection at Palmstead Nurseries©

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INTRODUCTION

When I started work at Palmstead Nurseries, I was amazed at the amount of time spent hand weeding. The only herbicide used on the crop was Ronstar 2G TRS® (oxadiazon) after potting. As a result, oxadiazon-resistant weeds such as chickweed and pearlwort flourished out of control and we were fighting a loosing battle.

Most of the herbicides available for nursery stock are developed for agricultural crops use because of the size of the potential market over which the agrochemical companies have to spread their development and registration costs. Horticulture has very few specific products for weed control. As a result, we have to use agricultural herbicides to achieve a good level of weed control on the nursery. With no recommendations in place for our specific crops, they have to be used at growers own risk in terms of phytotoxicity.

In the U.K., growers are fortunate that the Horticultural Development Council (HDC) has directed industry levy funds to commission ADAS (formerly Agricultural Development and Advisory Service) to conduct trials on herbicides for nursery stock (see paper by Atwood in this volume) resulting in the very useful publication *Practical weed control for nursery stock*. Unfortunately, it is impossible for those trials to cover all combinations of crops and weeds encountered on U.K. nurseries and at Palmstead Nurseries we felt the need to conduct a few of our own trials to help us select herbicides for their performance against our own weed spectrum and safety on our crops.

SELECTING HERBICIDES

The starting point was to review published results of trials that had already been carried out, including nursery industry guides such as HDC's *Practical weed control for nursery stock*, HDC project reports, and herbicide product labels.

I used the information to begin to build up a data set covering:

- Which products controlled the weeds encountered on our site
- Which products were safe on which plants
- What time of year were treatments most effective and safest to the crop
- Which products offered any post-emergence activity
- Persistence of the products
- Cost of the treatments

I also began to develop a computerised recording system that was easy to search.

As I sourced the information, I set up two Excel spreadsheets. The first would be a list of the herbicides used and the weeds they control. This list can be filtered by herbicide or weed to be controlled (see sample in Fig. 1).

	Butisan S	Ronstar 2G	Kerb	Lenacil	Dual Gold	Flexidor 125
MODE OF ACTION	Residual	Residual	Residual	Residual	Residual	Residual
Algae			pre & post emergence			
Annual meadow grass	pre-emergence	pre-emergence	pre & post emergence	pre & post-emergence	pre-emergence	
Canadian fleabane	pre & post emergence	pre-emergence				pre-emergence
Charlock		pre-emergence		pre-emergence		pre-emergence
Cleavers	pre & post emergence	pre-emergence	pre & post emergence	pre-emergence		
Common chickweed	pre & post emergence		pre & post emergence	pre-emergence		pre-emergence
Common knotgrass		pre-emergence	pre & post emergence	pre-emergence		pre-emergence
Common sowthistle		pre-emergence		pre-emergence		
Common speedwell	pre & post emergence	pre-emergence	pre & post emergence			pre-emergence
Dandelion		pre-emergence	pre & post emergence			
Fat hen	pre & post emergence	pre-emergence	pre & post emergence	pre-emergence		pre-emergence
Field pansy		pre-emergence				pre-emergence
Groundsel	pre & post emergence	pre-emergence		pre-emergence	pre-emergence	pre-emergence
Hairy bittercress	pre & post emergence	pre-emergence		pre-emergence		pre & post emergence
Liverwort	pre & post emergence	pre-emergence		pre-emergence		
Mayweed	pre & post emergence	pre-emergence		pre-emergence	pre-emergence	pre-emergence
Mosses	pre & post emergence	pre-emergence				
Mouse-ear chickweed	pre & post emergence		pre & post emergence	pre-emergence		pre-emergence
New Zealand Bittercress		pre-emergence		pre & post emergence		
Oxalis		pre-emergence				
Pearlwort	pre & post emergence		pre & post emergence	pre-emergence	pre-emergence	pre-emergence
Rushes						
Shepherd's purse	pre & post emergence	pre-emergence	pre & post emergence	pre-emergence		pre-emergence
Small nettle	pre & post emergence	pre-emergence	pre & post emergence	pre-emergence		pre-emergence
Sorrel			pre & post emergence			
Willow					pre-emergence	
Willowherbs	pre & post emergence	pre-emergence			pre-emergence	
PERSISTANCE	2.5 months	3 months	6 months	3 months	2 months	3 months
USE ON HERBACEOUS	YES	NO	SOME	YES	YES	YES
TIME OF YEAR	AUT/WIN	ANY	AUT/WIN	AUT/WIN	ANY	ANY
COST/20L KNAPSACK	£1.05	£3.80	£2.08	£1.87		£1.62

Susceptible
Moderately susceptible
Resistant

Figure 1. Sample of herbicide efficacy database.

The second spreadsheet is for crop tolerance (see sample in Fig. 2). This has an A–Z listing of the plants grown on the nursery, down the left column, and the herbicides along the top row. With this spreadsheet lists can be filtered by plant or plant group (e.g., grasses, conifers, herbaceous); or herbicides can be listed according to the crops they are safe to use on.

Filter Groups	PLANT GENUS	Aramo	Artist	Axit	Butisan S	Devrinol	Diuron	Flexidor	Goltix	Grazon 90	Kerb	Lenacil	Linuron	Propachlor	Ronstar 2G	Simazine	Stomp
H	*Aubrieta*																
S	*Aucuba*			T	T			T							T		
S	*Azalea*			T		T	M	T							T		
S	*Azara*																
B	*Bambusa*																
S	*Berberis*		S	T	T	T	M	T	M		T	T	S	T	M	T	M
H	*Bergenia*			T				T				S		T	T		
T	*Betula*							T							T		
CL	*Billardiera*																
S	*Brachyglottis*		M	T	T	T	S	T	S		T	M	S	T	T	S	T
H	*Brunnera*																
S	*Buddleja*			S	S	T	M	S			T	T			T		T
S	*Buxus*			T	T	T	T	S	M		T	T	T		T	T	
G	*Calamagrostis*	S	T		S	T					T	M		T			T
S	*Callicarpa*			T				T							T		
S	*Callistemon*																
S	*Calluna*																
C	*Calocedrus*																
S	*Camellia*			T		T	M	T							T		
S	*Campanula*			T				M				M		T	T		
CL	*Campsis*							T									
T	*Caragana*							T									
G	*Carex* 'Buchananii'	T	T		M	T					T	S		T			T
G	*Carex* 'Comans Bronze'	T	S		M	T					M	M		T			T
G	*Carex elata* aurea	M	M		M	T					T	M		T			T
G	*Carex* 'Evergold'	T	S		T	T		T	S		T	M	S	T	T	M	T

S	Susceptible (do not spray)
M	Moderately unsusceptible
T	Tolerant (Safe to treat)

	Filter groups
C	Conifer
CL	Climber
G	Grass
H	Herbaceous
S	Shrub
T	Tree

Figure 2. Sample of crop tolerance database.

The third record we can access is our pesticide spray records (see sample in Fig. 3). It is a legal requirement to keep these records for a period of 3 years but just keeping them on paper is fairly useless in terms of their potential as a management tool so we now also keep them on our database. The benefit is enormous. For example, if we notice any suspected herbicide damage, we can very easily look at the history of treatments applied to that crop. We can also tell who applied the product and the rate applied, weather conditions, etc. If we suspect a certain herbicide to have caused damage on a certain crop, we can then trial it further and highlight it on the spreadsheet as either safe or not safe to use on that crop.

We use this spray record for pest and disease control as well. Having the target pest or disease included (the "target" column on the right), means we can use the

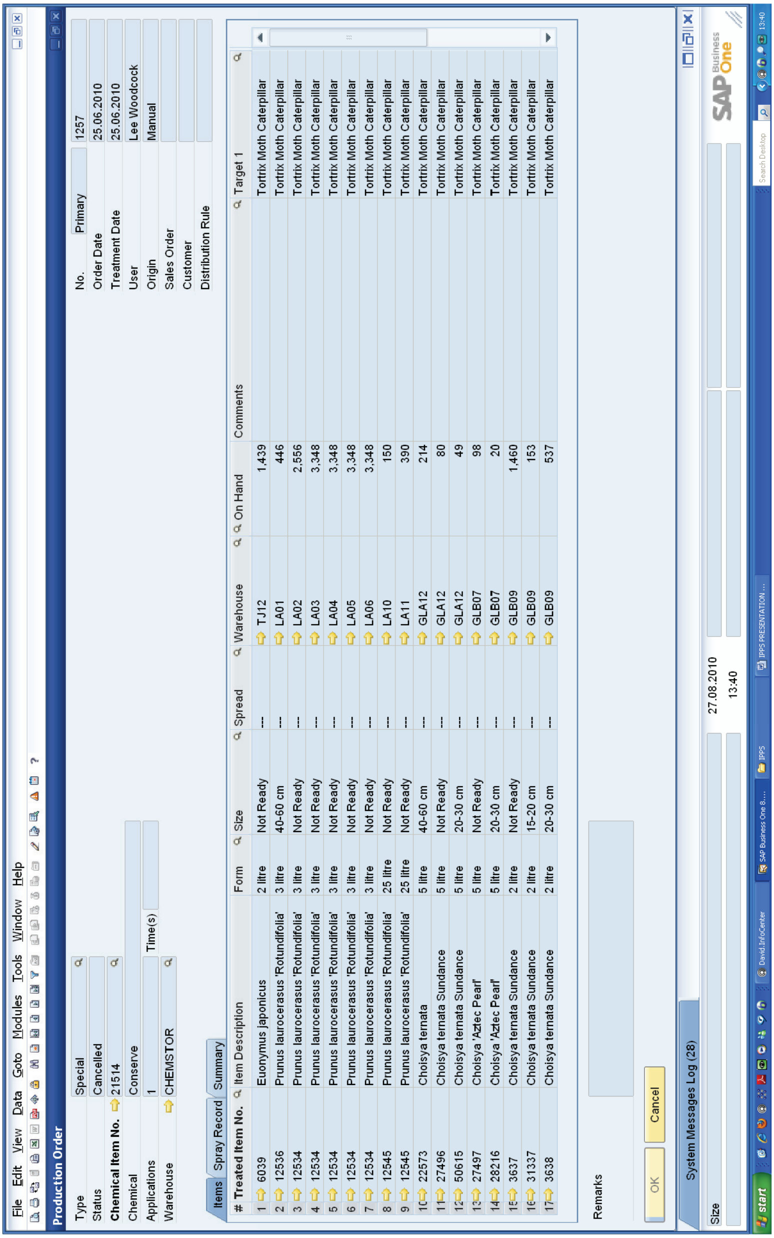

Figure 3. Sample of spray record database.

database to predict outbreaks of pests and diseases and so target control measures more effectively.

NURSERY TRIALS

The range of available crop protection products is constantly changing so we regularly undertake trials to ensure we understand the new products which are introduced and how they might fill gaps left by those which have been withdrawn. In the examples below, some of the products are no longer available but I have included the trials as examples of the trials system we have in place.

Herbicides for New Zealand Bittercress (*Cardamine corymbosa*). The objective of this trial in November 2005 was to find a herbicide to give both pre-emergence and post-emergence control of this weed in a range of container-grown plants. As liverwort was also present, we observed the performance of the products for potential control of liverwort too.

The chemicals used in the trial and rates of application applied were:

Herbicide	Rate
Axit (trifluralin)	100 $kg \cdot ha^{-1}$
Butisan S (metazachlor)	2.5 $L \cdot ha^{-1}$
Devrinol (napropamide)	9.0 $L \cdot ha^{-1}$
Diuron	0.8 $L \cdot ha^{-1}$
Flexidor 125 (isoxaben)	2.0 $L \cdot ha^{-1}$
Kerb Flo (propyzamide)	4.2 $L \cdot ha^{-1}$
Lenacil	2.0 $L \cdot ha^{-1}$
Ronstar 2G (oxadiazon)	200 $kg \cdot ha^{-1}$
Simazine	3.4 $L \cdot ha^{-1}$ (full rate)
Simazine	1.7 $L \cdot ha^{-1}$ (half rate)
Simazine	0.85 $L \cdot ha^{-1}$ (quarter rate)
Control (a batch of untreated plants included for comparison)	

The results are presented in Table 1. Only three of the herbicides trialled controlled New Zealand bittercress, the same ones also gave good control of liverwort. Of these, diuron was the most effective, giving good post-emergence and pre-emergence control of the bittercress and post-emergence control of liverwort. Simazine was quick to work and gave good control of bittercress and liverwort post-emergence, but less effective pre-emergence control. Lenacil was the least damaging of the three and gave good post-and pre-emergence control of the bittercress. Its post-emergence control of liverwort was good.

Our decision was that lenacil looked like the way to go for control of New Zealand bittercress. There was an issue with it being rapidly broken down by sunlight, therefore limiting its application to the winter months, as well as possible crop damage if applied in the spring onto soft growth.

Table 1. Control (none to excellent) of New Zealand bittercress and liverwort in nursery trials in 2005.

Herbicide product	N.Z. bittercress (Post emergence)	N.Z. bittercress (Pre-emergence)	Liverwort (Post emergence)	Liverwort (Pre-emergence)
Axit	None	None	None	None
Butisan S	None	None	None	None
Devrinol	None	None	None	None
Diuron	Excellent	Excellent	Excellent	
Flexidor	None	None	None	
Kerb Flo	None	None	None	
Lenacil	Moderate	Moderate	Excellent	
Ronstar 2g	None		None	
Simazine (full rate)	Excellent	Moderate	Excellent	
Simazine (half rate)	Moderate	Moderate	Moderate	
Simazine (quarter rate)	Little	Little	Little	

Herbicides for Spring Application. The purpose of this trial in May 2006 was to establish the crop safety — or otherwise — for a range of herbicides applied during spring, when weed growth is active but the crops are producing tender growth likely to be susceptible to herbicide damage.

The herbicides trialled and rates of application used were:

Herbicide	Rate ($L \cdot ha^{-1}$)
Flexidor 125 (isoxaben)	2.0
Diurex 50 SC (diuron)	0.8
Simazine	3.4
Lenacil	2.0
Goltix (metamitron)	5.0
Linuron	2.5
Butisan S (metazachlor)	2.5
Kerb flo (propyzamide)	4.2

The trial was divided into two experiments, in the first the herbicide was washed off the foliage immediately after application; in the second the plants were left unwashed.

The results in terms of crop safety are presented in Table 2.

SUGGESTED STRATEGY FOR HERBICIDE SELECTION AND WEED CONTROL

- Look at the specific weed to be controlled and select the appropriate herbicides for the job.
- Look at the crops and the weed problems and select herbicide(s) based on crop tolerance.
- Look at how environmental conditions affect the application of the selected herbicide(s), e.g., are they broken down by light or heat. Do they need to be irrigated in?
- Time applications correctly for maximum effect and minimum damage.
- Look at the application method, this will depend on the crop canopy cover, water volume, etc.
- Choose a programme which is long lasting.
- Develop a two-tier strategy, for example use liquids in the dormant periods and granules to follow on to reduce crop damage.
- Keep surrounding non-crop areas and standing down areas clean with the use of residual, contact, and translocated herbicides.
- Hand weed frequently, a little and often, to prevent any weeds that may be present from setting seed. This often involves a very quick crop walk, pulling out the odd weed here and there.

Table 2. Crop safety of spring-applied herbicides from results of on-nursery trial in 2006.

Herbicide trial 15 May 2006

W = washed off foliage NW = not washed off	Flexidor		Diuron		Simazine (Half Rate)		Lenacil		Goltix		Linuron		Butisan S	
	W	NW	W	NW	W	NW	W	NW	W	NW	W	NW	W	NW
Athyrium filix-femina	5	3	5	5	4	4	5	5	3	5	5	5	4	5
Berberis 'Amstelveen'	1	1	5	1	1	5	2	1	4	2.5	5	5	1	2
Berberis 'Rose Glow'	1	1	3	2	1	5	1	1	4	2.5	5	5	1	2
Brachyglottis 'Sunshine'	1	1	4	4	5	5	3	1	5	5	4	5	1	1
Buxus sempervirens	1	1	1	2	1	1	1	1	3	3	1	1	1	1
Escallonia 'Apple Blossom'	1	1	3	1	1	5	1	1	1	1	5	5	1	2
Euonymus 'Emerald 'N' Gold'	1	1	1	1	1.5	2	1	1	3	5	1	4	1	1
Hemerocallis 'Stella D'Oro'	1	2	2	1	2	3	1.5	1	2	2.5	1.5	4	3	2
Hosta 'Fire & Ice'	1	1	3	4	4	4	1	1	1	1	5	5	2	2
Iris 'Perrys Pride'	3	1	3	3	2.5	4	2	1	2	2.5	2.5	4	1	1
Lavandula 'Helmsdale'	1	2	2	2	5	5	1	1	5	3	1	5	1	2
Nepeta 'Walkers Low'	4	3	1	1	2	2	1	1	3	2.5	1	4	1	3
Sarcococca ruscifolia	1	1	2	1	1	3	1	1	2	2	2	2.5	1	1
Viburnum tinus	1	1	1	1	1	1	1	1	2	2	1	3	1	2

Key	
Dead	5
Extreme damage	4
Unacceptable damage	3
Slight damage (acceptable)	2
No signs of damage	1

Using Soil *Verticillium dahliae* Infestation Data to Determine Risk of Verticillium Wilt in Field-Grown *Acer* and *Tilia*©

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INTRODUCTION

In 2009 the production area of field-grown ornamental trees in England was estimated to be around 1000 ha, valued at £19.8 million (ADAS, unpublished data). Several of the subjects grown are susceptible to the serious, soil-borne fungal disease verticillium wilt, notable examples being some species of *Acer*, *Tilia, Fraxinus*, and *Catalpa*. The causal fungus, *Verticillium dahliae*, is widespread in U.K. soils. Until 2004, around 15 ha of land were treated each year with methyl bromide prior to planting trees, primarily to reduce the risk of verticillium wilt.

From 1 Jan. 2007, methyl bromide was no longer permitted in the U.K. for preplant soil disinfestation for tree production. This led to concern among growers that without an effective alternative the losses incurred to verticillium wilt were likely to increase substantially, effectively preventing the production of certain tree species in the U.K. on a commercial scale. Container production is not a viable option for growing trees to a large size.

Estimating *V. dahliae* levels in field soils in order to give advice on strawberry production has been an established procedure in the U.K. for many years. Based on the results of a soil test, growers are advised on the need for soil disinfestation or the use of wilt-resistant cultivars (Harris et al., 1991). The study reported here aimed to determine a basis for developing strategic planting in two different tree species, *A. platanoides* and *T. cordata*, based on levels of *V. dahliae* in the soil.

METHODS

Creation of a Range of *Verticillium dahliae* Soil Infestation Levels Using Soil Treatments. In 2005, in the first phase of a 5-year 25-plot replicated field experiment, various pre-plant soil treatments were applied to reduce the naturally occurring infestation levels of *V. dahliae* in a field in Hampshire, U.K. The four treatments used were chloropicrin, dazomet + metam sodium, biological soil disinfestations, and a pre-planting cropping with Sudan grass. Untreated plots were also included. These various treatments, together with a natural variation in *V. dahliae* infestation levels across the trial area, resulted in a range of pathogen populations from <0.1 to 62.2 colony forming units cfu/g soil, by January 2006. The results from this aspect of the project have been previously reported (O'Neill et al., 2010).

Regardless of the original treatments, for the purposes of this study, the plots were placed in three groups for statistical analysis. Nine plots had *V. dahliae* soil infestation levels of less than 0.7 cfu/g soil, six had levels in the range 2.9 to 10.0 cfu/g soil, and nine had levels above 10.0 cfu/g soil (one plot was not treated correctly initially and is disregarded in the analyses). Trees were planted in the Spring 2006 and disease assessments were carried out at the end of the growing seasons in 2006, 2007, and 2008.

Measurement of *Verticillium dahliae* Soil Infestation by Agar Plate Method. Soils from the plots were selected for testing using a wet-sieving method, whereby 25 g air-dried soil was suspended in 50 ml water and agitated for 1 h. The suspension was sieved to retain a 20–160 µm diameter fraction, which was resuspended in 20 ml distilled water. One ml aliquots were spread onto 20 Dox® soil extract plates containing antibiotics and biotin. The plates were incubated for 28 days at 22 °C, and colonies of *V. dahliae* counted after washing soil off the plates (Harris and Yang, 1996).

Assessment of Verticillium Wilt. Trees were assessed each autumn for the occurrence of symptoms potentially due to *V. dahliae* infection. Such symptoms included bark splitting, premature leaf yellowing/necrosis, branch death and, in a few cases, tree death.

A proportion of the *Acer* and *Tilia* trees were destructively sampled from the experiment each year for isolation of *V. dahliae* from a 30-cm section at the base of the main stem. For all stem sections, a 10-cm length was surface-disinfected in sodium hypochlorite (1% available chlorine, 1 min), and the bark was then removed. Three sections (4–6 mm thick) were sawn off, disinfected in alcohol (30 sec), placed onto PDA+streptomycin, and incubated at 22 °C in the dark. After 4 days, the vascular tissue was examined for the white, fluffy mycelium of *V. dahliae*. Agar plates were re-examined after 14 to 21 days for mycelial growth and microsclerotia of *V. dahliae* that had developed from the wood onto the agar.

RESULTS

***Verticillium dahliae* Infestation Density in Soil and Infection in *Acer* and *Tilia*.** No symptoms of verticillium wilt occurred in the first growing season. Field symptoms were first observed in *Acer* in Autumn 2007 and the incidence of both leaf yellowing and bark splitting differed significantly ($P<0.001$) according to soil infestation density with *V. dahliae* (Table 1). There were no obvious external symptoms of infection in the *Tilia* trees at this time, two seasons after planting.

Table 1. Occurrence of bark splits and leaf yellowing with necrosis in *Acer* according to soil levels of *Verticillium dahliae* prior to planting (field assessment, October 2007).

Level of *Verticillium dahliae* (cfu/g) in January 2006	Number of plots	Mean % *Acer* trees with	
		Leaf yellowing + necrosis	Bark split
<0.7	9	8.8	6.9
2.9–10.0	6	26.4	17.9
>10.0	9	32.3	23.9

Isolation from the stem bases in 2006 showed that many *Acer* trees were infected even though no external symptoms had developed (Table 2). There was a trend towards higher levels of infection in *Acer* with increasing soil infestation density of *V. dahliae* in both 2006 and 2007. However, considerable infection was found even in trees from plots with the lowest soil infestation level. Infection in *Acer* was so high by 2008 that no further isolations were undertaken.

In *Tilia*, very little infection had occurred after one growing season (2006) even on plots with very high soil infestation, and no detailed isolations were done that year. In 2007 and 2008 there was a marked increase in infection at the higher soil infestation level (>10 cfu/g) (Table 2 and Fig. 1). The correlation between increasing levels of *V. dahliae* in the soil, on levels of infection in *Tilia,* accounted for 52% and 54% of the variance in 2007 and 2008, respectively.

Table 2. Infection of *Acer* and *Tilia* stem bases according to three soil levels of the fungus at planting.

Verticillium dahliae in soil (cfu/g) at planting in 2006	Mean % trees infected at stem base (number of growing seasons after planting)			
	Acer		*Tilia*	
	2006 (1)	2007 (2)	2007 (2)	2008 (3)
<0.7	8.9	16.8	0.0	7.8
2.9–10.0	40.0	47.1	7.8	10.0
>10.0	34.8	37.8	21.7	27.8
Significance	0.009	0.003	0.003	0.003
LSD	21.25	17.31	12.92	12.45

DISCUSSION

The Value of Soil Infestation Threshold Levels for Advisory Purposes. The results from this experiment indicate that the use of a pre-planting test to determine *V. dahliae* levels in soil is not useful for advisory purposes with regard to *A. platanoides* cv. Emerald Queen production, as unacceptable levels of infection may occur even when very low soil infestation (<1 cfu/g) is present. As even the best soil disinfestation treatment is unlikely to eradicate *V. dahliae* in soil, it would be prudent to avoid land with even low levels of infestation, if *Acer* production is planned.

However, there may be scope for using such a test if planting of *Tilia cordata* cv. Greenspire is anticipated. Where *V. dahliae* soil infestation levels were below 0.7 cfu/g soil the pathogen was not isolated from *Tilia* stems after two growing seasons. Low levels of infection were found at that time where the soil level was in the ranges 2.9–10.0 and >10 cfu/g soil and also in the lowest infestation category after three season's growth.

Soil and Other Factors That Might Influence Planting Decisions. A direct relationship between *V. dahliae* inoculum density in soil and disease incidence has been shown in various herbaceous hosts and, less commonly, in trees (Lopez-Escudero and Blanco-Lopez, 2007). In other studies, no relationship could be

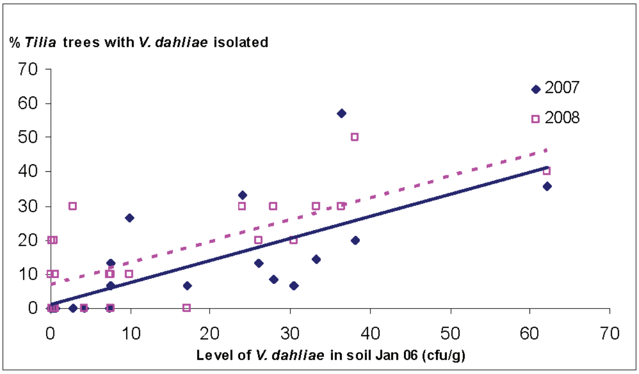

Figure 1. Effect of level of soil infestation with *Verticillium dahliae* at planting on recovery of the fungus from stem bases of *Tilia* after 2 and 3 years.

established, or results were inconsistent and strongly dependent on location. Likely factors which influence infection and make it difficult to develop models that apply generally include *V. dahliae* strain virulence, microsclerotia size and age, soil temperature and moisture, fertiliser use, soil disease suppressiveness, and root growth and architecture (Termorshuizen and Mol, 1995).

The natural ability of some trees to recover from verticillium wilt further complicates the ultimate aim of using soil inoculum density pre-planting to predict disease risk.

Even so, microsclerotial density in soil is a starting point and, as in this work with *Tilia*, many studies show a positive relationship with disease incidence. More data is needed on the factors which influence the relationship between inoculum density and disease progression over the relatively long duration of tree crops such as *Tilia*.

The traditional method for detecting and quantifying *V. dahliae* in soil in the U.K. relies on wet-sieving of soil and plating onto culture medium. Colonies growing from microsclerotia that resemble *V. dahliae* are counted. Other *Verticillium* species which may be found on the plates, mainly *V. tricorpus* and *V. nigrescens*, are disregarded.

Disadvantages of the soil plating method are that it is relatively costly, takes 6 to 8 weeks from sample receipt to reporting and results can vary between laboratories. A molecular, qPCR, test currently in development (Peters et al., 2009) aims to quantify the amount of target pathogen DNA in a few days for a lower cost. Additionally, the molecular test is capable of detecting *V. albo-atrum*, which the conventional test is unable to do.

Work is in progress funded by the Horticulture Development Company (HDC project SF 97) to examine if this new molecular method is able to quantify *V. dahliae* in soil with a sensitivity equal to or better than the plating method and accurately predict risk of verticillium wilt in strawberries, based on a pre-plant soil test.

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The Influence of Sugars on Root Vigour of Trees©

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Established semi-mature trees of four species (*Tilia tomentosa, Malus floribunda*, *Acer campestre*, and *Quercus robur*) showing symptoms of decline (leaf necrosis and branch die-back) were subjected to soil injections of sucrose at 25, 50, and 70 g·L^{-1} of water, applied at 1 L·m^{-2}. Trees were injected to an area 1 metre beyond the canopy drip line. Root dry weight was recorded 5 months later. Soil injections of sucrose significantly increased root dry weight compared with water-injected controls. Growth responses were influenced by species and the concentration of sucrose applied. Results indicate soil injections of sucrose 50 g·L^{-1} water were able to improve root growth of declining mature trees. Such a response is desirable as root damage following construction activities is a frequent problem encountered by trees growing in U.K. urban landscapes. The results have implications for nurseries producing trees and shrubs for transplanting.

INTRODUCTION

Within U.K. urban landscapes, trees frequently grow, or are planted, in close proximity to buildings and infrastructure. The process of developing land can be devastating to root systems of established trees and reduce survival of newly planted ones. For example, soil de-oxygenation caused by impeded drainage, mechanical compaction, or impermeable surface coverings is a common consequence of construction operations that results in physical impedance to root growth and reduced soil aeration. Trenching damage to roots is also implicated in the death of urban trees (Baines, 1994). Root damage reduces the root : shoot ratio and consequently the tree's ability to take up water and nutrients. This leads to water stress and reduced shoot growth, branch dieback, and ultimately tree death (Bellet-Travers et al., 2004; Davies et al., 2002; Fraser and Percival, 2003).

It is now recognised that the survival of trees following root damage is largely dependant on the rapid extension of the existing root system (Watson and Himelick, 1997). Consequently, a range of plant growth regulators (e.g., auxins), commercially available root biostimulants, and mycorrhizal products have been tested for their root-promoting abilities (Percival and Gerrittsen, 1998; Smiley et al., 1997; Fraser and Percival, 2003). While many of these have proved to possess some degree of root-promoting properties a number of problems have been encountered. These include cost, environmental impact and, most importantly, marked differences in growth responses between tree species. Ideally an inexpensive, non-toxic, and environmentally benign compound that can be applied to tree root systems after soil-damaging operations to stimulate root growth and restore the root : shoot ratio is required.

Sugars such as sucrose, glucose, and fructose form the end products of photosynthesis. Supplementing root systems with sugars affected root metabolism by significantly increasing lateral root branching and root formation compared with controls (Bingham and Stevenson, 1993; Bingham et al., 1997, 1998). Likewise, application of sucrose, glucose, and fructose as a soil drench to containerised and field-planted 4-year-old trees has been shown to significantly improve root dry weights compared with water-treated controls (Percival, 2002). This raises the possibility that the growth pattern of trees may be altered in favour of enhanced root formation by treating a damaged or severed root system with sugars such as sucrose.

Objectives of this investigation were to determine if soil injections with sucrose would improve the density or development of fine roots on established trees growing in urban environments. Sucrose was chosen as a test sugar as this form of sugar is the major photo-assimilate transported from source to sink tissues in most U.K. tree species (Lindqvist and Asp, 2002; Salisbury and Ross, 1985).

MATERIALS AND METHODS

Plots consisted of four mature oaks *(Quercus robur),* eight silver lime (*Tilia tomentosa*), six field maple (*Acer campestre*), and four ornamental apple (*Malus floribunda*) located at the University of Reading campus (oak, silver lime) and University of Reading experimental field site at Shinfield (field maple, apple). All trees were surrounded by grass. Tree size and soil conditions at each location are presented in Table 1. Soil phosphorus, potassium, magnesium, sodium, and calcium concentrations were determined using inductively coupled plasma emission spectroscopy following digestion in concentrated hydrochloric and nitric acids (Anon, 2002). Soil organic matter was determined following oxidisation with potassium dichromate, sulphuric acid, and orthophosphoric acid, and subsequent titration with ferrous sulphate solution (Walley and Black, 1934) and pH determined using a soil pH electrode at a depth of 20 cm.

Treatments consisted of the following soil injections:

- Sucrose at 70 $g \cdot L^{-1}$ of water
- Sucrose at 50 $g \cdot L^{-1}$ of water
- Sucrose at 25 $g \cdot L^{-1}$ of water
- Water control

Sucrose was obtained as domestic table sugar from a local supermarket. Quadrants beneath and to 1 m beyond the drip line of each tree were randomly assigned to each treatment. Injections were made to a depth of 20 cm on 1.0 m × 1.0 m spacing. Injection pressure was 80 psi and 1.0 L of the sugar solution was injected into each hole. Injection holes were marked with colour coded flags to indicate location of treatment. Treatments were made 22 April 2009. Root ingrowth cores (RlCs) were installed 26 April 2009 to monitor new root development (Marx et al., 1995). Root in-growth cores are 7.6 cm diameter by 20 cm deep plastic screen cages which allow in-growth of roots. They were filled with root-free, treated soil and were located within 15 cm of an injection site. Total herbicide (glyphosate) was applied 2 weeks prior to the experiment and periodically to the treatment area to eliminate grass and weed root contamination. Six RICs per quadrant were removed 5 months after treatment (22 Sept. 2009). Soil was gently removed from the RIC by gently shaking the root system after lifting from the ground and washing with water through a 4-mm screen. Root dry weight per RIC was then recorded after oven drying at 85°C for 48 h. Effect of sugars on root dry weight was determined using analyses of variance (ANOVA) for each species individually following appropriate checks for homoscedasticity (Anderson-Darling test). Differences between control and treatment means for each species were separated by the Least Significance Difference (LSD) at the 95% confidence level ($P>0.05$) using the Genstat for Windows 2000 program.

RESULTS AND DISCUSSION

Soil injections of sucrose increased fine root growth of all four test species 5 months after application compared with water-injected controls. In some cases, however, root growth increases were not significant (Table 2), i.e., applications of sucrose at 25 $g \cdot L^{-1}$ of water — where root dry weight was higher, but not significantly so, than control trees. This indicates injections greater than this concentration are required to significantly increase fine root growth of established English oak, silver lime, field maple, and ornamental apple. Applications of sucrose equal to or greater than 50 $g \cdot L^{-1}$ of water significantly increased, in the majority of cases, root dry weight of all tree species (Table 2). Reasons for improved root growth following sucrose application include the fact that the process of recovery following root damage is dependent on the ability of a tree to manufacture abundant sugars such as sucrose (Lonsdale, 2001). As carbohydrates function as a direct substrate for growth, then an abundance of sugars at and around the root zone is available for immediate use (Salisbury and Ross, 1985). In addition, work by Koch (1996) has shown that in plants, sugars such as sucrose affect sugar sensing-systems that initiate changes in gene expression and subsequent plant growth (Koch, 1996). Sucrose depletion, for example, upregulates genes for photosynthesis, carbon remobilisation, and export resulting in shoot growth. In contrast, incubation of root systems in sucrose solutions leads to the repression of photosynthetic genes, decreased rates of net photosynthesis, and carbon remobilisation in favour of enhanced root development. Finally, soil applications of sugars have been shown to stimulate changes in populations of naturally occurring soil microbes and fungi around the roots resulting in alterations to plant nutrient uptake patterns and growth (Finnie and Van Staden, 1985; Martinez-Trinidad et al., 2009). Use of sucrose as a direct substrate for root growth coupled with alterations in gene expression and microbial-plant interactions may account for increased root growth recorded in this investigation.

CONCLUSION

Applications of sucrose via a soil injection system should be considered to stimulate fine root development of established trees which in turn should improve water and nutrient absorption following construction damage and aid in their recovery (Percival, 2003). This is an area worthy of consideration given the fact that sugars are water soluble, nontoxic, environmentally safe, and inexpensive to purchase.

The nursery industry might also consider trials on the potential benefits of sucrose treatments pre-lifting or pre-despatch of trees and shrubs intended for landscape planting, especially of those species known to be sensitive to transplant stress or intended for planting where soil damage may be expected.

REGIONAL EDITOR'S NOTE

The conference discussion following this paper also raised the possible link between the results presented and the use of high-sugar substances such as honey as practiced by growers in some IPPS regions to aid rooting in difficult-to-root cuttings.

Table 1. Growth and soil characteristics of experimental trees and their location.

	Quercus robur (n = 4)	*Tilia tomentosa* (n = 8)	*Acer campestre* (n = 6)	*Malus floribunda* (n = 4)
Girth (cm)	207 ± 20.1	40.5 ± 4.3	30 ± 4.8	28.3 ± 3.66
Height (m)	7.10 ± 0.80	6.9 ± 1.1	4.2 ± 0.3	5.1 ± 0.62
Soil				
pH	6.7 ± 0.6	6.9 ± 0.7	7.1 ± 0.6	6.3 ± 0.8
Potassium (mg·L^{-1})	60.3 ± 5.33	59.8 ± 7.55	50.4 ± 10.30	63.7 ± 9.76
Phosphorous (mg·L^{-1})	395.0 ± 35.52	434.2 ± 38.27	576.7 ± 70.34	404.0 ± 36.54
Organic matter (%)	4.0 ± 0.03	5.1 ± 0.05	4.7 ± 0.09	4.6 ± 0.07
Magnesium (mg·L^{-1})	266.2 ± 32.54	285.9 ± 40.20	225.8 ± 21.66	229.8 ± 21.35
Calcium (mg·L^{-1})	1830.1 ± 189.2	2511.3 ± 114.60	3134.5 ± 379.05	1971.4 ± 126.92
Sodium (mg·L^{-1})	60.5 ± 7.36	70.5 ± 8.21	52.6 ± 3.98	49.9 ± 7.82
Type	clay	sandy loam	clay loam	clay loam

Girth and height values are the mean of n trees. Soil nutrient values are the mean of 5 soil analysis per tree. ± = standard deviation of the mean. All soil nutrient values refer to available, i.e., extractable soil nutrients.

Table 2. Mean fine root dry weights, expressed in grams per cubic metre of soil at month 6 after treatment.

	Species			
Treatment	*Quercus robur* (n = 4)	*Tilia tomentosa* (n = 8)	*Acer campestre* (n = 6)	*Malus floribunda* (n = 4)
Water control	0.28	0.22	0.13	0.10
Sucrose 25 g·L^{-1}	0.33ns	0.30ns	0.18ns	0.09ns
Sucrose 50 g·L^{-1}	0.93*	0.78*	0.22ns	0.29*
Sucrose 70 g·L^{-1}	0.45*	0.80*	0.38*	0.17ns

Note: ns = not significant, * = $P<0.05$ – significant from control value.

Fine root dry weights are mean of n trees, 6 RICs per tree.

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Water Storage and Conservation on Nurseries: The SEEDA Water Champion Project©

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INTRODUCTION

Water is a valuable resource which will become scarcer in south east England with changes in climate and increased pressure from population, housing development, and industry. The U.K. Environment Agency is therefore promoting alternatives to using clean mains water or abstracting from aquifers and rivers. Nurseries have a unique opportunity to recycle or capture their own water and to become self sufficient.

For nurseries currently relying on mains supply there are significant financial drivers and rapid payback periods on investment in water capture, storage, and recycling. For those using boreholes the drivers are water quality and crop benefits. In both cases, investment will also help growers to stay ahead of legislative developments. For example, closed irrigation systems help prevent nitrate release into ground waters.

In 2010 the South East England Development Agency (SEEDA) appointed the author to undertake the role of "water champion," funded by the Environment Agency. The aim of the role was to look at the future of water for horticulture in the U.K., assess the impact of irrigation water use on future supplies, and to see whether there are better ways in which water can be sourced and used by growers and what reductions in use can be gained by changing application methods.

This research included a number of case studies of nurseries which have already made significant investments in water capture and recycling, some of which are presented here. Each has seen good savings in water used and in many cases significant improvement in crops, particularly through reduced disease incidence.

There is a wide range of ways to clean water once it is harvested before application or re-application to the crop. Many work well but it would seem that with an environmentally sound concept such as water harvesting we should seek out biological systems wherever possible. A survey of these is included in the full project report, available from the author, along with a review of how a new water capture and recycling system was installed and demonstrated at Lowaters Nursery in 2010.

CASE STUDIES

Allensmore Nurseries, Worcestershire. Capillary beds have been built using a simple, easy to maintain capillary mat (Florimat 2). Each bed slopes towards a central drain point and water is applied to the top of the slope via a seep pipe which produces a pulse of water passing down the matting. The height difference from the edge of the bed to the drain point is 30 cm (the beds are double, 25.6 m across in total). These beds are used effectively for pots of up to 7.5 L. Water from the beds is channelled into a ditch with a gravel base which acts as a biological filter and drawn out through a pipe at the base — if the water greens then calcified sea weed is added to clear this.

From the ditch the water passes into a storage reservoir and is oxygenated on the way in using a pump fitted with a venturi and two pipes circulating oxygenated water into the base of the reservoir.

Barcham Trees, Cambridgshire. This large container tree grower was totally dependant on mains water but cost drove it to review its system. In 1994 it started to consult with its local water board about building a reservoir. The nursery had an area of 4.5 ha, which had been designated for water storage but to avoid the need for civil engineering planning consent, two reservoirs of 36,000 m^3 were constructed and lined using on-site clay.

The reservoirs are filled from a neighbouring dyke and the company has a license to collect water from October to the end of April. The water is checked annually once the reservoir is filled in May for *Pythium* and *Phytophthora* and the water chlorinated (1 ppm) — this has proven to be successful in removing all spores. Water is drawn from the reservoir as required and passed through a fast sand filter and then into the nursery irrigation system.

This project has freed the nursery from mains usage — though there is a back-up facility in place to use mains water if required. The project had a 3-year payback period and received grant funding of 30% for one of the reservoirs.

Boningale Nurseries, Worcestershire. Boningale has installed an area of capillary bed using Florimat 2 matting. The site is on a gentle slope so to overcome this, the matting is laid only on the used bed area where the plants are grown, not on the pathways. The mat has a strong enough hold on the water that none is seen to flow out. The beds have been constructed using a thick layer of plastic liner, a layer of Florimat 2, and woven geotextile as the cover. Irrigation water is applied via seep hoses while the overhead pin-jets have been kept to provide overhead irrigation to periodically flush any accumulated salts back through the compost.

Plants such as hebe, which are very water sensitive, are being grown on the beds and the foliage looks healthy. Since installing the new area no issues have been noticed other than the growers becoming accustomed to using significantly less water on the crops — to start with the same amount of water was applied as through the overhead system but this over-wetted the crop: a balance has now been found. All water on the site is from a borehole with a very high alkalinity, it was felt that in time this may block up the matting and mixing with collected rainwater would offer long-term benefits.

Hillier Nurseries, Romsey, Hampshire. Hillier Nurseries embarked on a water recycling and rainwater harvesting project in 1994 to improve its security of supply, reduce costs, and reduce its environmental impact.

The nursery had a summer surface abstraction license for the local river, although this alone would not have been sufficient so a storage, recycling, and treatment system was designed with help from consultant and IPPS member John Adlam. There was space for a 16-million-L reservoir and water usage models for the nursery, coupled with local rainfall information demonstrated that this would be sufficient in most years. The maximum nursery use is 1.4 million L per day and the design allowed for 450,000 L per day of nursery run off to be collected and 450,000 L per day of abstraction.

If no further water is collected then the reservoir has a storage capacity at peak use of 1 month. If this exceeded then mains water is used temporarily to maintain supply (the reservoir is never allowed to go totally empty so that there is an emergency store maintained in case of mains problems). The annual water bill was £70,000 to 80,000 compared with a project cost of £120,000.

All water that falls onto the nursery is routed into open block-built channels which work with the natural gradient of the site to feed back to the reservoir which is at the lowest point. Built into the system is a trash separator and silt trap to prevent debris from reaching the main storage reservoir. The reservoir is lined with low density polythene and has an overflow that runs into a stream via a small holding pool.

Water is drawn from the reservoir through a self cleaning centrifugal pump which separates out debris and then goes through a sand separator. To prevent disease the water is chlorinated at 5 ppm. The water then passes through three in-line high-pressure sand filters. Pumping to the nursery is via two pumps, one variable speed and one fixed speed, to deliver a wide range of different pressures and keep the system pressurised over the large site even when water demand is very low. There are various sensor and fail-safe mechanisms built in so that in the event of the cleaning system breaking down it will automatically switch to mains supply.

The water is regularly tested and no pathogens have been found in the water post cleaning. The chlorine appears to break down on its way through the sand filters and no build up has been seen on the nursery or in the recycled water. The water has also been tested for build-up of EC and herbicides and none detected. Nursery records show that between 40% and 60% of the water applied annually is recycled.

To enable the water to be properly used and channelled, nursery beds have been re-laid with a plastic lining to feed all run off to central collection. These are plastic laid direct onto levelled soil with geotextile covering. Irrigation is by sprinklers placed round the bed edges to give even distribution and avoid dry spots.

John Richards Nursery, Malvern, Worcestershire. The nursery is on a site which has always been short of space and with limited water availability, initially from a single small mains pipe. Even after a second pipe was installed capacity was soon overtaken by demand.

In 1985 a closed system was installed to catch and recycle all run-off. This recaptured 30% of the water applied and this water was being reused within an hour. The water was cleaned by means of a fast sand filter, then chlorination and acid dosing to amend the pH levels.

In 2005 a new system was put in place including a lagoon at the lowest point into which all run-off (except from lorry and car park areas) was fed. Water from the lagoon is circulated through a reed bed to remove chemical impurities and then stored in a 23-million-L puddle-clay reservoir — close to a year's water requirement for the nursery. From here it is pumped through a fast sand filter, then a mesh filter and finally a bag filter before it is fed through an iris bed with a capacity of 13 $m^3 \cdot h^{-1}$. Trials using a slow sand filter showed that on this site it blocked in a matter of hours because of the amount of suspended clay particles in the water. The clean water is stored ready for use in a 205,000-L tank inside a barn and kept oxygenated.

This system is producing what nursery owner Richards describes as biologically active water which is clean, free from pathogens, and has shown itself to be well suited to the crops on the nursery. The iris bed has been shown to reduce levels of filamentous fungi and bacteria as well as reducing the bicarbonate concentration and pH — water analysis is showing similar results to those expected from a fully operational sand filter.

Richards says that aeration to maintain aerobic conditions for beneficial organisms in the water is key to the process and air is incorporated at every possible point in the system. The size of the main reservoir was also felt to be a key part of the water cleaning process as its population of beneficial microbes and invertebrates will consume pathogenic resting spores while the time spent in the water will be long enough to kill the motile zoospores of pathogens through UV action.

The lagoon is kept quite empty to ensure it has enough capacity to cope with heavy rain. The reed bed is a large butyl lined pond with *Phragmites australis* planted on gravel banks with patches of clear water between to reduce the risk of sediment blocking water flow.

The iris bed is a 10 m × 10 m sloping area with a sequence of tiered butyl-lined channels 60 cm wide at the top, 60 cm deep and 30 cm wide at the bottom. The iris were sown into compost in polystyrene trays which float on the water in these channels. The trays have holes through which the roots pass to form a curtain in the water,. The water is cleaned as it flows past the roots. A three-stage mechanical filtration system is used to ensure that no particles of debris reach the iris bed.

Lansens Nursery Spalding, Lincolnshire. The nursery was established in the late 1990s by a Dutch grower to produce perennials and shrubs on 4.8 ha outside and under 5000 m^2 Venlo glass. The entire site uses ebb and flood floors, built in two phases.

The first phase of beds are in units of 250 m^2 with the ground levelled and the stones removed, the soil was then fine-levelled to slope each side at exactly 2% towards four central feed and drain points. A medium weight-butyl liner was then installed and covered in geo-textile. The edges are built up using a special 10 cm × 10 cm polystyrene-block system to give the flood depth — these are pinned in place with scaffold poles. The second phase has 350-m^2 beds with a central drain protected by a metal grid covering.

The first phase beds are much less prone to leakage even though it is much harder to seal the four inlets. To prevent the butyl liners lifting in high winds the irrigation computer is linked to the weather station so that those beds most exposed to the wind can be flooded. To avoid freezing all water pipes are 80 cm deep, and by using compressed air instead of conventional solenoids the valves are kept free of water and are actively drained by the constant air pressure so don't need draining down in winter. This is based on the systems used in fire sprinkler systems in large buildings.

The ebb-and-flood beds use 85% less water than a well designed overhead sprinkler system would for the same area and crops. The construction cost was £15/m^2 and the butyl liner is guaranteed for 15 years, though should last longer, and the geo-textile is being replaced after 10 years.

Water is moved around the system using a high-volume low-pressure pump. The system is operated using two tanks each containing 15,000 L — small enough that in the event of a problem they can be wasted and refilled –– each with a different nutrient solution so that two different liquid-feed regimes can be applied to any of the 107 bed areas. A Brinkman computer monitors and tests all water being applied and it is checked for EC and pH four times in the process of application — if any one of these falls outside the set parameters the system will stop and issue a warning.

The longest stretch for water to travel on the nursery is 25 min and beds are irrigated in groups of five so that as the water drains from the first the last is beginning to fill. It takes 6 min to fill a bed to 6 cm.

Once used the water passes in to a 50-cm-diameter drain pipe into a sump and then through a sieve filter fine enough to remove all weed seeds and is then sent by the computer back to the appropriate feed tank or, if it is rain draining from the bed, into the 2-million-L capacity holding tanks.

Though there is no anti-fungal treatment neither *Phytophthora* nor *Pythium* have been a problem to date.

The system is simple and has low running costs once established. It delivers water and nutrient accurately to a wide range of crops.

Experiences in Development of Green Compost as a Peat Replacement Material©

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In the U.K. it is government policy to replace the use of peat as a constituent of growing media and soil conditioners with other, preferably renewable, materials. There have been three types of barrier to peat replacement: technical, commercial, and psychological. Over the last decade the technical and commercial barriers have become far less significant, but misunderstanding and bad memories, aggravated by vested interests, still frustrate acceptance.

Although green compost, derived from garden waste collected by local authorities, is too nutrient rich to be used as the main component of growing media, improvements in quality, availability, and understanding have recently led to significant use of the material. Indeed, its nutrient content can replace some fertiliser additives and thus reduce manufacturing cost. Being high in woody material, it has high structural stability and is rich in beneficial microorganisms, notably bacteria and fungi, which suppress plant diseases and enhance nutrient availability. Its high humus content binds and buffers nutrients and holds water.

Green compost can be screened to different size grades. The 10–0 mm fraction is most commonly used in growing media but other grades may be used where different air : water balance or a different nutrient content (coarser fractions contain less nutrients) is required.

Green compost is now very plentiful and production standards (UK PAS 100) have been developed. However not all PAS 100 green compost is suitable for growing media. The most common quality issues are contamination (glass, plastic, and wind-blown weed seeds), maturity, and high bulk density (due to high moisture content). Contamination problems can be addressed with in-vessel composting but capital cost is significantly higher than an outdoor windrowing operation.

Vital Earth is believed to be a unique company in the U.K. composting industry as it composts in small (40 m^3) closed vessels, followed by indoor aerated static piles, ensuring thorough sanitisation and maturation. After size-grading, the compost is used as the basis — and main nutrient source — of peat-free growing media for hobby gardeners and professional users.

High pH has long been thought to be a barrier to use of green compost in growing media. However, experience has shown that this is a fallacy. Green compost behaves like an organic soil and "peat chemistry" is unlike soil chemistry in having a uniquely low optimal pH for exchange of cations ($K+$, NH_4+, $Mg+$, etc.). Trials with green-compost-based media have produced excellent ericaceous crops at pH values of 7 and more.

Dilution of green compost with composted conifer bark lowers pH adequately for most crops. It also reduces bulk density and nutrient levels and can be used to adjust air-filled porosity and water-holding capacity. In the case of ericaceous compost, humite (rich in humic acids) is added to lower pH further and to buffer pH. Humates have a high cation exchange capacity and also help to hold water.

Figure 1. Vital Earth is developing extended shelf-life, low density media for bedding. Front-right treatment is leading peat product; others are Vital Earth.

In any composting operation, some nitrogen is lost during processing and, if the N is not replaced efficiently, N lock-up can occur during storage and/or use. Until recently, N lock-up was a major barrier to performance — and thus acceptance — of peat-free growing media. At Vital Earth we believe we have solved the problem using an organic byproduct of U.K. food processing. Storage life of Vital Earth growing media exceeds 2 years and the products "starve out" more slowly than conventional peat products.

Apart from bark, other diluents — coir, woodfibre, composted wood wastes, and soil — can be used with or without green compost, to replace peat, as can processed minerals such as perlite, vermiculite, clay granules, and rockwool. However, to maintain a minimum carbon footprint, Vital Earth avoids the use of such "high energy" imported minerals and prefers to use recycled U.K. substrates that are relatively abundant, cost-effective, and have both appropriate appearance and handling properties.

Ten years of trialling have shown that growing media based on green compost and bark have some surprising performance benefits:

- Starvation is delayed, so feeding is less urgent and overwintered container nursery stock holds its saleable condition better (due to slow-release of organic nutrients).
- Liverwort is virtually non-existent and weeds are greatly reduced (due to surface drying effect).
- Risk of some diseases (especially leaf spots) is reduced.
- Internodes are shortened slightly in many subjects, notably bedding plants, where use of chemical dwarfing agents can often be eliminated.

Figure 2. Growing media based on green compost/bark (right) can reduce some plant diseases [e.g., leaf spots (left)] and shorten internodes slightly as shown on these ivy plants (Trial at Starplants).

- Growers undertaking trials report that overall water consumption is reduced. The irrigation pattern often needs to be modified to apply more frequent but smaller bursts because water-holding capacity is lower than in most peat media.
- The high humate content provides a unique binding action as the rootball dries out which is potentially beneficial in automatic plant handling.

Green compost is gaining significant use in other areas such as a planting medium for green roofing; production of field crops (edible and ornamental) and in landscaping, reclamation, and amelioration of soil erosion.

In field crops, the nutrient contribution of green compost has been appreciated better since the marked escalation of world-wide fertiliser prices, as well as its contribution to disease-suppression, soil structure, and overall fertility. Use of green compost to PAS 100 standard in organic food crop production has shown especially marked growth in recent years.

In landscaping, green compost has already displaced peat in root zone mixes and top dressings, topsoil manufacture, tree and shrub planting composts, and general soil improvement: a trend helped by U.S.A. experience of disease suppression on golf greens and other intensively managed turf.

In green roofing, green compost plays a crucial role in providing slow-release nutrients, water-retention and a healthy root environment in the face of conditions fluctuating from extreme drought to torrential rain or deep snow cover.

Figure 3. Composting in vessels destroys weeds/seeds and diseases (biofilter bed in foreground "scrubs" the vapour as it leaves the vessel). The green compost is then matured indoors with further aeration and temperature monitoring, then screened prior to further maturation and testing before blending.

FUTURE DEVELOPMENT

Having reduced normal bulk density of green compost from 600 $g \cdot L^{-1}$ to 450 $g \cdot L^{-1}$, Vital Earth is developing an "extra light" compost to challenge peat in sectors such as bedding where low crop weight is particularly desirable. Further extension of crop shelf-life is also being researched, as is flavour enhancement for fruit and vegetable crops and further suppression of pests and diseases.

In summary, most of the barriers of 10 years ago have been broken down. Green compost and other peat alternatives are proven and in wide-scale use. Such is the rate of progress that the National Trust, which reported a year ago that they could not source an adequate volume, or range, of peat-free container nursery stock are now delighted with both, grown by Boultons of Moddershall who, after 5 years trialing with Vital Earth, are now producing nursery stock 100% peat-free.

Availability of green compost is not an issue but the quality of some sources will need to be refined. By contrast, availability of bark and other diluents is cited by some sources as a constraint to peat replacement.

The key remaining barrier is psychological: bad memories of poor quality compost, supported by "peat dogmas" and industry inertia.

Creation of a Nursery for Oman's New Botanic Garden©

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INTRODUCTION

Established by royal decree in 2006 and currently under construction, the Oman Botanic Garden (OBG) will be a new and iconic botanic garden in the Sultanate of Oman. The mission of the Sultanate is "to conserve the unique botanical and ethnobotanical heritage of Oman and to ensure that its flora, heritage, and ecosystems are valued by all" and this will be achieved through the construction of a botanic garden aspiring to be world renowned in terms of its living collections, science, conservation work, and education programmes.

The 423-ha site lies near the village of Al Khoud in the north of Oman. It is beautiful, bordered by low hills, crossed by seasonal wadis, and with a healthy population of small trees such as *Acacia* and *Ziziphus* species. Oman Botanic Garden will only cultivate native plant species and the garden has the unique aim of propagating the complete indigenous flora of Oman (1,200 plant species including 78 endemics) and displaying it within seven defined major habitat zones. Two of these zones (the plants of the northern and southern mountains) will be housed in climate-controlled display greenhouses or "biomes" similar to those at the Eden Project in Cornwall, U.K.; the rest (central fog desert, northern gravel desert, sabkha, sand desert, and wadi) being irrigated habitat landscapes in the open.

The Flora of Arabia is a core taxonomic research project at the Royal Botanic Garden Edinburgh (RBGE) and for over 20 years this research has been led by botanist Tony Miller who is one of the world's experts on Arabian flora. Royal Botanic Garden, Edinburgh, is contracted to provide the botanical and horticultural expertise for the project (Morris, 2009) and because of his background in nursery production and training, over the last 4 years Leigh Morris has spent a significant amount of his time working in Oman as a consultant focusing on the design, construction, and operation of a new state-of-the-art nursery, which is growing all the plants for the project.

NURSERY DESIGN AND CONSTRUCTION

One of the key horticultural challenges facing OBG is growing approximately 400,000 Omani plants required to landscape the habitats and amenity areas. To start the propagation process, space was initially rented in local nurseries (which grow exotic plants for the amenity and retail market) to commence plant production (Patzelt et al., 2009). Three small polythene tunnels and some shaded standing area became the first OBG nursery. The decision was then made early in the project to construct a much larger nursery on the OBG site to produce the majority of the plants required. Royal Botanic Garden, Edinburgh, was fundamentally involved in producing the nursery design, which was then constructed in 2008 by the British company Cambridge-HOK.

Figure 1. The newly constructed nursery at the Oman Botanic Garden (OBG). The car park, office block, and compost bays are in the foreground, followed by the glasshouses, polythene tunnels, shade house, and hard standing area. Some of the 423-ha OBG site is in the background.

This state-of-the-art nursery (Fig. 1) consists of 0.75 ha of glass, 0.5 ha of polythene tunnels, 0.4-ha shade house, outside standing areas, an air-conditioned potting and propagation building, storage areas, and an administration/office block. A fully computerised (Hoogendoorn: <www.hoogendoorn-automation.com> climate control system is in place and greenhouse cooling is carried out by pad and fan evaporative systems. Oman Botanic Garden staff moved into the new nursery in July 2008 and it was officially opened on 15 Dec. 2008.

STAFF DEVELOPMENT

German botanist Annette Patzelt has been working in Oman for around 10 years and is leading OBG's botanical and horticultural development. A key challenge for Patzelt was the creation and training of a botanical and horticultural "Green Team" to grow and maintain the plants of the garden. The OBG nursery staff team is all Omani, the supervisors are horticultural graduates (BSc and MSc) from the Sultan Quabos University in Muscat, with their degrees being predominantly focused on commercial crops, but the general workers (nursery assistants) had no previous horticultural experience.

A key part of RBGE's work at OBG has been training and capacity building within the Omani team. In December 2006 Peter Brownless, the nursery supervisor at RBGE, accompanied Leigh Morris to Muscat in order to deliver an initial 2-week intensive training programme in nursery propagation, production, and integrated pest management techniques. The training was extremely well received, nursery

Figure 2. Some of Oman Botanic Garden's nursery horticultural assistants during the RBGE Certificate in Practical Horticulture training on potting and growing media.

production progressed and by early 2008 there were 51,851 individual plants in the nursery, consisting of 346 species from 68 different families (29% of the country's flora), already representing the largest documented Arabian plant collection (Patzelt et al., 2008).

A number of RBGE staff have since been to Oman to deliver training in various topics ranging from plant quarantine to plant records and creation and use of databases. The formal RBGE Certificate in Practical Horticulture has been delivered to 16 of the OBG team (Fig. 2) and some of the supervisors will subsequently teach the course in Arabic to the horticultural assistants.

A specific focus has been given to the development of the Omani horticultural graduates who have now taken control of the organisation of work schedules and meetings, procurement of materials, and staff management. A programme is also in place for them to visit other countries and institutions and three have already spent time in the U.K., predominantly at RBGE, but also visiting a range of U.K. gardens and nurseries. Membership and engagement with the IPPS is also proving very useful to the OBG nursery team. The assistant propagation supervisor, Hanan Moqbali, is a horticultural graduate of Sultan Qaboos University in Muscat, Oman, and she joined the OBG team as a horticulture expert in 2009. Hanan (hanan.obg@gmail.com) attended the IPPS conference in Ipswich in September 2010 and the plan is that others from OBG will attend and present at future IPPS events.

PLANT COLLECTION AND PROPAGATION

Propagation of the plants required has been the main horticultural focus for the OBG team during the first 4 years of the project (Patzelt et al., 2008). Only Omani

Figure 3. RBGE BSc horticulture with plantsmanship students Will Ritchie (left) and David Tyler, assessing germination rates in the seed viability testing at Oman Botanic Garden (OBG). Ritchie and Tyler carried out tests on a wide range of annuals and perennials as part of their 2-month internship at OBG in August/September 2009.

plants are being cultivated, with all propagation material being wild collected from across the whole of Oman by Patzelt's team, supported by RBGE staff. Most of the propagation material collected is seed to ensure a wide diversity within each habitat. Cuttings are taken for some species if seed is difficult to obtain, but in those cases a large number of mother plants are used. Seed collection was relatively straight forward, but the collection of cuttings in such a hot climate was more challenging and protocols had to be developed involving the use of cool boxes and ice packs.

Very few (<5%) of the Oman plant species were in any form of cultivation prior to the start of the project, which meant there was little or no knowledge on how to propagate and grow them. The OBG team, led by propagation supervisor (and IPPS member), Ismail Al-Rashdi, with assistance from RBGE staff, has therefore had to start developing plant propagation protocols for all the approximately 1200 Omani plant species. To achieve this, a huge amount of experimentation is being carried out in areas such as seed germination and dormancy breaking (Fig. 3).

Ismail Al Rashdi and Hanan Moqbali are recording and collating all the propagation data in respect to seed collection dates, pre-treatments (e.g., stratification or soaking), sowing rates, use of germination cabinets, viability, media type, and hormone usage.

Figure 4. Oman Botanic Garden nursery production supervisor, Khalid Al Farsi, checking the drip tubes on outdoor stock.

PLANT PRODUCTION

Khalid Al-Farsi (Fig. 4) is OBG's nursery production supervisor. Khalid, like Ismail Al Rashdi, has a master's degree in horticulture from Sultan Qaboos University, and he also gained experience in plant cultivation on his family farm before working at OBG. The aim for Khalid and his plant production team is to produce plants of a relatively mature size for planting in scheduled batches over the next 3 to 4 years, so that the garden appears established at the time of opening in 2014. An initial OBG plant production list was drafted by Morris and then much work has been done over the last 2 years by Patzelt on developing it into an extremely detailed and comprehensive document.

The OBG nursery is now growing plants solely for the planting up of the seven habitats and the various landscaped areas within the garden. However, the nursery is being run in a way that many commercial growers would recognise: the gardens are being treated as a "customer" who has placed a production order and the nursery is scheduling its production to coincide with the planting dates of the different locations within OBG. Oman Botanic Garden is quite different from other botanic gardens around the world as it is growing all the plants for the complete planting of such a large area itself. In effect it is growing commercial quantities of botanically interesting and challenging plants.

The plants being grown in the nursery are all used to the relatively harsh Omani climates and so when provided with good growing media, fertiliser, a plentiful supply of water, and a greenhouse environment, many of them start to grow extremely quickly (Fig. 5). One of the challenges has been to grow the plants quicker than they would grow naturally, but without making them too soft, lush, and unnatu-

Figure 5. Some of the c.80,000 plants currently in the nursery at Oman Botanic Garden. Many, but not all, Omani plant species thrived in this environment.

rally leggy. Khalid's team is therefore required to balance the feed and water, and manipulate plants by other horticultural techniques such as pruning in order to reproduce strong, natural-looking plants with variation in their sizes.

IRRIGATION

A fundamentally important aspect of building a nursery and botanic garden in a desert environment is the supply of water for irrigation. At OBG two wells have already been dug and there will be five more drilled over the next 2 years. However, this ground water needs to be treated and de-salinated before it can be used on plants and until the reverse osmosis equipment is in operation, all water is currently being brought onto the site in tanker trucks. Ideally recycled water from the local town would be used, supplemented with water from the wells, and this is currently being worked on. Water conservation is paramount at OBG and the nursery has been designed to collect and recycle all irrigation water and the waste water from the wider project (cafes, toilets, etc.) will be cleaned in reed beds and re-used for irrigation in the landscapes.

In terms of nursery irrigation systems; drip tubes are used on the larger nursery plants (and within the landscape habitat plantings), but there are also overhead sprinklers in the greenhouses (as much for cooling as actual irrigation) and capillary benches.

Figure 6. Oman Botanic Garden's plant health coordinator Shadia Al-Rijeiby (left), monitoring succulent plants in a polythene tunnel with Ismail Al Belushi, one of her crop protection team.

EQUIPMENT AND MATERIALS

There are horticultural suppliers and wholesalers in Muscat, but the range of nursery products they hold within their stock is quite limited. Therefore the majority of supplies for the nursery such as pots, growing media, fertilisers, propagation trays, as well as nursery machinery, have to be imported from Europe. Over the last 3 years OBG has brought in materials such as controlled-release fertilisers, liquid feeds, ingredients for growing media, and machinery such as compost mixers, compact tractors, nursery trailers, hose trolleys, and an industrial pot washer.

PESTS AND DISEASES

Initially there were very few pest and disease issues. As expected, however, as time went on they started to appear. Many of the major problems are the same as encountered in many nurseries; red spider mite, thrips, mealy bug, nematodes, vine weevil, *Pythium* spp., and mildews.

Shadia Al-Rijeiby is OBG's plant health coordinator (Fig. 6). Shadia was also a horticultural graduate of Sultan Qaboos University and then spent time working in a vegetable farm before arriving at OBG. Shadia is implementing OBG's integrated pest management programme. Monitoring the crops regularly is a key strategy and as well as carrying out daily walks of the nursery herself, Shadia is also training the wider horticulture team in monitoring techniques — visual pest identification sheets have been produced to assist with this. Some pesticides are currently being used in the nursery, but these are kept to a minimum and the aim within the wider gardens and biomes is to adopt a non-pesticide regime.

MATURE PLANT COLLECTION

The majority of the plants required for the OBG habitats are being propagated in the nursery. However, in order to provide a sense of maturity within the biomes, some mature trees are being collected from the wild (Patzelt et al., 2009). This is being carried out as sustainably as possible and in accordance with the OBG collections policy, which stipulates that whole plants must only be collected from areas that are, for example, already scheduled to be damaged or destroyed by development projects such as roads or building construction).

To facilitate this work a team from RBGE has developed protocols for tree translocation to OBG, trained OBG staff in the methods of tree translocation, and carried out initial tree translocation work. Accompanied by Saif Al-Hatmi (OBG's ethnobotanist), Khalid Al-Farsi, and a team of OBG horticultural assistants, two specific regions were targeted:

Jabal Al Sarah (in the northern Hajar Mountains) on a site destined to become farm land, the initial preparation (i.e., root pruning and crown thinning) was carried out for the translocation of specimens of *Juniperus excelsa* subsp. *polycarpos*, in advance of lifting them next year for the northern biome.

Mountains of the Dhofar, where Saif had arranged for us to link up with a current road construction project. One of the key framework species for OBG's three southern biomes is *Anogeissus dhofaricus* and more than 20 mature specimens have now been collected and are currently being held at Royal Farm in Salalah, prior to re-location to OBG.

THE FUTURE

OBG is set to open in around 2014 (the date is still to be confirmed) and once the growing of the plants for the garden is complete, the nursery will be able to take on other roles. These could include continued cultivation of plants for planting into the collections — new accessions or replacements for plant deaths; production of plants for sale in the retail outlet at OBG; and growing of plants for conservation projects within Oman.

Another aim for OBG is to promote the use of indigenous plants for landscaping projects. The information being gathered on plant propagation and production, as well as the subsequent knowledge that will be acquired from the actual growing of the plants in the garden, will be extremely valuable in encouraging more people to grow native plants. The aim is to eventually publish guidelines from OBG on the cultivation of Omani plants.

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TECHNICAL SESSIONS

SOUTHERN REGION OF NORTH AMERICA

Thirty-Fifth Annual Meeting

October 9–13, 2010

RALEIGH, NORTH CAROLINA

TECHNICAL SESSIONS©

MONDAY MORNING, 11 OCTOBER, 2010

The 35th Annual Meeting of the International Plant Propagators' Society-Southern Region of North America convened at 7:45 $am at the Sheraton Raleigh Hotel with President Rick Crowder presiding.

PRESIDENT RICK CROWDER

President Crowder welcomed everyone to Raleigh, North Carolina for the 35th Annual Meeting of the International Plant Propagators' Society-Southern Region of North America. He thanked Local Site Committee Chair, Tony Avent, and Co-chair Lanny Thomas, and their committee for the long hours in arranging the excellent tours, hotel, other planning activities and all their attention to detail. He thanked the Executive Committee and Bob Black's Sponsorship Committee, which raised around $39,500 in donations. He 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, Dr. Donna Fare, for the excellent program and slate of speakers she assembled.

PROGRAM CHAIR DR. DONNA FARE

Program Chair Donna Fare welcomed all members, guests and students. She thanked the membership for the opportunity to serve them, and then reviewed the scheduled program, including the silent and live auction, new comer's reception and banquet. The Question Box was scheduled for Tuesday evening to be co-chaired by Dr. Cheryl Boyer and Brian Upchurch. Moderator Scott Langlois then introduced the first speaker, Dr. Sandy Reed.

Breeding and Propagating Oakleaf Hydrangeas

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INTRODUCTION

Oakleaf hydrangea (*Hydrangea quercifolia* Bartr.) is an ornamental shrub that is native to the southeastern U.S.A. (McClintock, 1957). Most plants grow 2 m (6 ft) or taller in height with an equal to wider spread (Dirr, 2004), but two compact selections ('Pee Wee' and 'Sike's Dwarf') are commonly available in the trade. Both reach approximately 1 to 1.2 m (3 to 4 ft) in height and width at maturity, but lack some of the ornamental traits found among the more attractive standard-sized oakleaf hydrangea cultivars. The oakleaf hydrangea breeding program at the U.S. National Arboretum's worksite in McMinnville, Tennessee, was started in 1996 for the purpose of developing attractive, compact oakleaf hydrangea cultivars suitable for use in small residential gardens. During the course of this breeding project, we have gained experience in both seed and cutting propagation of oakleaf hydrangea. This report describes the development of two new compact cultivars of oakleaf hydrangea along with techniques used for propagating the species from both seeds and cuttings.

BREEDING

'Ruby Slippers'. Controlled hybridizations were made in 1998 between *H. quercifolia* 'Flemygea', Snow Queen™ oakleaf hydrangea and 'Pee Wee'. While most of the F_1 progeny had the upright, full inflorescences of Snow Queen™ oakleaf hydrangea, none had a compact growth habit. In 2001, ten of the most attractive Snow Queen™ oakleaf hydrangea × 'Pee Wee' progeny were intercrossed, using bulked pollen from the 10 selections. A seedling from this second-generation population was selected in 2004 for further evaluation. In 2006, plants of this selection were sent for evaluation to nursery and university cooperators. The selection, which was released in 2010 under the name 'Ruby Slippers', grew to 1.1 m (3.5 ft) high and 1.5 m (5 ft) wide after 7 years of growth in McMinnville, Tennessee (Fig. 1). It produces inflorescences up to 25 cm (10 in.) in length and 10 cm (4 in.) in diameter that are held above the foliage. At full flower, the exterior surface of the inflorescence is almost completely covered by large, showy sepals. Flowers initially open white but quickly begin to turn pink. Sepals eventually deepen into a bright rose color.

'Munchkin'. Open-pollinated seed was collected in 1997 from *H. quercifolia* 'Sike's Dwarf'. Two seedlings from this population, one with moderately compact plant habit and the other with large, upright inflorescences, were hybridized in 1999. A seedling from this second-generation population was selected in 2002 for further evaluation. In 2007, it was sent for evaluation to nursery and university cooperators. The selection, which grew to 0.9 m (3 ft) high and 1.4 m (4.5 ft) wide in 9 years of growth in McMinnville, Tennessee, was released in 2010 under the name 'Munchkin'. It produces inflorescences up to 17 cm (6.7 in.) in length and

Figure 1. 'Ruby Slippers' oakleaf hydrangea.

12 cm (4.7 in.) in diameter that are held above the foliage. The exterior surface of the inflorescence is primarily covered by large, showy sepals. Flowers open white aging to medium pink.

Availability and Additional Information. Like other woody ornamental plants released from the National Arboretum, 'Ruby Slippers' and 'Munchkin' are not patented, so may be propagated and sold freely. Plants are available from wholesale, mail-order, and a limited number of retail nurseries (source list available on request). The National Arboretum does not have plants of these cultivars available for general distribution but can supply a limited number of cuttings to nurseries wanting to propagate these plants. Images of 'Ruby Slippers' and 'Munchkin', along with additional information on these and other U.S. National Arboretum releases, can be found at <http://www.usna.usda.gov/Newintro/awards.html>.

PROPAGATION

Seed. Seed capsules are harvested in late September to mid October and, if necessary, placed in paper bags in the refrigerator for a couple of weeks to finish drying. A portable sieve shaker is used to extract and clean seeds. Seeds are then placed into small glassine bags and stored in a refrigerator until sown.

Although seeds can be sown immediately, we usually wait until just after the first of the year. Shallow seed trays are filled with a commercial seed germination medium and then a very thin layer of the same medium is sifted over the top of the trays. This layer of sifted medium provides a smooth surface for seeding, but an excess of sifted material should be avoided as it can become a hard barrier to seed germination. Seeds are sown on top of the germination medium and then placed in a greenhouse on heating mats set to 27 °C (80 °F). Seed trays are watered every 2 days by placing them into large shallow trays filled with water until thoroughly moistened. If any areas of the seed trays begin to dry out between sub-irrigations, they are lightly moistened using a misting nozzle.

Seeds usually germinate within 2 weeks. At this point, a 100 ppm water-soluble fertilizer is used in place of plain tap water when sub-irrigating seed trays. Seedlings are transplanted to 5-cm (2-in.) containers containing a commercial seedling medium when they have developed their second set of true leaves. Sub-irrigation with 100 ppm fertilizer every 2 to 3 days, depending on moisture level of medium, is continued until the next transplant. When roots have filled the containers, the plants are transplanted to 13-cm (5-in.) square containers filled with a shredded pine-bark medium amended with 7.6 $kg{\cdot}m^{-3}$ (6.4 lb/yd^3) 19-5-9 Osmocote Pro fertilizer (Scotts-Sierra Horticultural Products Co., Marysville, Ohio), 0.9 $kg{\cdot}m^{-3}$ (1.5 lb/yd^3) Micromax (Scotts-Sierra Horticultural Products Co.), 0.6 $kg{\cdot}m^{-3}$ (1.0 lb/yd^3) iron sulfate, and 0.6 $kg{\cdot}m^{-3}$ (1.0 lb/yd^3) lime. Low-volume drip stakes are used for irrigation. Plants are occasionally watered thoroughly using a hose to ensure even distribution of moisture throughout the pot. When plants begin to crowd each other on the greenhouse bench [usually at 15 to 20 cm (6 to 8 in.) in height], they are pruned backed to the 2nd or 3rd node and large, lower leaves removed; regrowth from axillary buds creates a full, sturdy plant. By early May, plants are large enough to be transplanted to #3 containers or the field.

Two problems are routinely encountered when growing oakleaf hydrangeas from seed — fungus gnats and algae. Fungus gnat populations are monitored using yellow sticky traps. Adults are controlled through spray application of appropriate insecticides throughout the greenhouse. Larval populations within the seed trays are controlled by insecticide drenches that are started at the time of seed germination. The insecticide solution is placed in the watering trays and applied in place of one of the regular watering/fertilizations. Build-up of algae on the seed trays can become a barrier to seed germination. Even though the shade cloth is kept closed on the greenhouses during germination, it is helpful to place an additional layer of shadecloth over the seed trays prior to germination. Lower light conditions slow down the development of the algae until after the seedlings have fully emerged.

Cutting. Semi-hardwood cuttings are taken in mid-July to early August. Following a quick-dip in a 4000 ppm IBA in 50% ethanol solution, cuttings are stuck into 13-cm (5-in.) square pots filled with a shredded pine-bark medium (same formula as used for seedlings, except controlled-release fertilizer used at half-rate). Cuttings are placed in a fog-filled greenhouse. Overhead mist is used to supplement the fog, but is run less often and for shorter durations than if a fogging system had not been available. Rooting usually occurs within 4 to 6 weeks.

After plants have developed sufficient root systems, they are removed from fog and overhead watered for a few days. They are then switched to low-volume drip stakes for irrigation. Plants are watered for 1 min twice a day initially. The greenhouse is maintained at approximately 24 °C (75 °F) during the day until early December when we gradually begin to lower greenhouse temperatures. By mid-January, only enough heat is added to keep greenhouse pipes from freezing. Watering is decreased as greenhouse temperatures drop, first to once a day and then to every 2 days. As plants begin to break dormancy in spring, the frequency of irrigation is gradually increased. Plants are occasionally watered thoroughly with a hose to eliminate dry spots within the pot and prevent salt build-up. Plants are ready to be transferred to #3 containers and placed outside after the danger of frost has passed (usually late April in McMinnville, Tennessee).

DISCLAIMER

Mention of trade names or commercial products in this article is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture.

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Breeding New Plants for Modern Landscapes©

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INTRODUCTION

Breeding new plants is an adventure. There is a lot to consider and learn, from the objective to the subjective. There are, of course, issues of genetics, reproductive biology, adaptability, and disease and insect resistance. Productions considerations are important as well. Does it root easily, is it fast in production, does it look good in a container, etc.? And then there are consumer and marketing issues. Does it have sales appeal, will it be in bloom during spring sales, does it re-bloom, is the color right, is it fragrant, will it get too big, etc.? Ultimately, we want it to perform in the landscape with little care and maintenance. We want it all!

Breeding landscape plants is like being a kid in a candy store. So many genera and species to work with, and unlike many other crops, our customers typically value diversity and novelty and like to try something new. This provides endless opportunities for plant breeders and, as a result, we are always on the lookout for new plants with unusual and desirable traits that become our genetic building blocks. Thus, plant exploring, collecting, trading, evaluating, and breeding all go hand-in-hand. As part of our adventure, here are a few new plants, some from the wild and some from the lab, and the background behind them.

A FEW NEW PLANTS

×*Gordlinia grandiflora* 'Sweet Tea' — Mountain Gordlinia. As if ×*G. grandiflora* (a rare intergeneric hybrid between *Franklinia* and *Gordonia* (Ranney and Fantz, 2006) was not unusual enough, 'Sweet Tea' is a polyploidy form with extra sets of chromosomes. The result is huge 13-cm (5-in.) diameter, showy flowers that look like big fried eggs. Semievergreen foliage with large, single, camellia-like flowers from July through September. Why 'Sweet Tea'? Well, it is a member of the tea family, the flowers have a light sweet fragrance, and it comes from the South where sweet tea runs in our veins. Okay, it is not the toughest tree on the planet, so give it a good site. More resistant to *Phytophthora* than *Franklina* (Meyer et al., 2009), but it is still a bit finicky. Best in full sun or a little afternoon shade as long as it's not too dry. Roots readily from stem cuttings, then takes off growing. Mature height is estimated to be 6 to 9 m (20 to 30 ft). It is adapted to Zones 7–10, developed at North Carolina (NC) State University, and neither patented nor trademarked.

***Clethra alnifolia* 'Crystalina' PPAF — Summersweet Clethra.** The late Fred Galle hit on something with his selection of a compact form of *C. alnifolia* named 'Hummingbird'. Reining in the height of summersweet greatly expands the potential of this native shrub in modern landscapes. Although 'Hummingbird' was a breakthrough, it does tend to mature with a floppy habit and spreads by rather vigorous rhizomes. Selected here at NC State University from a population of seedlings derived from an open pollinated 'Ruby Spice', 'Crystalina' provides a handsome improvement with a compact, round form maturing at around 0.9 m (3 ft) high. It is somewhat taller in shade. Flowers are particularly showy with long, floriferous racemes.

***Illicium floridanum* 'Swamp Hobbit' — Florida Anise.** Discovered by the intrepid plantsman, Dr. Ron Miller of Pensacola, Florida, 'Swamp Hobbit' is an incredible dwarf *I. flroidanum* that Ron discovered in Coosa County, Alabama. It reaches 15 to 20 cm (6 to 8 in.) in height and around 30 cm (1 ft) in breadth within 5 years. The original plant is about 0.6 m (2 ft) tall, surrounded by a 1.5 m (5 ft) circle of offsets. Leaves and flowers are of normal size; it just has particularly short internodes. The plant benefits from some shade. It is a native, shade-tolerant, evergreen ground cover with showy flowers and good deer resistance, which are characteristics that few plants have. It has proven hardy in Delaware, so should be good in Zones (6?) 7–10. It roots readily from stem cuttings, but is somewhat slow in production. It has no patent or trademark.

***Hypericum androsaemum* 'Pollock', 'Matisse', and 'Picasso' — Tutsan.** In some parts of the world, tutsan can be a bit weedy, even invasive. These three cultivars were bred and evaluated at NC State University as part of our efforts to develop new, non-invasive nursery crops. All three are triploid, seedless, non-invasive forms of tutsan (Olsen et al., 2006; Trueblood et al., 2010). Special credit goes to Richard Olsen (former Ph.D. student, now at the U.S. National Arboretum) and Clara Trueblood (former M.S. student, now at the Phipps Conservatory and Botanical Gardens) for their efforts on this project. These new abstract/expressionistic tutsans include: 'Pollock' — dripped and splattered with green and white variegation; 'Matisse' — infused with a bold purple blush; and 'Picasso' — a neo-expressionistic integration of surreal colors and abstract patterns. Other characteristics are typical of the species. They are neither patented nor trademarked.

***Rhododendron minus* var. *minus* 'Southern Cerise' — Piedmont Rhododendron**. Selected by Ron Miller, Clarence Towe, and Tom Ranney along the shore of Gantt Lake in southeastern Alabama. An exceptional southern form of *R. minus* with vivid pinkish-red (i.e., cerise) flower buds and tubes that open with bright, pinkish-violet petals. Compared with *R. minus* var. *chapmanii,* another southern form of *R. minus,*'Southern Cerise' has much showier flowers, lusher foliage, and a less rangy habit. Heat tolerance is a given based on its provenance [within 48 km (30 mi) of the Florida border]. Definite potential for breeding programs. No patent or trademark.

***Weigela florida* 'Sunset' PPAF — Weigela.** Developed at NC State University, 'Sunset' provides unique variegated foliage with green centers and multicolored margins ranging from and including ivory yellow, yellow, yellow-green, green, and red depending on age of foliage and time of year. The habit is compact and reaches approximately 38 cm (15 in.) high and 64 cm (25 in.) wide. Flowers are a light pink. Good in full sun to part shade with adequate water. Other than that, it is what you would expect from a weigela.

***Exochorda* 'Blizzard' PPAF — Pearlbush.** Considered old-fashioned by some, Pearlbushes are tough, dependable plants that explode with pearl-like buds and frilly petals at the hint of spring, giving forsythias a good run for their money. 'Blizzard' takes pearlbush to a new level — a tetraploid hybrid that combines *E. ser-*

ratifolia, E. racemosa, and *E. korolkowii* in its pedigree. Unlike many pearlbushes (e.g., 'The Bride') that can resemble a tangled cascading brush pile, 'Blizzard' has a distinct upright to rounded form with a mature height and width of 0.9 to 1.2 m (3 to 4 ft) that makes a refined shrub or small tree. 'Blizzard' is extremely floriferous with flowers that can be twice as large as other pearlbushes. It was developed at North Carolina State University.

Clerodendrum trichotomum **'Betty Stiles' — Harlequin Glorybower.** As a species, *Clerodendrum trichotomum* has a lot going for it — tough and adaptable with exceptional showy, fragrant flowers that bloom throughout the summer followed by showy metallic-looking blue fruit. It is also one of the best trees for attracting butterflies. However, as Mike Dirr mentions, harlequin glorybower often has the appearance of "an overturned Dempster Dumpster" and it's rare to find good, cold-hardy tree forms. 'Betty Stiles' ~~fits~~ the bill. Hollis Wild of Appalachian Trees shared this plant with us and recommended naming the tree after her neighbor, Betty Stiles, who first recognized the merits of this tree and started sharing it with her friends and neighbors. One additional bit of advice, if you know *C. trichotomum*, you are probably aware that it can sucker from the roots much like a *Rhus*. A good way to prevent this is to plant it in a lawn area where any suckers are mowed off or use it in a planter. It is neither patented nor trademarked.

Acknowledgements. Thanks go to Liz Meyer, Richard Olsen, Tom Eaker, Joel Mowrey, Nathan Lynch, Jeremy Smith, Darren Touchell, and the staff at the Mountain Horticultural Crops Research Station for all of their efforts collecting, propagating, breeding, evaluating, and distributing these plants. Special thanks also to Ron Miller, Clarence Towe, Hollis Wild, and Betty Stiles for sharing their plants and stories.

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Redbud Propagation at Hidden Hollow Nursery©

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INTRODUCTION

My name is Alex Neubauer. My father and I own and operate Hidden Hollow Nursery in Belvidere, Tennessee. One of the goals of our nursery is to propagate new and/or hard to propagate plant material. In order to reproduce new and superior plant cultivars selected for specific traits that may include flower or leaf color, improved architecture, or disease resistance, the plants must be asexually propagated by any number of methods. Many plants we grow do not root easily from cuttings or other methods, so our approach is budding and grafting. Budding and grafting is a skill (or maybe an art form) that has been practiced since before 2,000 B.C. in China and has persisted through today as an effective method to reproduce desirable plant clones. Grafting is a blanket term for many different techniques of attaching the tissue of one plant to another and then forcing it to grow. Today my talk will focus on the propagation of *Cercis canadensis* or Eastern redbud by budding at our Nursery in Middle Tennessee. *Cercis* is a difficult genus to propagate, and there are many new selections that have been made in the last decade or so with many more under evaluation for the future.

MATERIALS

Rootstock. To successfully transform a redbud seedling into a desirable and uniform cultivar that is ready for sale as a liner is a process that takes us 2 years. We begin the process by purchasing a healthy and hardy 1-year-old rootstock that is approximately 30 to 61 cm (12 to 24 in.) in height and ranges in caliper from 0.3 to 0.6 cm (1/8 to ¼ in.). We trim the roots to encourage branching and discourage one sided, or "J- roots." The tops can also be pruned back to a uniform height for ease of planting. Planting takes place from late March through April using our small tree planter attached behind a tractor. We use normal, tidy cultural practices such as band spraying pre-emergent herbicides, administering granulated fertilizer, and regular watering through a drip irrigation system in order to ensure transplant success and to maintain vigor in our seedlings.

Scionwood. Scionwood is the shoot with the buds from your known desirable tree that will be attached to your rootstock and become your future cultivar. It is of utmost importance to begin with the correct scionwood. Some *Cercis* cultivars are easily recognized visually by their physical appearance, yet others are not obvious until later in their life. One example of the importance of proper cultivar identification happened to a customer we could not supply 200 'Appalachian Red'. 'Appalachia' was the original name Dr. Max Byrkit gave it but it has been transformed. Our customer purchased from a different supplier that did not take the critical step of procuring proper scion wood, so the next spring when they bloomed only two plants out of 200 were the correct 'Appalachian Red', proving to be a costly mistake for both parties. The best scions or budsticks are the current year's growth that is pencil-size with some variation to match the diameter of your rootstock. Budsticks can be collected from the current crop you are growing, or from stock plants maintained on the nursery.

We normally collect our ripe budsticks early in the morning, remove the leaves with a pair of clippers, wrap them in a wet towel, and place the budsticks in an ice chest until we use them up later in the day.

Tools. The main tools needed for a successful budding procedure include a good sharp grafting knife and a material to tie and hold the buds in place on the rootstock until callusing occurs. There are many knife manufacturers, but we prefer to use Tina brand knives. They are of high German quality — much like my father!

The material we use for tying, or "wrapping" the buds is called Buddy Tape. It is a pliable, parafilm-like material manufactured in Japan that comes in perforated segments on a roll. Each tab is 2.5 × 7 cm (1 × 2.8 in.) and comes on a 40-m roll of 500 tabs.

Conveniences. There are a few other items to make the arduous, but rewarding task of budding just a little more comfortable, but are certainly not required. Our entire budding season usually lasts for around 8 weeks so we indulge ourselves. The big one is the shade buggy with or without a radio. It is a metal frame on four bicycle wheels supporting a white sheet that you wheel along with you to provide shade. I highly recommend it! Other items to keep on hand might be a box of band-aids for the "greenhorn budder" and a bottle of Aleve® for your back. One item beyond our control is possibly proper alignment of the moon and stars, because while all conditions may seem perfect, the budding success can be less than so.

METHODS

The Slicing and Dicing. As everyone in this room knows, the learning curve in a nursery is huge. The way you started is not necessarily the way you do it now, and what works for some may not work for other propagators. We have successfully propagated *Cercis* by other techniques, but we have found chip budding to be the most practical method for our production. We bud from mid-August to late September when the rootstock is in a good state of growth and "juicy" in budder's lingo. The scionwood is also still growing, but the buds are well formed and the bark has hardened so it is not easily skinned.

To begin the budding procedure in the field you must bend at the waist and back up to the rootstock, or straddle the row with the bud stick in the left hand and knife in the right hand for a right handed person. We always prefer to move to our left along the row with our wrapper close by on our right side. I first cut the chip out of the rootstock 2.5 to 3.8 cm (1 to 1 $^1/_2$ in.) above the soil line. The knife is drawn horizontally across the rootstock at a steep angle to make the first cut, which I call the heel. The second cut is made approximately 1.3 cm ($^1/_2$ in.) above the first, drawing the knife through the plant just below the bark and skimming just above the pith to reveal the vascular cambium. The order can be reversed for personal preference. This chip of bark is removed and discarded leaving a long inverted U shape.

Next, with the bottom of the bud stick towards my body, a matching chip is cut that contains a bud to replace the one removed from the rootstock. With this procedure I usually make the long, smooth cut first, beginning above the bud and ending just below the remaining petiole or leaf stem. I slide the knife out from below the chip and make the second steeper and shorter heel cut to release the chip from the scion. I then grab the chip between my thumb and index finger and gently push it onto the cut rootstock. My father grabs the chip between his thumb and his knife, again personal preference. In a perfect world the greenish cambial ring on your chip will exactly line up with the cambial ring on the rootstock. "Getting it right" will most likely occur sometime after 100,000 repetitions or more. Perfecting your technique in the beginning supersedes speed. You must take time and fight for every bud to live. A good stand is the ultimate goal. Speed comes with practice.

As the "budder," once I am comfortable that I have made a good match, I let the individual working as the "wrapper" terminate the procedure. The wrapper takes a single tab of Buddy Tape behind the rootstock and stretches one corner around to the front and just below the bud with the left hand and holds this against the rootstock. With his right hand, he stretches the tab around the right side of the rootstock and over the first corner of the other side of the tab to initially secure it. The wrapper then continues to wrap the tab around and over the union until the entire site is covered, usually in four to five wraps stretching the tab as he goes. To finish is as simple as tearing the tab, while pulling against the rootstock or using the entire tab. A proficient budder can skillfully accomplish 100–150 buds per hour depending on cultivar. Straight, plump budsticks are much faster than skinny, zig-zag sticks.

AFTERCARE DURING THE CURRENT YEAR

Once budding is completed care for the rest of the year is minimal. It is important to maintain vigor and health, and keep the budded liners weed free for the next few months until the onset of winter and dormancy. It is possible after a few weeks to check the success of your budding. The Buddy Tape biodegrades and splits open. At this time you can see if the buds have attached successfully, or if they have been pushed out. A nicely attached bud shows sign of callus around the edges and is slightly sunken in the center. It should have normal healthy color and not look dry or brown. At this point you can check your take and decide if it would be beneficial to re-bud the unsuccessful plants. At our nursery we typically see a 75%–90% bud success rate. This of course does not mean we will ultimately harvest these plants, since as there are many other factors to contend with. These include early and late freezes (during the Easter 2007 freeze, we lost 80% of our crops), wind breakage, worker damage, animal and insect damage, and harvest damage. Again, you must fight for the survival and successful harvest of each budded plant.

AFTERCARE AND PROCESSING DURING THE SECOND YEAR

As fall turns to winter, we get busy with the harvest of finished trees for spring sales. The healed buds lie dormant during the winter. In mid- to late February we come back to our rootstock with the grafted bud attached and we remove the top of the rootstock with pruners just above the top of the attached bud. This cut slopes from the top of the bud straight back at approximately a 30^{o} angle. This step is very important so that the cut will callus and close up almost totally by the end of the growing season. This makes the plant straighter, stronger, and more resistant to disease, and of overall higher quality.

When the buds break dormancy, all the energy of the established rootstock is forced into the one remaining bud that was grafted. At this point we apply fertilizer, and shortly thereafter we place a fiberglass stake to maintain a straight stem and prevent wind breakage. Removing the top also forces many shoots, or suckers to arise from the rootstock below the bud union. These must be removed by pruning close to the rootstock. This process is carried out up to three times per season. By the third pass in mid-August, not many are found and the new clone is growing strong. May through August is spent tying the central leader to the stake and removing lower branches approximately every 2 weeks depending on growth rate. I estimate that we go over each tree nearly 20 times in two growing seasons from trimming the roots on the rootstock, planting, budding, wrapping, staking, cutting back the top, removing suckers and pruning, taping a minimum of five passes, harvesting, grading, bundling, storing, and final shipping — aside from the normal pest spray regimen.

CONCLUSIONS

The summer budded *Cercis* cultivars ultimately yield plants of 1.2 to 2.1 m (4 to 7 ft) with a stem caliper of 1.9 to 3.2 cm ($^3/_4$ to 1 $^1/_4$ in.) by the end of the following growing season, which are sold as liners. Other methods yield mixed results. Rooting stem cuttings is reportedly difficult and varies between cultivars. One study reported a maximum success of 83% on only one cultivar, although this appeared to be a deviation from the norm and well above the success reported in other investigations. *Cercis chinensis* does appear to root easier, but 2-year bed-grown plants are smaller in size than budded liners. While I have no personal experience, *Cercis* are being produced from tissue culture. They also tend to be smaller (Hotte, Hines, pers. commun.) and not readily available to the trade with limited cultivars being produced. It would take a minimum of 1 to 2 years to equal the size of a budded liner. Our personal experience and the lack of plants available to the market by other means of propagation leads us to believe that chip budding in the nursery on established rootstocks is a very successful and viable method for producing cultivars of *C. canadensis* and var. *texensis* liners in Middle Tennessee. Important *Cercis* cultivars in the trade, new cultivars, and desirable characters needed in future cultivar development are listed below.

Important *Cercis* Cultivars.

- *canadensis* 'Appalachia Red'
- *canadensis* Lavender Twist™ pp#10328
- *canadensis* 'Floating Clouds'
- *canadensis* 'Forest Pansy'
- *canadensis* 'Hearts of Gold' pp#17740
- *canadensis* 'Pauline Lily'
- *canadensis* 'Royal White'
- *canadensis* 'Silver Cloud'
- *canadensis* 'Tennessee Pink'
- *canadensis* var. *texensis* 'Traveller' pp#8640
- *reniformis* 'Oklahoma'

Important New *Cercis* Cultivars.

- *canadensis* 'Ace of Hearts' pp#17161: smaller symmetrical stature
- *canadensis* 'Alley Cat': superior variegation
- *canadensis* 'Kay's Early Hope': one of the showiest and earliest to bloom redbuds
- *canadensis* 'Litwo' Little Woody pp#15854: smaller bluish textured leaves
- *canadensis* 'Ruby Falls' ppaf: purple leaved and weeping
- *canadensis* 'Merlot' ppaf: *C. candensis* var. *texensis*: × *C. canadensis* hybrid with thick, glossy purple leaves

Desirable Traits Needed in Future Cultivar Development.

- Weeping and variegated
- Red leaves with variegation
- Double flowered with better color and architecture

Winners and Losers at Stephen F. Austin Gardens: Surviving the Winter of 2009-2010©

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INTRODUCTION

Stephen F. Austin Gardens (SFA) comprises 52 ha (128 acres) of on-campus property at Stephen F. Austin State University, Nacogdoches, Texas. Stephen F. Austin Gardens is the umbrella organization responsible for the activities, growth, and development of four gardens. Stephen F. Austin Mast Arboretum was the first phase of the SFA Garden and is composed of 17 ha (10 acres). The SFA Mast Arboretum was initiated in 1985 and includes the horticulture facility of the Agriculture Department. The Ruby M. Mize Azalea garden is a 3.2-ha (8-acre) garden of primarily azaleas, camellias, and Japanese maples and was dedicated in April 2000. The 17-ha (42-acre) Pineywoods Native Plant Center (PNPC) was dedicated by Lady Bird Johnson in April 2000. Finally, the newest land resource, SFA's Recreational Trail and Gardens was dedicated in March 2010 and comprises 27.5 ha (68 acres) of mostly undisturbed forest. As the result of a donor with a vision, SFA Gardens is currently responsible for the development of a new 3.2-ha (8-acre) garden in the SW portion of this property, directly across from the Ruby M. Mize Azalea Garden. That garden is in the early stages of planning and the exact mission yet to be defined. Stephen F. Austin Gardens enjoys four full-time employees and two half-time employees, all funded by a combination of state and external grant funding. The SFA Gardens is a collector's garden, one that adds hundreds of new plants each year to the plantings. Those that survive, perform well, and impress visitors make their way into propagation and distribution. This program has introduced and promoted numerous plants through a wide range of print and electronic media <http://arboretum.sfasu.edu>. Many plants have been documented in past *International Plant Propagators' Combined Proceeding* (Creech, 2001; Creech, 2003; Creech, 2005; Creech, 2009).

SURVIVING RECENT CLIMATE EXTREMES

Nacogdoches is a small town of 30,000 citizens near the center of east Texas, about 100 km (60 miles from the Louisiana border. Our region is part of the great swath of Pineywoods that runs from here to the east coast. Soils are generally well drained, slightly acidic, and the native flora is dominated by pine, oak, river birch, sweetgum, sycamore, Florida maple, hornbeam, elm, hackberry, pecan, and hickory. Nacogdoches lies on the Zone 8 a/b line with an average annual rainfall of 1219 mm (48 in.). Nacogdoches is about 800 km (120 miles) north of the Texas coast, but both Hurricane Rita in 2005 and Ike in 2008 managed to sustain 100+ mph winds in our city. Many towering pines and oaks were lost. June through August is characteristically hot and dry. Record low and high temperatures for the Garden were, respectively, 1 Sept. 2000 44.4 °C (112 °F) and 23 Dec. 1989 -17.8 °C (0 °F). Since that record low in 1989, winter low temperatures have been in the teens. On 10 Jan. 2010, the temperature dipped to a low of -12.2 °C (10 °F).

PLANT PERFORMANCE

The following list is comprised of notes taken on a few plants at SFA Gardens selected on the basis that there is limited prior evidence of response by these species to a winter as severe as this past one (three significant snowfall events, extended cold periods, numerous events below freezing, and a 10 Jan. 2010 low of -12.2 °C (10 °F).

***Alocasia odora,* upright elephant ear, Asian taro.** Suffering no damage, this small yet architecturally perfect tropical boasts spade-shaped foliage held upright on sturdy stems. Plants typically reach 60 cm (2 ft) in our garden. Our specimens have been in the ground for 3 years.

Acer coriaceifolium. Received by SFA Gardens as *C. cinnamomifolium*, this is a rarely encountered evergreen Chinese maple that suffered minor leaf damage and some tips were nipped. *Acer fabri* and *A. oblongum* both suffered leaf scorch, but no branch or bud damage, and growth was vigorous in the spring.

***Acer saccharum* subsp. *skutchii,* Mexico mountain sugar maple.** This maple suffered no winter damage. Our oldest tree was planted in 1994, a seedling grown from seed collected at Tamaulipas, Mexico, by John Fairey and Carl Schoenfeld. It is now over 12 m (40 ft) tall with a 0.5 m (20 in.) circumference at breast height. The tree generally produces butterscotch yellow to orange-red or yellow foliage in the fall depending on the year. Leaves hold well into the winter here. The tree is drought resistant, and possibly quite alkaline tolerant. While many seed are infertile (>90%), they are plentiful and those that do have viable embryos germinate readily after a few months of stratification.

Bambusa* species, clumping bamboos.** While most died to the ground or lost most of the upper parts of the plant, they generally regenerated well in the spring. *Bambusa multiplex* fared best but suffered leaf burn and shoot damage and our largest plants of this species suffered the least. *Bambusa sinospinosa* survived after dying back to the ground, which it has done every year in our garden. Those frozen to the ground but regenerating in the spring include *B. tuldoides*, *B. malingensis, B. ventricosa,* and *B. eutuldoides.**

Beschorneria. False red yucca (the name we are calling the species) suffered only modest winter foliage damage. This evergreen, clumping desert lily is proving to be excellent for dry shade. The strange flowering stalk — often bright red on some genotypes — produces oddly interesting bell-shaped greenish-burgundy flowers that turn into hanging green egg-sized fruit. These ripen to produce a bounty of black seed that readily germinate. We are primarily working with seedlings of a *B. septentrionalis* × *B. yuccoides* subsp. *dekosteriana* cross we have come to like in our garden. Once well established, and in the right spot, these plants have been bullet proof.

***Callistemon* taxa.** Bottlebrush is an exciting ornamental, one that we thought might have more potential here. However, this past midwinter low took most of taxa to the ground or badly damaged above-ground parts. *Callistemon viminalis* 'Hannah Ray' is one of our favorites but it too died to the ground. It resumed resume growth late in the spring. *Callistemon linearis*, an old plant from the JC Raulston

Arboretum, was unaffected. *Callistemon brachyandrus* also fared well with damage only to the foliage and smaller branches.

***Cestrum nocturnum,* night-blooming jasmine.** Greenish white tubular flowers are produced in abundance throughout the summer. Flowers are sweetly fragrant, emitting their soft perfume in the later hours of the day. Our plants have survived two mild winters and were equally as vigorous after the 2009–2010 Winter.

***Costus tropicalis, Costus afer,* spiral ginger.** Dead after the Winter of 2009–2010, but not a surprising loss in our garden as we have tried this genus before. *Costus* species do not typically overwinter for us with the exception of spring planted *C. speciosus.* Our strategy to offer better drainage and more sunlight did not improve survival.

***Dalea greggi,* Greg's dalea.** This plant suffered damage this winter to leaves and a few of the thinner branches. However, this small groundcover is proving to be a very durable and perhaps the ultimate green roof or container plant. This clone was rescued from the original Benny Simpson planting at Texas A&M University, Renner, Texas.

***Distylium racemosum* 'Ishi's Variegated'.** *Distylium racemosum* 'Ishi's Variegated' is an evergreen isu tree that suffered only minor tip damage and leaf scorching, but rebounded quickly in the spring. This clone was a gift from Mr. Ishi of Japan to the SFA Mast Arboretum years ago. It sports new growth often pure white with pinkish overtones, which fades to a spider-web green/white splotchy appearance, and finally changes to dark green in the summer. Our 3-m tree has become more impressive with time, a large shrub under the high canopy of pines. Other *Distylium* in the gardens were unaffected by the winter.

***Ensete ventricosum* 'Maurelii', Abyssinian red banana.** A single-trunk banana with 3-m (10-ft) leaves bathed in red failed to survive this winter. Often used in cooler climates as a container specimen or tropical annual and in our garden plants easily reach 3 to 4.6 m (10 to 15 ft) in one season. During previous milder winters *Ensete* typically suffer damage to the foliage only and recover fine.

***Furcraea foetida* 'Mediopicta'.** This spectacular spineless *Agave* relative native to Brasil failed to survive. Succulent leaves can reach up to 4 ft (1.2 m) in frost-free climates. Leaves have a spectacular, creamy-white stripe and are more vertical than horizontal in mature plants. Typically this is something we would keep in a container for several years, overwintering in a greenhouse, to produce a large plant, one more likely to survive a winter test.

***Gaillardia aestivalis* var. *winklerii,* Texas white firewheel.** It was unaffected this past winter, has been trialed for over 20 years at SFA and tested in Georgia, Florida, Arizona, North Carolina, Tennessee, and Connecticut. This endangered species is known from only one small area in southeast Texas. Stephen F. Austin Gardens has introduced 'Grape Sensation' with purple petals and dark purple center which comes true from seed. The species offers breeding opportunities for flower colors with petal hues varying from white, pink, rose, lavender, and purple, and flower centers varying from yellow to dark purple.

***Musa velutina,* pink velvet banana.** A "diminutive" banana reaching a relatively small 1.8 m (6 ft) and reliably producing small, seedy fruit with pink skin. While the flesh is sweet and tasty, its edible charm is compromised by a copious amount of seed. While our mother plants died this year, seedlings were, as usual, prolific in this heavily mulched plot.

Nothaphoebe cavaleriei. This is a rare Chinese evergreen tree in the laurel family. Our sole specimen reached 9.1 m (30 ft) in 15 years and appeared on track to make a large tree. However, during this past winter, the tree was killed back to the main trunk and a few of the larger branches. It lost all its leaves and smaller branches, but it did survive and force vigorous new growth. This species sports lustrous dark green foliage and the leaf underside is a bright gray. As a result of this winter, we surmise the species is a candidate for Zone 9 and higher.

Quercus rhysophylla. The loquat-leaved oak from the San Madre Oriental Mountains was introduced in the 1970s by Lynn Lowrey. Our oldest tree is 12.2 m (40 ft) and was planted in 1988 and is normally fully evergreen in our region. The 10 Jan. 2010 freeze did scald a few leaves and leaves dropped at the very top of the tree, but no twig or bud damage was evident. Our oldest tree, grows reasonably fast, and features coarse leather-like leaves that do not shed until new growth has emerged. This is an underutilized oak that is drought resistant and alkaline tolerant.

***Scuttelaria suffrutescens* 'Texas Rose'.** 'Texas Rose' is a pink-flowering skullcap found in 1986 near Horsetail Falls, west of Monterrey, Mexico, by Lynn Lowrey and me. This plant suffered only mild leaf burn and rebounded quickly in the spring. Dry loving, performs well in sun, blooms on rainfall events, and is already quite popular in the trade.

***Taxodium distichum* var. *mexicanum*, Montezuma cypress.** This cypress suffered no damage. The bald cypress is well represented at SFA Gardens. The SFA Mast Arboretum has been collecting and evaluating bald cypress genotypes since the mid 1980s (Creech, 2003a; Creech, 2007a; Creech, 2007b). Over the years, the gardens have grown to include over 100 different genotypes, varieties, or selections. Selection T302, later named 'Nanjing Beauty', was provided by Professor Yin Yunlong of the Nanjing Botanical Garden, Nanjing, China, and was introduced into the SFA Mast Arboretum as 50 small bare-root cuttings in December 2001. Because this plant was registered at both the provincial and federal level in China, and it was popular in commerce, the decision was made not to initiate a patent, but instead to introduce the concept of clonal bald cypress to the marketplace. With the approval of Nanjing Botanical Garden, T302 was given the cultivar name of 'Nanjing Beauty'. That clone has been cutting propagated and distributed to many locations. It has been proven to have good adaptation in a wide range of sites. We are currently working with six Chinese bred clones that are now in trialing agreements across the south. Readers interested in SFA's *Taxodium* research can access the plants page of our website: <http://pnpc.sfasu.edu>.

***Thysanoleana maxima,* tiger grass.** This is an awesome ornamental grass with the look of bamboo but the size of a well-mannered ornamental grass. Established plants returned with less vigor and plants planted in Spring of 2009 did not survive the winter.

***Yucca cernua*, nodding yucca.** This yucca is an E.L. Keith discovery found in Jasper and Newton counties in southeast Texas and just described in 2003! No damage. It is apparently quite hardy in Zone 8, and deserves further testing in Zones 6 and 7.

***Xanthosoma maffafa* 'Aurea', lime zinger elephant ear.** The bright, yellow-green foliage brightens up shady areas. In our garden, plants are dug and potted for the next year as the vigor diminishes considerably in a normal winter. Surprisingly, one clump left in the garden returned and performed considerably better than in previous years.

***Zingiber officinale* 'Twice as Nice', common ginger.** 'Twice as Nice' is an exceptional selection of common ginger. Plants produce pine-cone-like, succulent bracts both basally and terminally. This cultivar has overwintered better for us than the species, but has diminished vigor each successive year. We would be hard pressed to call it truly hardy.

CONCLUSIONS

While certainly one of the worst winters in almost two decades, many plants fared better than expected. Older specimens fared better than younger ones and the fact that the mid-winter low came well into the winter may have allowed many plants to harden off properly before the hard freeze event.

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Processed Corncob as an Alternative to Perlite in the Production of Greenhouse Grown Annuals©[1]

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INTRODUCTION

Topsoil was used in container plants in the greenhouse and nursery industry until the 1960s when new soilless substrate alternatives were developed. One of the pioneers in this new soilless substrate was Cornell University with their peat-lite mixes. The peat-lite mix was a combination of peatmoss, used for its fine particles to hold water, and perlite and vermiculite were used to create air spaces in the substrate (Boodle and Sheldrake, 1977). Peatmoss is derived from the decomposition of mosses, sedges and sphagnum's under acidic and wet conditions (Bunt, 1987). Vermiculite, an aluminum-iron-magnesium silicate is produced by heating the rock to 1,000 °C (Bunt, 1987). Perlite an igneous glassy rock that is mined and heated to 1,600 °C to remove all water and expand the rock (Moore, 1987). While perlite has no known health hazards it is considered a nuisance causing lung and eye irritation (Evans and Gachukia, 2004).

Growers are interested in alternatives to perlite that provide the same functions without the nuisance of the fine dust particles. Some of these alternatives have included pumice, parboiled rice hulls, and expanded polystyrene. Pumice is a naturally occurring mineral from aluminum silicate, potassium, and sodium oxides often developed from volcanic eruptions. When compared to perlite pumice was found to have similar chemical and physical characteristics (Noland et al., 1992).

In one study parboiled rice hulls (a byproduct of the rice milling industry) and perlite were mixed with peat at rates of 10% 15%, 20%, 25%, 30%, and 35%. In the growth of impatiens, marigold, vinca, and geranium there was no significant difference between root-dry weight and shoot-dry-weight (Evans and Gachukia, 2004).

Polystyrene beads (PSB) are a byproduct of the polystyrene industry. In a study by Cole and Dunn (2002) a substrate containing PSB was found to produce similar plants to those grown in similar mix containing perlite.

Another possible alternative to perlite is processed corncobs. Corncobs are often left over from the harvesting of corn seed and are used for many different products. There are four main parts of cob that are processed and used commercially; the three outer parts of the cob are the beeswing, chaff, and the woody ring which are considered to be the most absorbent part of the cob. These outer parts are often pelletized and used for absorbent tasks including chemical waste, oil, grease, animal bedding, and litter and sweeping compounds. The inner part of the cob is considered the pith and it is often used as an abrasive material in tasks such as sand blasting, metal finishing, polishing, and carriers for pesticides.

Corncob is a waste byproduct of the corn feed and seed industry and requires less energy to produce than perlite. Because it is a byproduct, no rise in the feed and seed market prices would be anticipated. Corncob is a product of the United States and does not have to be imported; therefore decreasing transportation cost. Because of these and other potential advantages of using corncob as a perlite alter-

[1]First Place – Graduate Student Research Paper Competition

native, this study was conducted to determine the effects on container grown annuals when grown in a substrate mixed with corncob and compared to the industry standard perlite.

MATERIALS AND METHODS

This study was conducted at the Paterson Greenhouse Complex, Auburn University, Auburn, Alabama. Processed corncob was obtained from The Andersons Inc., Maumee, Ohio. A base substrate was blended containing 70 pine bark : 30 peat (v/v) (PBP). This base substrate was mixed with either corncob (CC) or perlite (PL). Treatments were 9 PBP : 1 CC (v/v), 8 PBP : 2 CC (v/v), 7 PBP : 3 CC (v/v), 9 PBP : 1 PL (v:v), 8 PBP : 2 PL (v/v), 7 PBP : 3 PL (v/v). Substrates were amended with 1.4 $kg \cdot m^{-3}$ nitrogen (Sta-Green 12-6-6 Pursell Industries, Inc. Sylacauga, Alabama), 2.9 $kg \cdot m^{-3}$ of dolomitic lime and 0.8 $kg \cdot m^{-3}$ of Micromax (The Scotts Company, Marysville, Ohio). On 18 June 2010 1.96 L containers (Dillen Products. Middlefield, Ohio) were filled to capacity, tamped and filled to capacity again. Two plugs from 200-cell flats of either impatiens (*Impatiens walleriana* 'Dazzler Cranberry'; 5 weeks from sowing), or petunia (*Petunia* 'Dream Rose'; 4 weeks from sowing) were planted in each container. Containers were placed in a twin-wall polycarbonate greenhouse on elevated benches and hand watered as needed.

Before planting, pH and EC of the treatments were determined (Accumet Excel XL50; Fisher Scientific, Pittsburgh, Pennsylvania) using the pour-through method (Wright, 1986). Subsequently pH and EC of petunias were taken at 14, 21, 28, and 35 days after potting (DAP). At 35 DAP all plants were measured for growth index (GI) [(height + width + perpendicular width)/three (cm)], and bloom count (BC) (open flowers and unopened buds showing color). Roots were visually inspected and rated on a scale of 0 to 5 with 0 indicating no roots present at the container substrate interface and 5 indicating roots visible at all portions of the container substrate interface. At 35 DAP, petunia and impatiens shoots were removed at the substrate surface and oven dried at 70 °C for 72 h and weighed. Containers were arranged in a randomized complete block with 12 single-plant replicates. Each plant species was treated as a separate experiment. Total porosity (TP), container capacity (CNC), air space (AS), and bulk density (BD) were determined using the NCSU porometer method (Fonteno and Harden, 1995). Data were subjected to analysis of variance using the general linear models procedure and a multiple comparison of means was conducted using Duncan's Multiple Range Test (Version 9.1; SAS Institute, Cary, North Carolina).

RESULTS

Substrates containing corncob had greater AS and TP than those containing perlite (Table 1). The reason for the higher TP and AS could be a result of the particle size of the corncob. Particle size distributions (PSD) showed that corncob had a consistent particle size while perlite had a wide range of sizes (data not shown). The consistent PSD of the corncob relative to the variability in PSD of the perlite could be the reason for greater AS and TP.

Substrate pH was highest for treatments containing perlite throughout the experiment. There was little difference in EC among any treatments except for the 28 DAP readings where EC for the 9 : 1 and 7 : 3 PBP : PL treatments ranged from 31% to 49% higher than any treatment containing CC.

Table 1. Physical Properties of Substrates.[z]

Substrates	Air Space	Container capacity	Total porosity	Bulk density
	---------------- (% vol)		----------------	(g/cm^3)
90:10 PBP[y]:corncob	24.2	55.0	79.2	0.8
80:20 PBP:corncob	26.5	51.6	78.0	0.8
70:30 PBP:corncob	29.6	52.0	81.6	0.8
90:10 PBP:perlite	19.3	55.4	74.7	0.7
80:20 PBP:perlite	19.9	52.7	72.6	0.7
70:30 PBP:perlite	25.9	49.9	75.8	0.7

[z]Analysis performed using the NCSU porometer.
[y]PBP = pinebark:peat, 70:30 (v:v).

Table 2. Effects of substrate on pH and electrical conductivity of greenhouse-grown *Petunia* x*hybrida*.

	14 DAP		21 DAP		28 DAP		35 DAP	
Substrates	pH	EC[y]	pH	EC	pH	EC	pH	EC
90:10 PBP[x]:corncob	7.0bc[w]	3.96a	7.1c	1.50a	7.1ab	1.01c	6.1b	0.44a
80:20 PBP:corncob	6.9c	4.32a	6.9d	1.78a	7.1ab	1.20c	6.1b	0.86a
70:30 PBP:corncob	6.5d	4.06a	6.7e	1.76a	6.8bc	0.99c	6.2b	1.07a
90:10 PBP:perlite	7.2b	3.33a	7.2b	2.22a	7.1ab	1.73ab	6.7a	0.78a
80:20 PBP:perlite	7.5a	2.84a	7.5a	2.16a	7.3a	1.26bc	6.9a	0.44a
70:30 PBP:perlite	7.4a	3.04a	7.3b	2.21a	6.6c	1.94a	6.2b	0.75a

[z]Days after potting.
[y]Electrical conductivity (dS cm) of substrate solution using the pourthrough method.
[x]PBP = pinebark:peat, 70:30 (v:v).
[w]Duncans Multiple Range Test ($P \leq 0.05$, n = 4).

Growth indices for impatiens were similar for all treatments except for the 7 PBP : 3 CC which was smaller than all other treatments. Bloom counts for impatiens were similar among all treatments while petunia in 9 PBP : 1 CC had twice the number of blooms compared with BC in 7 PBP : 3 PL. Shoot dry weights in impatiens were similar among all treatments containing 10% or 20% CC or PL. Similar results were found in parboiled rich hulls where no difference was found between treatments comprised with the same amount of perlite and rice hulls (Evans and Gachukia, 2004). Petunia grown in 7 PBP : 3 PL were one third smaller than the average of all other treatments with respect to SDW. There was great variability within treatments with root rating, however the general trend, especially among petunia, were that root ratings were lower in treatments containing PL (Table 3). This lower root rating could possibly be a result of lower substrate airspace for those treatments with less PL.

DISCUSSION

In conclusion, the data presented here indicate that processed corncob is a possible organic substitute for perlite in greenhouse production. Growth of both impatiens and petunia in substrates containing 10% or 20% corncob were equal to those grown

Table 3. Effects of substrate on growth of greenhouse-grown *Impatiens walleriana* and *Petunia* ×*hybrida*.

Substrates	Growth index[z]	Bloom count[y]	Shoot dry weight[x]	Root rating[w]
	Impatiens walleriana 'Dazzler Cranberry'			
9:1 PBP[v]:corncob	28.1a[u]	18.7a	12.2abc	3.5ab
8:2 PBP:corncob	27.4a	17.8a	11.8abc	3.8a
7:3 PBP:corncob	24.0b	16.7a	7.9c	3.5ab
9:1 PBP:perlite	28.5a	18.4a	13.4ab	2.8bc
8:2 PBP:perlite	28.3a	21.8a	13.8a	2.5bc
7:3 PBP:perlite	25.5ab	14.5a	9.3bc	1.8bc
	Petunia ×*hybrida* 'Dream Rose'			
9:1 PBP:corncob	35.2ab	26.8a	13.7a	2.7ab
8:2 PBP:corncob	36.0a	22.8ab	13.2a	2.8ab
7:3 PBP:corncob	33.3abc	21.1bc	11.2a	3.5a
9:1 PBP:perlite	29.6c	17.4cd	12.5a	1.7bc
8:2 PBP:perlite	30.9abc	17.7bcd	11.6a	1.7bc
7:3 PBP:perlite	30.7bc	13.2d	8.4b	1.3bc

[z]Growth index[(height + widht1 + withdth2)/3].
[y]Bloom count = number of blooms or buds showing color at 35 days after potting.
[x]Shoot dry weight measured in grams.
[w]Root ratings 0-5 scale (0 = no visible roots and 5 = roots visable on the entire container substrate interface).
[v]PBP = pinebark:peat, 70:30 (v:v).
[u]Duncans Multiple Range Test ($P < 0.05$, n = 12).

in equal amounts of perlite. However, it has been reported by others that the use of ground corncob as an amendment can cause nitrogen depletion (Jozwik, 1993). While no nitrogen deficiency was noted in this study, the authors acknowledge that this could likely be due to the high nitrogen rate used. Further investigation using multiple nitrogen rates and fertilizer sources is warranted. Processed corncob could be a more sustainable and "greener" alternative to perlite.

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Improving Germination of Red Elm (*Ulmus rubra*) Seeds With Gibberellic Acid©2

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Red elm (*Ulmus rubra*) is considered an important tree for many Native American tribes in the United States. Native Americans use red elm, a native tree species, for firewood in cultural ceremonies, to treat skin and respiratory conditions, and as an eyewash. Since red elm is susceptible to Dutch elm disease it is not grown commercially. Tribal leaders would like to plant more of this species on tribal land, but it is difficult to germinate due to multiple dormancy mechanisms. This has led to declining natural tree populations and difficulties in commercial propagation. The objective of this study was to evaluate techniques to promote germination of red elm. Studies were conducted with stratified and nonstratified red elm seeds treated with 0, 250, 500, or 1,000 ppm of gibberellic acid (GA_3). Highest seed germination occurred at 500 and 1,000 ppm GA_3 with nonstratified seed. While seed stratified for 90 days had higher germination than nonstratified seed, germination of stratified seed was lower when treated with GA_3.

INTRODUCTION

Red elm, also called slippery elm, is a native American tree that is valued by many American Indian tribes as fuel for ceremonial fires at pow wows, funerals, or sweat lodges. Other past uses of red elm included the inner bark for cordage, fiber bags, and storage baskets. The mucilaginous inner bark has several medicinal uses, including as a treatment for swollen glands, as an eyewash, for sore throats, and women drink a tea of the bark to make childbirth easier (USDA, 2010). Current tribal use centers on using red elm for firewood in traditional ceremonies. Unfortunately, red elm is also susceptible to Dutch elm disease (caused by the fungus *Ophiostoma ulmi*) which is transmitted by bark beetles and root grafts. Due to this susceptibility, red elm has not undergone extensive research.

Gibberellic acid (GA_3) is a naturally occurring plant hormone that can release seeds from dormancy. The positive effect of GA_3 promotes uniform seedling germination and higher percent germination (Adams et al., 2010). Gibberellic acid removes physiological dormancy mechanisms that often require lengthy stratification or light to maximize germination (Norden et al., 2007). However the seeds of red elm exhibit several kinds of dormancies which is the subject of this investigation.

MATERIALS AND METHODS

Seeds of red elm were collected from two locations, near the town of Leon, in south-central Kansas (37° 41' 25" N / 96° 46' 56" W), and at Lawrence in northeastern Kansas (38° 58' 18" N / 95° 14' 6" W), in late April 2010. Seeds were air dried for 3 days and stored in a sealed container. On 11 May 2010 half of the seeds (240 seeds) received cool moist stratification at 5 °C (41 °F) for 90 days. Stratifica-

[2]Second Place – Graduate Student Research Paper Competition

tion was achieved by placing seed (60 per bag) in a polyethylene bag containing 1 lb (450 g) of moist peat moss. Remaining seeds (240 seeds) were immediately treated with GA_3 (Research Organics, Cleveland, Ohio) at 0, 250, 500, or 1,000 ppm dissolved in distilled water. Sixty seeds were placed in beakers containing 120 ml of GA_3 solution and placed on a shaker at 175 RPM for 24 h. Seeds were then placed on filter paper in 47-mm-diameter petri dishes (Fisher Scientific). The filter paper was moistened with 2 ml of distilled water to maintain humidity. Petri dishes were arranged on a lab bench at room temperature 18 °C (65 °F). Stratified seed were handled identically upon removal from the peat moss after 90 days.

Germination was monitored every 3 days starting on 13 May 2010. Seed germination was recorded when a radicle of 3 mm long had emerged. Data were taken over a period of 2 weeks, when seeds in all treatments either germinated or died. The experimental design was completely randomized with a 2 × 4 arrangement of factorial treatments. There were two stratification treatments and four GA_3 treatments. The experiment was replicated six times with two petri dishes per replication per treatment with 5 seeds per dish. Data were subjected to ANOVA (Statistical Analysis System, SAS Institute Inc., Cary, North Carolina) and the means separated by LSD test ($p<0.05$).

RESULTS

Both seedlots exhibited similar trends in germination across the various treatments (Tables 1 and 2). For the Lawrence seedlot, the best treatment for the nonstratified seeds was 1000 ppm GA_3, with a 78.3% germination rate (Table 1). Germination steadily increased from the control (0 ppm), 250, and 500 ppm GA_3, respectively with 13.3%, 28.3%, and 45% germination. For the stratified Lawrence seed, the best germinating treatment was the control (0 ppm of GA_3) with 30.8% germination. With increasing GA_3 concentrations of 250, 500, and 1,000 ppm, respectively, the germination of stratified seed was 22.3%, 14.1%, and 5.6 % germination, although treatments of 250 and 500 ppm GA_3 were statistically similar. Germination of stratified seed from the Lawrence seedlot exposed to 1,000 ppm GA_3 was significantly lower than all other treatments (Table 1).

For the Leon seedlot, the highest germination rate for nonstratified seeds was also 1,000 ppm GA_3 with 86.6% germination; however, seeds treated with 500 ppm GA_3 had statistically similar germination (73.3%) (Table 2). Nonstratified seeds treated with 0 and 250 ppm GA_3 had 30% and 50% germination, respectively. The reverse situation was true for the stratified seed, with the best treatment being the

Table 1. Percent germination of red elm seedlot from Lawrence, Kansas.

	Treatments	
GA_3 concentration (ppm)	Non-stratified	Stratified
0	13.3 cd B	30.8 bc A
250	28.3 bcd A	22.3 bcd A
500	45.0 b A	14.1 cb B
1000	78.3 a A	5.6 d B

Means within a column (lower case) or row (uppercase) followed by the same letter were not significantly different with LSD ($p<0.05$); n = 6.

Table 2. Percent germination of red elm seedlot from Leon, Kansas.

	Treatments	
GA_3 concentration (ppm)	Non-stratified	Stratified
0	30.0 cd B	47.3 bc A
250	50.0 b A	30.5 cd B
500	73.3 a A	19.5 de B
1000	86.6 a A	2.8 e B

Means within a column (lower case) or row (uppercase) followed by the same letter were not significantly different with LSD ($p<0.05$); n = 6.

control (0 ppm GA_3) with an average of 47.3% germination. Germination of stratified seed declined with increasing GA_3 concentrations, with 47.3%, 30.5%, 19.5%, and 2.8% germination, respectively, for 0, 250, 500, and 1,000 ppm GA_3 (Table 2).

DISCUSSION

Seed germination of nonstratified seeds was highest at 1,000 ppm GA_3, with 86% and 78.3% germination, respectively, for the Leon and Lawrence seed lots. Previous work (Dirr and Heuser, 2006) has indicated that stratification will increase red elm germination. While this was true for the control treatment not exposed to GA_3, treatments with GA_3 resulted in significantly less germination of 90-day stratified seed from both locations.

Gibberellic acid treatment had a negative effect on germination of stratified seeds that was consistent with both seedlots. There was also a strong interaction between the stratification and GA_3 treatments. This suggests that there may be a supraoptimal response of stratification to red elm seeds treated with GA_3. Nonstratified seeds benefited from exposure to exogenous GA_3, while stratified seeds (which naturally produce endogenous gibberellins) experienced an inhibitory response when exposed to additional GA_3. This relationship will be an important one to investigate in the future.

Based on this study, we recommend red elm seed be soaked in 1,000 ppm GA_3 for 24 h before sowing. Seeds typically took 10–15 days to germinate. Future studies should evaluate higher levels of GA_3 and shorter stratification periods to determine optimum rates for maximum germination.

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An Annotated List of Plant We Love to Hate©

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INTRODUCTION

By definition, ornamental herbaceous plants known as "annuals" complete their life cycle in a single growing season (e.g., *Cosmos sulphureus*), but not all commercially available "annuals" fit this definition. In some cases, it is only relevant that these plants are used for a single growing season in cultivated landscapes rather than expecting them to set seed and die before the onset of winter (e.g., *Impatiens walleriana*). For the purpose of this paper, the term "annuals" is used for plants characterized by either of the above situations. It is empirically interesting that among plant materials and landscape design professionals, annuals are often held in lower esteem than their herbaceous perennial and woody counterparts, despite their vast economic value. While the reasons may not be easily documented, this assessment may relate directly back to the fact that annuals have a useful landscape value limited to only a single season, whereas herbaceous perennials and hardy woody species last for many years.

Contemporary cultivars and hybrids of ornamental annuals are far removed from their species origins, but several species have routinely ranked as the most popular since the start of the 1950s, including (in no particular order) zinnias (*Zinnia* spp.), marigolds (*Tagetes* spp.), portulacas (*Portulaca* spp.), petunias (*Petunia* spp.), begonias (*Begonia* spp.), impatiens (*Impatiens* spp.), cosmos (*Cosmos* spp.), pansies (*Viola* spp.), and geraniums (*Pelargonium* spp.). From within this group, three genera have enjoyed great popularity in residential and commercial landscapes, but even these genera have faced challenges. Each of these three, the petunias, zinnias, and impatiens, will be highlighted in this paper for their performance challenges (despite their high popularity), as well as for recent breakthroughs aimed at significantly improving the palette of available cultivars and hybrids.

ZINNIAS

Historically, *Z. elegans* has been the species foundation for most zinnias used in the cultivated landscape. Bright, subdued, and multiple-colored flowers combined with tall, mid-range, and dwarf plant habits characterize current cultivars and easily underscore the plant's popularity. However, in many parts of the U.S.A., landscape performance is greatly reduced in mid-summer by a susceptibility to powdery mildew (*Golovinomyces cichoracearum)*, a fungal disease that can devastate plant aesthetics and lead to premature death. In the 1980s, a team of horticultural scientists at the University of Maryland screened *Zinnia* species for levels of disease resistance, leading to one, *Z. angustifolia,* which showed exceptional resistant qualities. This species was subsequently hybridized with *Z. elegans*, resulting in plants that truly remained free of disease and possessed a much more attractive and long-lasting landscape appearance. Modern day Pinwheel, Profusion, and Zahara series of zinnias set new performance standards and were also characterized by free-branching, compact habits that made them even more attractive to the landscape industry.

PETUNIAS

Long a staple for both home gardeners and commercial designers, petunias have withstood the test of time with a seemingly endless appearance of new cultivars annually. New cultivars, however, did not necessarily mean unique cultivars, a fact that was not lost on plant professionals. What was seemingly tolerated but never admired was the plant's response to rain; its flowers would collapse and its foliage would succumb to disease, making for an unacceptable appearance. Plants generally rebounded but it often took days to do so. While so-called "rain-resistant" cultivars were released with regularity, their performance was inconsistent and geographically dependent. Adding to the list of tolerated frustrations, petunias were well known to set seed in early summer following their first flush of strong flowering. This invariably required laborious deadheading, or severe and indiscriminate pruning of whole plants to remove developing seeds and encourage acceptable flowering. The petunia's entrenched value to the field of landscape color seemed to justify these efforts to restore flowering in either laborious or drastic ways. Arguably, the lack of unique, new flower colors amidst a predictably standard and static array already in the trade may have contributed to a perceived indifference among its fans. The pursuit of "something new" appeared to be stalled for petunias. While the advent of yellow flower color in the early 1980s should be given credit for uniquely advancing the color palette, the exploitation of a heretofore little known species, *P. integrifolia*, may have been the most important stimulus to spearhead a revolution in new petunia development and popularity. *Petunia integrifoli*a is a prostrate, freely flowering, rapidly growing species that quickly covers landscape beds. It does not require deadheading for continuous flowering and it holds its own after typical summer rains. An improved look-alike, 'Purple Wave', soon emerged on the market, having larger flowers than *P. integrifolia* and possessing the desirable qualities of rain resistance, vigorous growth, self-cleaning, and outstanding flowering potential. In the years following the introduction of 'Purple Wave', interest and utilization of the genus expanded with renewed excitement, especially with the appearance of new cultivars from many breeders who introduced bicolor flowers of green and pink, nearly black flowers, and fast-growing ground cover habits with excellent weather resistance.

IMPATIENS

Impatiens walleriana cultivars have traditionally dominated annual plant choices for shade, taking a back seat to, perhaps, only *Begonia* Semperflorens Cultorum Group. Cultivars of *I. walleriana* have not become overshadowed by the comparatively recent introductions of the New Guinea impatiens [*I. schlechteri* (syn. *hawkeri*)] but have likely suffered from a relatively slow infusion of new cultivars into the marketplace. Double-flowered types had a reputation of slower growth and fewer flowers per plant, but more contemporary introductions have produced vigorous, well-flowered cultivars. The real potential for exciting ornamental advancements within this species may be found in identifying heretofore unutilized or underutilized species, which may be used by themselves or as genetic pools for new hybridization. Several key species worth consideration and/or continued refinement include *I. auricola, I. repens, I. niamniamensis,* and *I. namchabarwensis*.

SUMMARY

In closing, the arena for new plant development will likely continue its rapid pace for annuals, as long as there are species with the potential for landscape performance that exceeds those already available, coupled with a consumer base willing to design with and use them.

Back to the Basics and What's New in Propagation©

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DEVELOPMENTAL ASPECTS OF ADVENTITIOUS ROOT FORMATION

De novo adventitious root formation is composed of four stages: 1) dedifferentiation of parenchyma cells in the phloem ray area, 2) formation of root initials, 3) formation of a fully developed meristematic area — the root primordia, and 4) elongation of the root primordial through the cortex and periderm (Hartmann et al., 2011). What separates out an easy vs. difficult to root species is the ability to complete the first two stages: dedifferentiation and root initial formation (early organization of the root primordia). If a cutting can complete these first two steps, it will successfully root — provided the proper environmental conditions are maintained.

While we have gotten to be pretty good at manipulating stock plants, using auxins and controlling environmental conditions to maximize commercial rooting of cuttings — there are still many woody plant species that are too difficult to root in acceptable numbers. It would be great if we could manipulate a single gene to enhance rooting, but we know that adventitious root formation of cuttings is a complex process involving many genes. It was recently reported that some 220 genes are differentially expressed during adventitious root development in lodgepole pine (*Pinus contorta*) hypocotyls cuttings (Brinker et al., 2004). Genes were up-regulated (increased gene expression) or down-regulated (decreased expression) during various stages of rooting (Fig. 1). Genes are important because they are expressed through the production of proteins, some of which are enzymes which help drive chemical reactions. Hence, a mature, difficult-to-root plant species has certain genes that are being turned off or on, whereas the juvenile, more easy-to-root form of the same species differs in its gene expression, even though the genome (gene composition) is the same between the two. Bottom line: we still have a long way to go in understanding and utilizing the molecular biology of rooting.

CHRONOLOGICAL VS. PHYSIOLOGICAL AGE AND MANIPULATION OF STOCK PLANTS

Juvenile-mature gradients occur in seedling trees from the base of the tree to the top. The juvenile root-shoot junction, which is "*physiologically juvenile*" has a high rooting potential — even though chronologically it may be decades old (Fig. 2). Flowering occurs in the "*physiologically mature*" part of tree at the apical part, even though some of the flowering shoots may be *chronologically* only several months old; shoots taken from this region generally have low rooting potential. Juvenile structures arising from the "*cone of juvenility*" [dark area] near the base (crown) of the tree include: adventitious root "suckers," watersprouts (epicormic shoots), and sphaeroblasts. Stump sprouts result from severe pruning, and shoots from heavily pruned or hedged bushes (Fig. 2). Rooting potential is highest from these structures close to the cone of juvenility.

Days	Phase of Development	Up ↑ or Down ↓ Gene Regulation
0 to 3	Dedifferentiation	↑ Cell replication ↑ Cell wall weakening ↑ Water stress ↓ Cell wall synthesis ↓ Auxin transport ↓ Photosynthesis
3 to 6	Root Intitial	↑ Flavonoid pathway enzymes
6 to 9	Root Primordia	↑ Auxin transport ↑ Auxin responsive ↑ Cell wall synthesis ↑ Hypersensitive response proteins ↑ Pathogenesis proteins ↓ Cell wall weakening ↓ Cell wall modification ↓ Water stress
9 to 12	Root Formation	↑ Auxin transport
12 to 33	Root Elongation	↓ Water stress ↓ Cell replication

Figure 1. Microarray analysis of gene expression during the synchronized development of different stages of adventitious root formation of *Pinus contorta* hypocotyl cuttings. Transcript levels of 220 genes and their encoding proteins were up-regulated (increased expression) or down-regulated (decreased expression) (Brinker et al., 2004).

Stock plants can be manipulated to enhance rooting of woody plant species. One technique is to force softwood cuttings (epicormic shoots) from woody stem segments to propagate hardwood species (Fig. 3). Using river birch, silver maple, and stem segments of other woody species, epicormic shoots are forced under intermittent mist, and later harvested as softwood cuttings and rooted under mist (Preece and Reed, 2007).

Various layering systems are used to enhance rooting. With Monterey pine *(Pinus radiata*), which is the most important timber species in New Zealand, trench layering is used in clonal propagation systems. For example, stoolbeds are used and mother plants are topped and their shoots pinned down to produce fascicle cuttings.

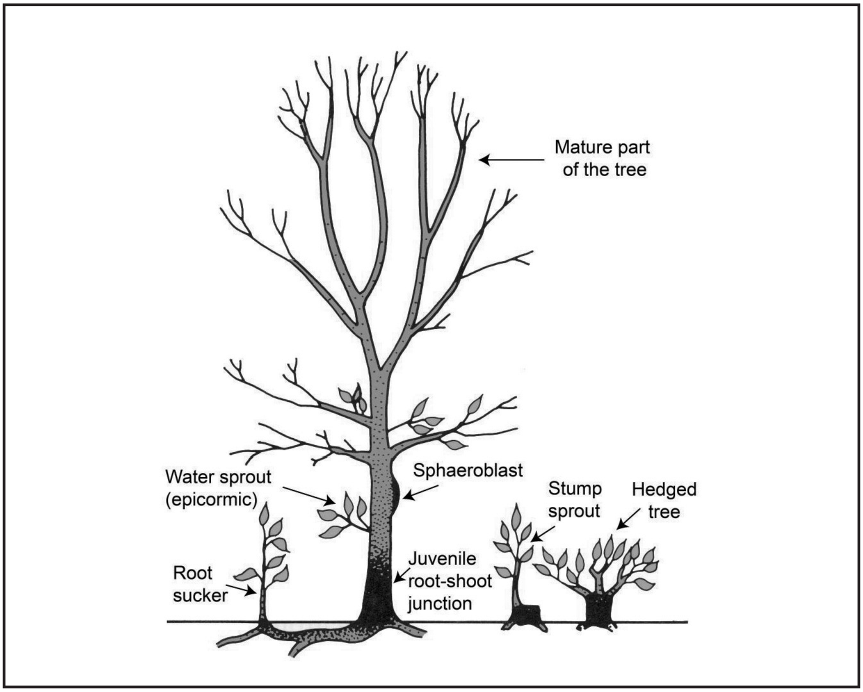

Figure 2. Juvenile-mature gradients occur in seedling trees from the base of the tree to the top. The juvenile root-shoot junction, which is "*physiologically juvenile*" with high rooting potential — even though chronologically it may be decades old. Flowering occurs in the "'*physiologically mature*" part of tree at the apical part, even though some of the flowering shoots may be *chronologically* only several months old; shoots taken from this region generally have low rooting potential. Juvenile structures arising from the "*cone of juvenility*" [dark area] near the base (crown) of the tree include: adventitious root "sucker," water-sprout (epicormic shoot), and sphaeroblast. Stump sprout from severe pruning, and shoots from heavily pruned or hedged bush. Rooting potential is highest from these structures close to the cone of juvenility (Hartmann et al., 2011).

Etiolation or the absence of light can also be used in stock plant manipulation. Etiolation frames are placed over stock plant hedges of lilac (*Syringa vulgaris*) (Fig. 4). *Right:* There is improved rooting following etiolation of *S. vulgaris* 'Madame Lemoine' and *S. vulgaris* 'Charles Joly', compared with cuttings from nonetiolated stock plants which have poor rooting (Fig. 4) (Howard and Harrison-Murray, 1997). Sometimes etiolation of stock plants is used in combination of wrapping black Velcro containing an auxin talc and wrapping it around the base of the etiolated shoots, which are gradually exposed to higher light levels. Enhanced rooting occurs with etiolated Mountain-laurel or spoonwood (*Kalmia latifolia*) 'Ostbo Red' treated with Velcro-impregnated IBA powder. After the shoots green up, they are removed and rooted under mist as softwood cuttings. Highest rooting occurred with Turkish hazel (*Corylus colurna*) shoots that were etiolated and banded with velcro, than made into cuttings and treated with 2000 ppm IBA (Maynard and Bassuk, 1990).

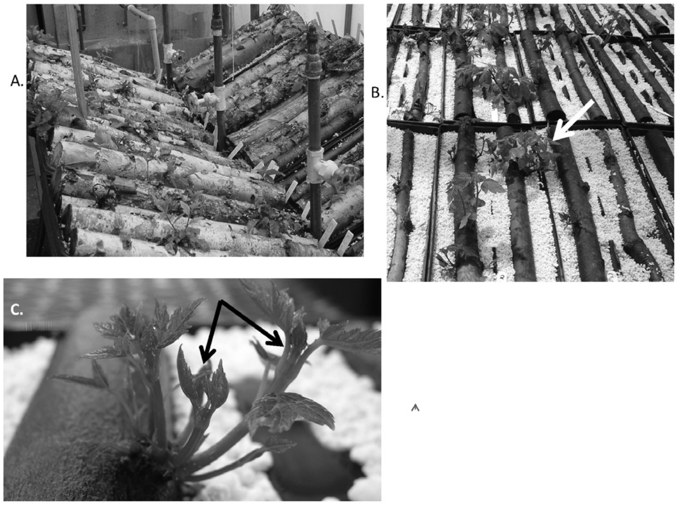

Figure 3. Forcing softwood cuttings from woody stem segments to propagate hardwood species. (a) River birch shoot forcing under intermittent mist, (b) shoot forcing of white ash and silver maple, and (c) epicormic shoots from forced silver maple — will later be harvested as softwood cutting and rooted under mist (Preece and Reed, 2007).

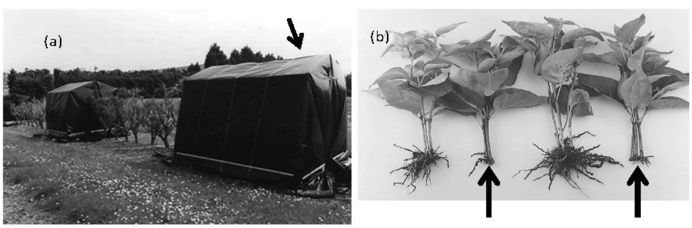

Figure 4. *Left:* Etiolation frames [arrow] in place over stock plant hedges of lilac (*Syringa vulgaris*). *Right:* Improved rooting following etiolation of *S. vulgaris* 'Madame Lemoine' (far left) and *S. vulgaris* 'Charles Joly' (second from right). Cuttings from nonetiolated stock plants have poor rooting (second from left and far right [arrows]) (Howard and Harrison-Murray, 1997).

LONG CUTTINGS

The majority of cuttings are typically 5–20 cm (2–8 in.) long. However, long cuttings of 50–152 cm (20–60 in.) are used to propagate ornamental and fruit crops with enhanced rooting success (Spethmann, 2007). Successful rooting with long, semi-hardwood cuttings has been done with rose (*Rosa* 'Pfaenders') rootstock, elm (*Ulmus* 'Regal'), sycamore maple (*Acer pseudoplatanus*,) pear (*Pyrus* 'Williams Christ'),*Tilia cordata* (linden), and English oak (*Quercus robur*) (Fig. 5). Part of the

Figure 5. (a) A majority of cuttings are 5–20 cm (2–8 in.) long. However, long cuttings of 50–152 cm (20–60 in.) are used to propagate ornamental and fruit crops. (b) Long, rooted semi-hardwood cuttings of rose (*Rosa* 'Pfaenders' rootstock for standard roses) in a greenhouse propagation bed. (c) 9-month-old rooted liners of elm (*Ulmus* 'Regal'), sycamore maple (*Acer pseudoplatanus*), pear (*Pyrus* 'Williams Christ'), (Linden) *Tilia cordata*, and English oak (*Quercus robur*) propagated from long cuttings. Part of the advantage of long cuttings may be the pruning management of the stock plants enhances rejuvenation and rooting (Spethmann, 2007).

advantage of long cuttings may be the pruning management of the stock plants enhances rejuvenation and rooting (Spethmann, 2007). Long cuttings are propagated using fog systems, rather than intermittent mist systems.

AUXINS AND THEIR APPLICATION

Auxins are used to enhance rooting of cuttings and are typically applied as 1–5 second quick-dips, which entails inserting the cutting base into the auxin solution (Fig. 6). Auxins are also applied as talc powder applications to the base of the cutting, and sometimes combinations of a liquid quick-dip followed by a powder application are used with more difficult-to-root species (Hartmann et al., 2011). Some common auxin formulations include: (a) Dip'N Grow liquid rooting compound, (b) Woods liquid rooting compound, (c) Seradix and Hormodin rooting powders, and (d) Hortus IBA water-soluble salts. Auxin solutions used to dip cuttings are discarded at the end of the day. Auxin preparations are stained with food dye to denote different concentrations and stored in color-coded containers. Refrigeration of liquid auxin formulations is used to extend their shelf-life.

The auxin, IBA, is a "pesticide" with an LD_{50} of 100, e.g., it is 15-fold more toxic than the insecticide malathion (LD_{50} of 1,500). While no one has been fatally poisoned by IBA, one needs to be careful in handling auxin. Spray applications of

Figure 6. (a, b) Liquid auxin quick-dips of 1 to 5 seconds. (c) Application of auxin by talc. (d) Spray application at end of day reduces exposure of the propagators to auxin (Hartmann et al., 2011).

auxins can be applied at the end of the day with the mist system turned off, or early morning prior to turning on the mist system. This avoids worker contact with auxin, since just the protected applicator applies the auxin as spray. Some commercial nurseries use auxin spray applications of Hortus water soluble salts from 500 to 1,500 ppm (Drahn, 2007). In Holland aqueous IBA is applied to chrysanthemum cuttings in low concentrations (100 ppm) using an overhead boom system (Fig. 7). The trick to using aqueous auxin sprays is to apply it within the first 48 h of sticking the cuttings (Hartmann et al., 2011).

TIMING, SCHEDULING, AND MAINTAINING THE PLANT'S MOMENTUM

It is important to maintain stock plants that are nutritionally fit and under optimal irrigation regimes. Timing and scheduling is important from "maintaining the plant's momentum" to minimize stress, to harvesting the optimum propagation wood — for maximum rooting and reducing the propagation time under mist. Examples are shown in Figure 8 from: (a) harvesting the right kind of cutting wood during the optimum season — i.e., shoot tips of *Nandina* with no brown wood, trimmed to 4 cm, (b) harvesting cuttings early during the day when water status is optimum are plants are stress-free, and (c,d) storing cuttings in cool-moist refrigerated environments until they can be processed and stuck. Storage under low light, high RH and cooler temperatures helps to control vapor pressure deficit (VPD). Processed cuttings are covered with moist burlap until stuck to minimize plant stress.

During the initial week or two of cutting propagation, it is not necessary to maintain high light conditions under mist. In a study with poinsettia, relative water content, xylem water potential, net photosynthesis and stomatal conductance were initially low with unrooted cuttings (Svenson et al., 1995). Only when cuttings started

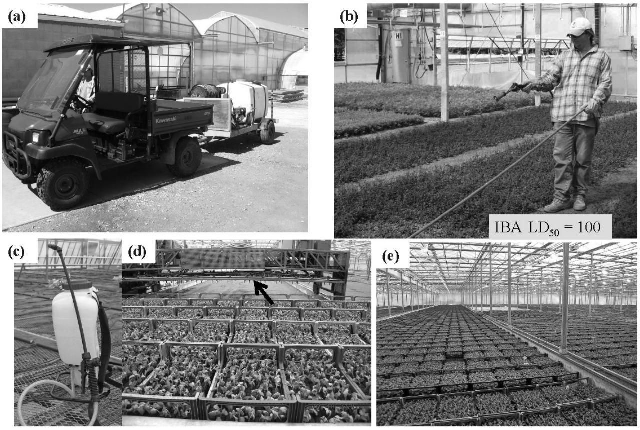

Figure 7. (a, b) Applying aqueous sprays of auxin to cuttings with a high pressure system [the applicator will wear a protective suit, glasses, gloves and respirator during application] (Drahm, 2007). (c) Spray application of auxin can also be applied with back-pack sprayer, or (d,e) with a spray boom applying IBA at 100 ppm in a chrysanthemum propagation house (courtesy Kees Eigenraam and Joel Kroin).

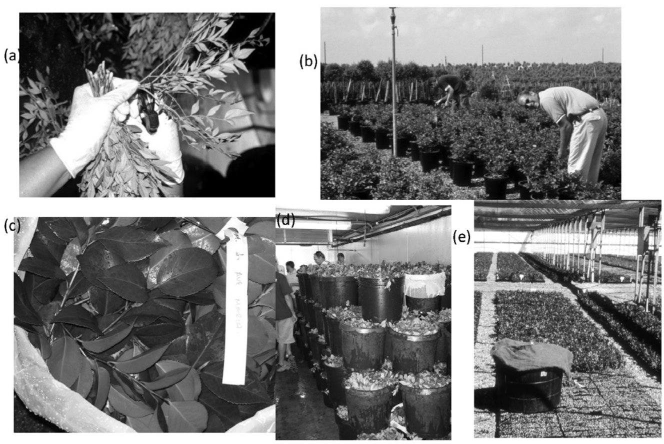

Figure 8. Timing and Scheduling: "Maintaining the plant's momentum" to minimize stress. (a) Harvesting the right kind of cutting wood during the optimum season — i.e., shoot tips of *Nandina* with no brown wood, trimmed to 4 cm. (b) Harvesting cuttings early during the day when plants are stress-free. (c,d) Storing cuttings in cool-moist refrigerated environments until they can be processed and stuck. (e) Processed cuttings covered with moist burlap until stuck.

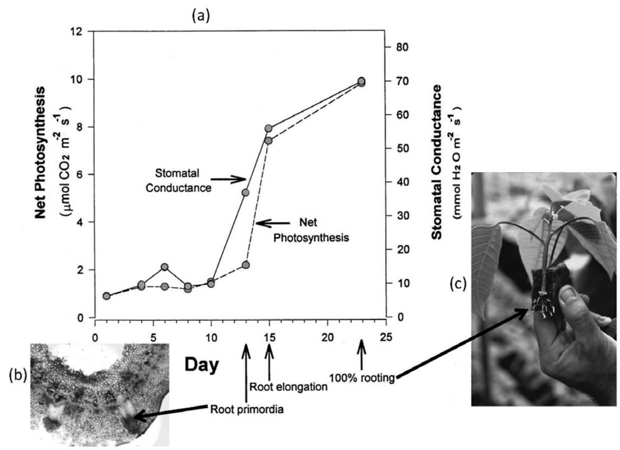

Figure 9. (a) Influence of adventitious root formation on gas exchange of poinsettia (*Euphorbia pulcherrima* cv. Lilo) cuttings. (b) Root primordia were microscopically observed at day 13, when photosynthesis began to increase. (c) Maximum photosynthesis was at 100% rooting (Svenson et al., 1995).

to form root primordia and adventitious roots first became visible did stomatal conductance and net photosynthesis start to increase (Fig. 9). The take home message is that prior to visible roots — keep light levels low to reduce VPD. When roots start to form, increase the light so plants can take advantage of higher photosynthetic rates to improve root development and production of rooted liners.

WATER MANAGEMENT OF CUTTINGS

Proper water management is critical for maintaining proper tissue moisture — if cuttings are to survive, successfully form adventitious roots and develop into commercially acceptable rooted liners. About 1%–2% of water utilized is needed for photosynthesis and plant growth, while the remaining 98% of water is lost to transpiration and the subsequent cooling of leaves. Evaporative cooling occurs during transpiration as water passes from a liquid to gaseous phase (vapor). Transpiration is the "engine" that pulls (lifts) water up from the roots. Unlike people, who can move and find a more comfortable location, a cutting lacks mobility so it needs to do its best to reduce the heat load, which it does through transpiration.

There are three environmental factors that effect transpiration: light, temperature, and humidity. Light causes plants to transpire more rapidly, stimulates the opening of the stomata and warms the leaf. Temperature increases transpiration since water evaporates more quickly. Humidity affects the diffusion of water as a vapor from the leaf through the stomata into the surrounding drier air. Water travels from a high potential (saturated internal leaf cavities) to a lower potential (unsaturated, drier) surrounding air outside the leaf (Davies, 2005).

WATER RELATIONS OF CUTTINGS

The water relations of cuttings is a balance between transpirational losses and the uptake of water. Water travels from the soil (propagation media) through the roots into the stems and into the leaves where photosynthesis and transpiration occurs. Cells must maintain adequate turgor for growth and for initiation and development of adventitious roots. Root meristematic areas also produce a phytohormone, ABA or abscisic acid, which is a chemical signal for drought. As the surrounding soil (medium) dries, ABA travels through the xylem from the roots to leaves and causes the guard cells to collapse, which closes the stomata and helps to regulate the loss of water.

THE PROBLEM

Since cuttings initially do not have roots, they cannot produce ABA to control water loss, and lack effective organs to replace transpired water lost. Cuttings take up water poorly through the base of the stem — until adventitious roots are formed. The cutting base and any foliage immersed in the propagation media are main entry points of water until adventitious roots form. Water absorption through leaves is not a major source/contributor of water balance. It is Important to maintain hydraulic contact between the cutting base and propagation media — thus improving water uptake of cuttings. Wounding increases the contact area between the cutting base and propagation medium for more optimum water uptake of cuttings.

CONTROL OF WATER LOSS IN CUTTINGS (WILKERSON ET AL., 2005)

Intermittent Mist is the most common system for propagating cuttings. Mist is composed of water droplets that average >50 µm, and have a size range of 50 to 100 µm (the diameter of a human hair strand is around 100 µm). The mist condenses and forms a film of water on the leaf surface. Water evaporates from the leaf surface rather than from internal water in leaf tissue. Fog systems produces fine water droplets that average around 15 µm. Fog has a high surface to volume ratio that allows it to remain suspended in air as a vapor (gas) to maximize evaporation. Fog does not condense, which avoids the over-saturation of media and foliar leaching that occurs with mist. Problems with fog systems include high costs and high maintenance requirements — including clogging and wearing out of nozzles. Filtration/deionizing systems are required to remove any salts from the water supply. Contact systems and nonmisted enclosures reduce water loss from foliage and the condensation increases the relative humidity of the air. These systems are simple, inexpensive, and cost-effective. There is minimal condensing, which avoids the over-saturation of media and foliar leaching that occurs with mist. This system works well with hardwood and semi-hardwood cuttings of difficult-to-root species that require longer propagation times. While inherently cheaper, there are problems with contact systems/nonmisted enclosures. It is critical to control irradiance and subsequent heat load via shade and temperature control. The system easily traps heat via light irradiance, which adversely can increase the VPD by reducing RH of air and increasing the air and leaf temperature.

SUMMARY OF OPTIMIZING WATER RELATIONS OF CUTTINGS (DAVIES, 2005)

- Maintain the plant's momentum by propagating during optimum rooting periods, collecting cuttings early in the day and minimizing plant stress.
- Control stress—light, temperature, and humidity (RH) to reduce the vapor pressure deficit (VPD), i.e. an atmosphere of low evaporative demand decreases transpirational losses from cuttings.
- Do not increase light until cuttings start to form adventitious roots.
- Apply just enough mist to form a thin film of water on leaf surface.
- Use a loose propagation media for proper aeration.
- Group cuttings in propagation by species requirement for moisture, i.e. *Zelkova* and Chinese elm have a lower tolerance for mist and saturated propagation media than River Birch.

SYSTEMS FOR STICKING CUTTINGS — DIRECT ROOTING

Systems for sticking cuttings. More cuttings can be rooted per unit area in a conventional plastic rooting flat, but additional labor is needed to initially transplant rooted cuttings into small liner pots, and then transplant into larger containers or produce as a field-grown crop. Direct sticking (direct rooting) allows cuttings to be rooted directly into small liner pots which saves labor and avoids transplant shock to the root system (Fig. 10). With some species it is possible to direct root into large 3.8-liter (1-gal) containers with no transplanting steps (Fig. 10).

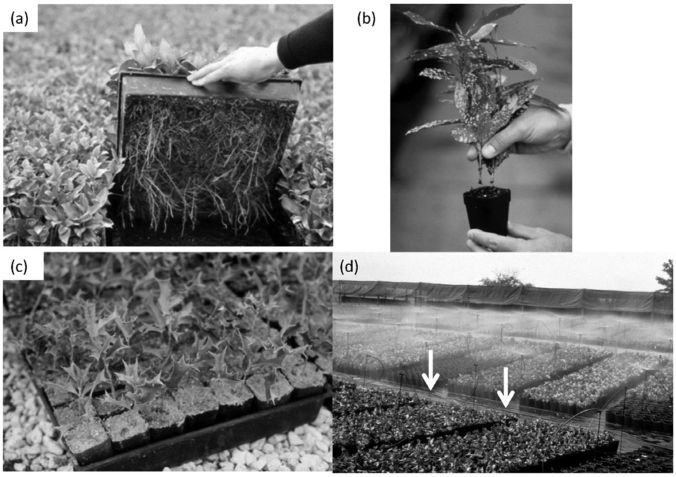

Figure 10. Systems for sticking cuttings. (a) More cuttings can be rooted per unit area in a conventional plastic rooting flat, but additional labor is needed to initially transplant rooted cuttings into small liner pots, and then transplant into larger containers or produce as a field-grown crop. (b and c) Direct sticking (direct rooting) allows cuttings to be rooted directly into small liner pots which saves labor and avoids transplant shock to the root system. (d) Direct sticking into large 3.8-liter (1-gal) containers with no transplanting steps. Notice sloped incline (arrow) for better drainage.

DO NOT PROPAGATE ALL ITEMS IN YOUR INVENTORY

It is not always cost-effective to propagate all inventory items in a nursery or greenhouse operation. It may be more cost-effective to buy in rooted liners, seedling plugs, tissue culture-produced liners, and/or grafted or budded liner trees. Custom propagators can be more efficient and effective in producing selected liner plants. A good example of this is the millions of unrooted cuttings being produced and shipped internationally from Central America to U.S.A. nursery and greenhouse companies to root and finish off the plants. Propagators need to be diligent in their handling, storing, processing, and sticking.

SANITATION & DISEASE CONTROL

Good sanitation and disease control are part of best management practices (BMPs) to minimize plant stress, production costs, and enhance plant quality. Some correct and incorrect ways to propagate are illustrated in Fig. 11. Poor sanitation with algae build-up (arrow) — can harbor disease, insects and creates a poor propagation and work environment for personnel. (b) Good cultural & chemical practices: Sanitizing concrete pads before starting the next propagation crop. Some common

(a)

(b)

Figure 11. Some correct and incorrect ways to propagate. (a) Poor sanitation with algae build-up (arrow) — can harbor disease, insects, and creates a poor propagation and work environment for personnel. (b) Good cultural and chemical practices: Sanitizing concrete pads before starting the next propagation crop.

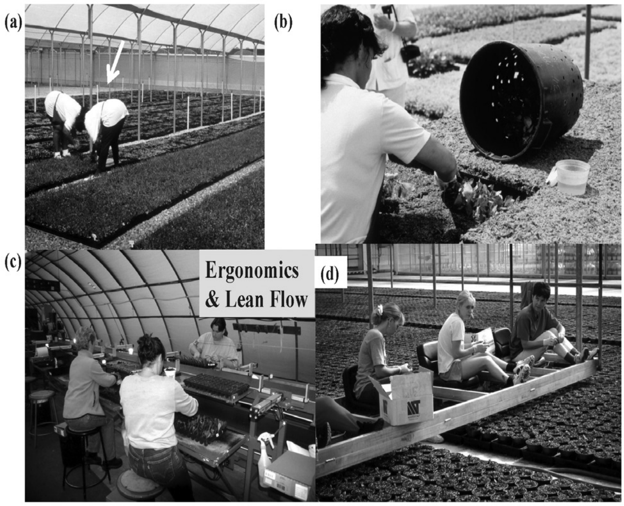

Figure 12. The importance of ergonomics and efficiency of movement. (a) Poor ergonomics with uncomfortable back posture, compared to (b,c) good ergonomics with correct posture, close proximity of materials and economy of movement which enhances worker efficiency. (d) Ultimate of efficiency with propagators "floating" about the containers sitting in a trellis system for direct sticking in a flood floor system (Hartmann et al., 2011).

chemicals for disinfecting propagation facilities and propagules are: (a) Benzylkonium chloride, (b) hydrogen dioxide, (c) bromine and (d) diluted sodium hypochlorite solution (household bleach) can be used for (d) disinfesting both propagation facilities and propagules. Diluted household vinegar can control algae and moss along walkways. Always follow directions and try small trials first.

ERGONOMICS AND LEAN FLOW (EPPS, 2009)

Figure 12 depicts the importance of ergonomics and efficiency of movement. (a) Poor ergonomics with uncomfortable back posture, compared to (b,c) good ergonomics with correct posture, close proximity of materials, and economy of movement which enhances worker efficiency. (d) Ultimate of efficiency with propagators "floating" about the containers sitting in a trellis system for direct sticking in a flood floor system.

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Innovative Options in Plant Selections for Southern Gardens©

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INTRODUCTION

It probably began in the late 1970s to early 1980s when Dr. J.C. Raulston started making the nursery industry more aware of the importance of new species and cultivar introductions that would broaden the market for the ornamental plant industry. No one ever comes into a garden center and asks, "What's old?" Now with increased breeding of annuals, perennials, and "woodies," this has become even more important. But other sources of new introductions can come from exploring foreign markets as well as local hobbyists. We will examine some selections that will increase the plant palette of southern growers.

DISCUSSION

Akebia trifoliata **'Silver Dust'** is a new selection found in Japan and hardy to Zone 5. This species is not as well known as *A. quinata*, which also has a variegated form, but this variegation is more stable. It has deep burgundy-red flowers in hanging panicles. It is easily propagated from semihardwood cuttings. It climbs by twining and does well in either full sun to fairly dense shade. Fruit is edible.

Anodendron affine **'Gold Splash'** is a genus and species native to Japan and is not well known in the west. It is in the family *Apocynaceae* with *Trachelospermum*, *Nerium*, *Adenium*, *Mandevilla*, and many other genera. It is a vine which climbs by twining with narrow lanceolate leaves to 6 in. long, and in this cultivar are heavily splashed yellow and cream. It forms terminal and lateral paniculate flower heads in the fall which then open in late winter as light greenish yellow with an extremely sweet fragrance. The cold hardiness is not well known although I have had a 5-gal specimen remain out of doors through -8 °C with no damage, which would probably make it a Zone 8–10. Its incredible fragrance and variegated foliage will be its greatest assets. Roots best with high temperatures using semihardwood cuttings.

Ardisia crispa **'Kokkou Daruma'** is a cultivar of this very cold hardy species of *Ardisia*. In Japan one will find numerous cultivars of this species which are often displayed in shows in the "Koten Engei" style where they are shown in decorative porcelain pots. But in the nursery trade, this would make an ideal plant to be sold for the Christmas season market. Even with its variegation, it comes reasonably true from seed that needs no pretreatment for germination. It is a very slow grower and a Zone 7 plant.

Campylotropis macrocarpa is an obvious member of the legume family with its lavender to purple pea-like flowers which are arranged in panicles, terminally and laterally, along its stems from late summer to fall. It has a trifoliate leaf similar to *Lespedeza* on slightly pendulous branches which can reach 1.2 to 1.5 m (4 to 5 ft). It will perform well in full sun to part shade and roots well on softwood cuttings. Zones 5–9. Native to Korea and China.

***Callicarpa dichotoma* 'Shiiji Murasaki'** is grown more for its foliage than for its fruit. It is a weak bloomer and fruiter, but its soft white variegation has a much longer period of interest than either its flowers or fruit would have had. This is one of the few callicarpas that is a foliage plant. It is likely a Zone 7–9 plant even though this cultivar is definitely hardy to Zone 5. It propagates easily from softwood cuttings.

***Calycanthus floridus* var. *glaucus* (syn. *Laevigatus*) 'Purpurescens'** is an unusual selection of our native sweetshrub which has purple undersides to its leaves on the new growth. Another great characteristic of this cultivar is its incredible fruity fragrance. I acquired this selection from a collector in Japan, but he acknowledged that he had gotten it from Europe. As with all *Calycanthus*, it is very difficult to propagate from cuttings, but it suckers profusely from spreading rhizomes.

Euchresta japonica is a rare leguminous (family *Fabaceae*) plant found in mountainous areas of its native Japan. It is a small evergreen understory shrub 30 to 80 cm (1 to 2.6 ft) native to the main island of Honshu as well as the two southern islands of Shikoku and Kyushu. In April, it flowers with 20- to 25-cm (8- to 19-in.) terminal and axillary racemes of small white pea-like flowers and has dark green, alternate, trifoliate, entire leaves. It produces 10-mm glossy berries along its rachis which begin green and then turn a purplish-black.

***Enkianthus quinqueflorus* 'Pink Chandelier'** is an evergreen shrub native to southern China which produces "glass-like" pink-edged, lantern-like flowers which are three times the size of *E. campanulatus*. They hang from the tips of its branches amongst the leaves which are whorled around the terminal bud. When first acquired from a specialty nursery in Japan, it was thought to be very cold tender, but since it has grown outside in a container down to -10 °C with no damage. It flowers in Zone 8 between mid March and early April and propagates by semi-hardwood cuttings.

***Gardenia jasminoides* (syn. *augusta*) 'Kaleidoscope'** was an unnamed *Gardenia* with variegated foliage found in a small rare plant nursery in Japan. It has a quite variable variegation of irregular cream-white to yellow margins and fragrant single white flowers. The flowers are followed by very ornamental red seed pods. But its most amazing trait is that it is extremely cold hardy for a variegated *Gardenia*. It is quite vigorous and will probably easily reach 1.2 to 1.5 m (4 to 4.9 ft) in height and spread.

***Hieracium nevosum* or rattlesnake weed** is an incredible little native "weed" that might be overlooked if one were just walking in the woods, but when grown in cultivation it doubles in size and is extremely ornamental with its small 2.5-cm (1-in.) daisy-like flowers produced on wispy wands of 30–36 cm (1 to 1.2 ft) from mid-April to early May. It is amazing how long it will flower. It maintains a rosette of leaves all year round at ground level, but in March, it begins to put up gossamer-like stems which terminate in loose panicles of brilliant yellow flowers from April into May. It is native to a good portion of the Southeast mostly in the Piedmont on clay soils. Not often found in sandy soils. Grow in full sun to part shade.

***Hedychium densiflorum* 'Assam Orange'** is one of the most cold-hardy of our ornamental gingers. This is the true *Hedychium densiflorum*. Unfortunately there are many plants being offered as this species that are not correct. Its name "*densiflorum*" alludes to its small brilliant orange flowers which cling tightly to its rachis, forming a dense flower spike late in the summer into early fall. It was found by the superintendent of the botanical garden in Katmandu, Nepal, and named for his son, Assam. One of the nicest characteristics of this selection is that it only gets to about 0.8 to 0.9 m (30 to 36 in.) tall in a tight clump. It seems to be happiest for us in filtered sun or morning sun and afternoon shade.

Ilex latifolia **'Variegated'** is a selection found in Japan and shared with us by Mr. Mizunami Yamaguchi, Gifu Prefecture. This luster-leaf holly has irregular gold to cream yellow margins and has proven extremely stable. The only reversions have been to all yellow, but even this will harden off to green. It has not flowered for us so its sex is unknown. Even the parent plant in Japan which was about 3 m (9.8 ft) tall, had no fruit, so this cultivar may be a male. It roots in high percentages, but it is extremely slow, taking very firm wood in late summer or early fall on bottom heat. It grafts quite easily using 'Nellie R. Stevens' as the understock.

Itea virginica **'Japanese-American'** was sold to me in Japan as *I. japonica*, but it is fairly obvious that it is not. The native Japanese *Itea* does not sucker like our native species. It is thought that this form was carried to Japan in the early 1900s from the U.S.A. and became known there as *I. japonica*. Flowers open white and then turn blush pink and the foliage is practically evergreen in Zone 8 with no fall color. So the provenance of this selection is probably the Deep South. But it has also not shown the propensity for leaf spotting common with many of our established cultivars.

Morus alba **'Issai'** is a compact fruiting mulberry that produces large edible fruit even when the plant is only 46 cm (18 in.) high. The Japanese said that it was found in a very "outlying" province of China. It makes a superb backyard fruit bearer of a large shrub to small tree proportions. It roots very easily from softwood cuttings under mist. Many times, succeeding flushes through the growing season will also fruit. It is probably the same hardiness as the species.

Magnolia changhungtana is a species Chinese magnolia that has large white flowers with red anthers. Growing at the South Carolina Botanical Garden at Clemson, this species has tolerated temperatures to -15 °C. Presently it is being chip budded with success using *M. maudiae* as an understock. Northern hardiness is unknown, although it is at least a Zone 7.

Magnolia **(syn.** ***Michelia*****)** ***crassipes*** grows similarly to the species *M figo* as a large shrub or small tree to 5 m (16.4 ft) in its native China. This is a selection found in the wild in China with its intensely velvety burgundy flowers which have great fragrance. It does not root as easily as *M. figo* and in Japan it is commonly sold as a grafted plant.

Magnolia **(syn.** ***Michelia*****)** ***laevifolia*** **'Snow Angel'** is a selection of Bobby Green, Green's Nursery, Fairhope, Alabama. It has a dense, lower spreading habit than the species. It flowers in late March and early April in Zone 8, which misses most of the late freezes. It roots from semihardwood cuttings. This species is probably at least Zone 7 hardiness.

Magnolia **(syn.** ***Michelia*****)** ***foveolata*** **'Shibamichi Gold'** has proven quite cold hardy into Zone 7. In its native China, this species will reach 30 m (98 ft) tall with leaves 17 to 23 cm × 6 to 11 cm (7 to 9 in. × 3 to 4 in.). Its most unusual asset on this selection is the gold indumentum on both the top and undersides of its leaves on the new growth. With mature leaves, the indumentum remains on the undersides.

The flowers are only 6 to 9 cm (3 to 4 in.) in diameter. It does well as when grafted to *M. maudiae* understock.

***Poncirus trifoliata* 'Snow Dragon'** is a variegated, contorted hardy-orange. It is quite variable in its variegation with some new branches and leaves being devoid of chlorophyll initially, but the stems will eventually harden off to green. This is truly a novel "collector" plant; not for the big boxes. It propagates quite easily by cleft grafting on seedling understock in late winter, but it can also be rooted. Zones 6–9.

Poliothyrsis sinensis is the sole member of this genus and an interesting Chinese species which flowers in the Deep South in early summer, but later further north. The only other member of its family, Flacourtiaceae, commonly grown is *Idesia polycarpa*. It was only discovered late in the nineteenth century by Augustine Henry. It exhibits 15- to 20-cm (6- to 8-in.) terminal panicles of small white apetalous fragrant flowers turning yellow as they age. Foliage is an attractive dark lustrous green, turning yellow-burgundy in fall. In its native habitat it reaches to 15 m (49 ft). It propagates quite easily from softwood to semihardwood cuttings.

***Platycrater arguta* 'Kaeda'** is found in the family Hydrangeaceae and makes a low deciduous shrub of only 75 cm (30 in.). In late spring it exhibits terminal panicles of sterile florets and complete flowers, and it has a stunning gold fall color. It roots very easily from softwood cuttings. Hardiness is probably Zones 7–9.

Prunus japonica or Japanese bush cherry is one of the more showy flowering shrubs for us here in early to mid March with its branches being encircled with small medium to deep pink flowers so that the branches are not even visible. It will reach 1.5 to 2 m (5 to 7 ft). It is content to grow in full sun to part shade. The flowers are followed by bright red "cherries" that are edible. Far superior to *P. glandulosa*. Easily rooted from softwood cuttings. Hardiness Zones 4–8.

Podocarpus macrophyllus is normally considered to be a shrub with medium green foliage, but with two selections from Japan, 'Royal Flush' and 'Golden Crown' have bright pink and yellow new growth, respectively; these break the mold of this species. All flushes of new growth on each selection show their respective colors, even in the heat of the summer. Easily propagated from semi-hardwood cuttings. Zones 7–10.

Rhodoleia henryi is a more cold-hardy species than its better known relative, *R. championii*, found at over 2,400 m (7,874 ft) elevation. This unusual evergreen in the family Hamamilidaceae has exquisite geometrically shaped rose-red flowers up to 3 to 4 cm (0.8 to 1.6 in.) in diameter. This species makes a large shrub to small tree [to 15 m (49 ft) in its native haunts] and roots easily from semihardwood cuttings.

Rohdea japonica is an evergreen perennial preferring dry shade and will grow in Zones 6–10. The Japanese have made many selections for unusual foliage, form, and variegation, growing them in the garden or in containers where they are shown in the "Koten Engei" style. Slow to divide, but they have been propagated by tissue culture. When growing variegated selections from seed, one may get new variegated forms.

CONCLUSION

With the intense interest in "new" selections and the ability to "protect" new introductions, there will continue to be much interest in finding and developing new cultivars. Many times, this will also increase the marketing in plants by broadening the gardening public's palette as they discover the newest and the best.

The American Nursery Industry: A Look Fifty Years into the Future©

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INTRODUCTION

Fifty years ago gasoline was $0.35 a gallon and the minimum wage was $1.25. A 40-h week at minimum wage earned a take home pay of about $45.00. Many people aspired to make $15,000 per year. A new car was between $1,500 and $2,000. Fast forward to today, the minimum wage is around $8, a new car costs around $25,000, and many people aspire to make $50,000 per year.

Back in the day, container stock became a staple 50 years ago and the containers of choice were two types: 1-gal food cans, which were cheap and plentiful, and 5-gal egg cans or nut cans from India that were dipped in tar to retard rusting. Nursery flats were either made of wood or heavy gauge zinc. Plastics were rarely used. Fertilizer came in two forms: either a quick-acting field-grade fertilizer with obvious dangers to container plants due to burning, or very limited organic nutrition in the form of dried animal manure. Potting soils were made from sedge peats, sawdust, and other locally available organic waste products.

CHANGE STARTED TO CREEP IN: THE FORMATION OF THE IPPS

In addition to those basic ways of life both for individuals as well as the nursery industry — change was coming. What affected us most was the formation of the International Plant Propagators' Society. It was started by the great James Wells, who was President in 1951. The IPPS has progressed steadily ever since. With a great deal of work and diligence, let us hope that another 50 years are still in the offering for the IPPS. The IPPS help to forge and focus the nursery industry towards a much greater level of cooperation, as well as fostering new developments and a vastly improved communication among members.

Glass greenhouses, traditionally used for floriculture crops, found new uses as propagation houses for woody plants, especially with the advent of mist systems for the rooting of cuttings. The old Nearing frames and cold frames found other uses, but were quickly abandoned for rooting of cuttings in favor of the newer, improved rooting techniques. Container culture became more standardized as nurseries began to emulate one another. This standardization was critical because it allowed for greater consumer acceptance of our products. It also had the positive affect of opening a market for suppliers to offer a universal product that was useable by all nurseries and not limited by tailor-made high cost items. Without standardization, the suppliers to the nursery trade would have ignored the industry, since the old system was too hard to service. Uniformity of needs and wants resulted in an increased emphasis on products that had a broader appeal.

The IPPS also fostered increased university participation, which in turn lead to an awareness of the needs of the nursery trade and a subsequent increase in research by professors and graduate students — directed to solve complex production issues. As a result of this, liquid fertilizers began to make an appearance in the mid-1960s followed later in the decade with the use of controlled-release fertilizers. Back then, we all had a steep learning curve to keep pace with such developments.

Uniformity of soils, containers, and fertilizers lead to a consistency in plants — which lead to a greater potential for marketing superior plants. Consumers came to expect a standard grade or form, such as the common usage of generic terms such as 1-gal and 5-gal, stemming from the old days of using metal food containers. This had nothing to do with the plant parse, but more to do with the container and how it was sold. Such changes, once started, progressed quickly. Fast forward 50 years: gasoline in recent years is around $4 per gallon, containers are made of plastic, and we have progressed from 1-gal to greater than 60-gal containers, and all sizes in between.

Flats and trays are made of plastic, and there is considerable cross-over technologies from all facets of horticulture — so that the annual growers affect perennial growers who then influence woody plant growers. However, the heavy use of fuels for equipment and heat, the use of plastics for overwintering as a non-reusable throw-away technology and the massive use of plastic pots as an eventual throw-away product has contributed to our global carbon addiction.

CARBON ADDICTION AND HEAT SOURCES

Cheap sources of hydrocarbons to facilitate our industry have lead us to an irrational use of products that we take for granted, and ones that we eventually throw away. Fifty years from now much of what we assume is here to stay will be gone, and we should start making adjustments now to anticipate the loss of most of the materials we commonly use. If we start to embrace the change that is coming and develop sound renewable systems to compensate we will progress into the future with ease. An obvious place to start looking are heat and energy systems.

Heat systems of the future will make use of several different technologies such as solar, air and hot water systems, solar-generated electric systems, and above all waste heat systems that make use of cast-off and residual materials, much of which currently is buried to dispose of it. We will also have to make use of farmed energy supplies. Costa Rica and Panama are home to a unique tree, *Brunellia costaricensis*, which has freshly flowing sap that is flammable. The local natives in the jungles use it as a fuel for flame torches. Such plants could be improved and utilized on farms to produce fuels. Thomas Edison took a long hard look at species of *Solidago* (goldenrod) , some of which grow to 3 m (10 ft) or more, because of their high latex content. *Hevea brasiliensis* (the rubber tree of commerce) has been forgotten in place of rubber produced from petroleum. In fifty years, we may not have sufficient petroleum to produce rubber. These plants and many others could well come to the forefront once again. A whole new industry will form to develop and produce renewable fuels from natural sources.

SUSTAINABILITY

A key word these days is sustainable — and when directed to the nursery industry it means the development of systems that are not ultimately on a one-way track to a landfill. Sustainable means that nurseries will have to retool their physical plant and operations to make a closed system that provides their needs and at the same time allows for the continued export of consumer materials. Technologies will have to be developed to accommodate new sources of materials that can be converted to potting soils and energy supplies.

Nurseries will move beyond cell phone towers as cash cows, and adaptations will be made towards greater use of combined space to make use of solar, wind, and biomass production. In some cases there will be in-house utilization of these products and perhaps some surplus to sell off-site. Soil mixes will change from fossilized peat moss to the use of self-generated organic matter and sedge peats (oddly something that was in vogue 50 years ago), but done with more efficiency and effectiveness in the coming 50 years. Water systems will be completely closed and reusable as many are today, and it is the water system recycling and usage that will serve as the model for these other systems.

CHANGING WHAT WE GROW AND SELL

For many nurseries the product mix we feel so strongly about will change. Either through a change in consumer demands, but more importantly there will be a change in the availability of raw materials to produce that product which will limit or eliminate some plants from profitable production. An example of what can happen is the affect that high fuel costs for heat is having by increasing the costs of grafting small container plants, in some cases the cost increase has precluded the nursery from further grafting operations. Hopefully, 50 years from now transportation limitations based on the high costs of fossil fuels will be eliminated; but if the nursery industry is still dependant on fossil fuels, subsequent costs might very well eliminate the long-distance hauling of finished plants. Even with a resolution to the transportation problem, there will be an increased emphasis on local or regional plant production as opposed to the current cross-country shipping that is practiced by growers on the U.S.A. West Coast. A locally driven nursery economy might also dictate a change in plant varieties and push a marketing selection process towards specific plants, with a loss of other plants. Of course as with all markets, a shortage of “x” or “y” plant will lead to a cost escalation of those plants. This will be a double-edged sword, since some nurseries will lose out not having these varieties in their inventory, while others will capitalize on the induced shortages.

Fifty years ago there were many operations that grew carnations, roses, and other cut flower crops, even well into the late 1970s. But those operations today are gone, falling victim to high energy costs for heat. Old rose production houses and carnations production houses are littered all over the U.S.A. as relics of a bygone era. Today, labor costs take some of the largest bites out of nursery production costs; however, 50 years from now, energy will be the largest nursery production cost. The labor work force will shrink as more automation and intelligent robotics are utilized.

During the latter half of the 20th century, more than 50% of the combined populations of the U.S.A. and Canada lived within a 805 km (500 radial miles) of New York City. But as we approach the 2nd decade of the 21st century, population dynamics now show the most rapidly growing state in the Union is well away from New York. Indeed, the exodus is south to Florida and the surrounding U.S.A. South Eastern Atlantic and Gulf Coast States. In 50 years a higher percentage of the population lives below the Mason-Dixon line. What is driving this migration: quite simply — it is energy costs. It is cheaper to live in the deep South than it is in the energy consuming Northern U.S.A. This trend will foster a new set of nursery products, and to pursue this — nurseries will leave the north and relocate in the Southern U.S.A., especially since transportation costs will alter costly long-distance shipping .

GLOBAL WARMING AND THE CHANGE IT BRINGS

As a practical matter global warming is a reality, and it too will drive plant production patterns distinctly. Plants such as *Rhododendron catawbiense* (Catawba rhododendron) may well disappear from the radar screen and might be replaced by *Fuchsia magellanica* (fuchsia). We might see the development of more cold-hardy citrus and other plants that have both a cold tolerance to some levels and an increased heat tolerance. Plants from what is now the lower South will move up to the Mid-Atlantic States. The population shift from the North to the Southern U.S. will bring a nostalgia for what was once familiar — so some plants may undergo a breeding or selection shift towards accomplishing the goals of greater heat tolerance, as well as maintaining a connection to the past, such as lilacs (*Syringa vulgaris*) 'Lavender Lady', 'Blue Skies', and 'White Angel' from Southern California.

Global warming will also foster a legion of new pests, which might exacerbate existing pests, and will present a new set of problems to nurseries as well as allowing the introduction of new pests into new environments. We are just now beginning to see the impact of pests such as emerald ash borer, bacterial leaf scorch in oaks, Asian long-horned beetles, and sudden oak death. These pests will undoubtedly prosper from global warming as will a host of pests we have not had to deal with. Some pests such as Japanese beetles are held in check somewhat by below zero temperatures in the Northern states. However, when these low maximum temperatures are no longer reached, Japanese Beetles will have every opportunity to prosper. Pests such as Emerald Ash Borers, which entered the US via wooden pallets from China, and Japanese stilt grass (*Mycrostegia* sp.), which came in as packing material from Asia — illustrate how easy it is for pests to enter our environment undetected, until they become problematic. With the advent of even more trans-global transportation links and increased movement of people the advent of more pests will certainly occur.

CONSUMER SELECTION PRESSURE FOR PLANTS

Climate is not the only factor that will drive change in the next five decades. Consumers will change their focus, and there will be a shift from the whole garden experience to that of a much more narrow focus. There will be more emphasis on "throw-away" plants. Consumers will shift to buying plants that look good for awhile and when they do not hold up the plants will be tossed in favor of something more attractive. In association to this will be a change from the traditional garden center to the fast food version of plant selling: the box store. Actually the process will go beyond the box store and will infiltrate new venues such as discount stores and supermarkets. In addition to annuals and showy flowering plants such as dwarf roses and poinsettias, throw-away plants will also encompass some flowering shrubs and hardy perennials. Just recently, one mid- sized perennial grower has signed a contract with Whole Foods Market® to distribute perennials with good flowering characteristics.

Container gardens will become more prominent and plants to satisfy that demand will become a norm. Gardening will be a quick and entertaining activity and less of a chore. The consumer will not want to spray, weed, or otherwise do something that will increase their work load.

Tough, low-maintenance plants will become the standard. For those willing to adapt, this will be a new market opportunity.

SO WHAT ABOUT B&B TREES?

Will balled and burlapped (B&B) trees become a thing of the past? In 50 years, probably so. The specialized labor force to produce B&B trees is rapidly disappearing and it will only get worse. Larger trees take up a large amount of production space and will cease to be cost effective. There are few if any new B&B nurseries being formed now. The high cost of real estate cannot be offset by the production of B&B trees. The consumer does not want to bother with such labor intensive upkeep at the home level, which will cause a further decline in B&B tree sales. The labor pool within the U.S.A. will continue to shrink away from the agricultural/ horticultural industries, and the high cost of shipping will be the death knell for the B&B tree market .

There will be increased emphasis on pot-in-pot culture and in regular container culture of trees, with the possible exception of exceedingly large trees which generally occupy a separate market niche than that of smaller B&B trees. A most important facet of this production shift from B&B trees to container trees is the adaptability of container tree operations to more nimbly adapt to consumer demands and changes of preferences. B&B tree nurseries cannot do this, and so will lose out in the long run.

FERTILIZERS THAT WERE NOT YOUR GRANDFATHER'S

Much of what we take for granted as always being there, will quite simply not be there — at least not in the form that we currently recognize. Fertilizers are but one example. In 2002, ammonium sulfate cost $200 per ton, but by 2009 the price rose to $800 per ton and continues to increase. Unless they are derived from natural organic materials, most increase in price. Nurseries will have to develop new strategies to capitalize on renewable resources of fertilizers since products derived from fossil fuels, such as ammonium sulfate, will be cost-prohibitive. Fertilization practices based on nonrenewable products and methods are not sustainable and will disappear. Practices based on renewable products such as soybean, peanuts, and other nitrogen fixing legume-derived fertilizers will become the new benchmark.

NEW PLANT INTRODUCTIONS

What can we expect with respect to new plant introductions within the next 50 years? The consumers will demand more showy and colorful annuals and tropical perennials. Plant diversity available through nurseries will increase to meet the needs of the small scale gardens. Tropicals will continue to advance and fill much of the market demand for "Fast Paced Plants." Cold hardy perennials will have a place in the future, but to a lesser extent than today. The perennials of the future will have to bred to adapt to a production process that pushes them from seed or cutting to blooming size in a matter of months — not years as it takes now. For consumers, perennials will become hardy annuals.

"Fast-Paced Plants" will mean fast-paced nurseries, just-in-time deliveries and the servicing of more local markets. The selection pressure to find new varieties to fill the new market niches will mean an increased demand for plant breeders and development. There will be genetic engineering for low-volume crops such as roses and trees and shrubs so that they can meet specialized demands. Chances are that due to increased environmental awareness and the reluctance of the consumer to devote large amounts of time to garden maintenance, much of the pesticides that we know today will not be available. Plants will have to be bred and developed to be more self-sufficient, in other words — "bullet proof." Emphasis will be on bigger and showier blooms, greater durability in the home or office environment, greater disease resistance, and more tolerance to environmental pressures.

LOCALLY GROWN RAW MATERIALS — WHAT IS THAT?

Other innovations in the future will be in the development of locally grown raw materials such as the trend nowadays towards raising pine trees for raw materials for potting soils. Biofertilizers, such as mycorrhiza, could be extensively used and become part of the horticulture/agriculture process. Fixed structures may once again become part of the nursery environment for overwintering as opposed to plastic-film-covered hoop houses with the associated throw-away mentality. Biocontrol agents for weeds such as using species of *Brassica* as alleopathic agents to kill weed seedlings will be a key component for nurseries.

To meet the challenges of the future, we will have to have some critical tools. We will need high-tech field-experienced *whole plant biologists*. We will need plant breeders with imagination and foresight to see beyond just a pretty flower. We will need bioengineers to develop new forms of raw materials, and horticulturists and nursery specialists to make use of these raw materials. Raw material production will become a new horticulture activity on its own.

Finally, to paraphrase Oliver Wendell Holmes: "We do not quit working or playing because we grow old, rather we grow old because we quit working and playing."

Holly Response to Phosphorus in Controlled-Release Fertilizer©

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INTRODUCTION

Controlled-release fertilizers (CRFs) labeled with more than 3% P_2O_5 are often applied to container-grown plants. Soluble phosphorus (P) leaches rapidly in substrates composed mostly of pine bark (Yeager and Barrett, 1984). Thus, one approach to achieving a reduction in P loss from the nursery is to reduce the amount of P applied. Midcap (2004) determined that application of CRFs labeled as 2% or 6% P_2O_5 and applied at P rates of 71 or 136 $g \cdot m^{-3}$ (54 or 104 g/yd^3) of substrate, respectively, resulted in similar growth of *Hydrangea macrophylla* (Thunb.) Ser. ('Nikko Blue' and 'Bailmer', Endless Summer™ hydrangea). The purpose of this research was to evaluate holly plant growth response when the substrate was amended with CRF containing different amounts of P.

MATERIALS AND METHODS

Multiple-branched liners of *Ilex cornuta* 'Dwarf Burford' (syn. 'Burfordii Nana') Lindl. & Paxt., *I. crenata* 'Helleri' Thunb., and *I. vomitora* 'Nana' Ait. (dwarf yaupon) potted 15 Aug. 2006 in 10-L (#3) containers were grown in a substrate of 2 pine bark : 1 Canadian peat : 1 sand (by volume). The substrate was amended with 4.2 and 0.9 $kg \cdot m^{-3}$ (7 and 1.5 lb/yd^3) of dolomitic limestone and Micromax® micronutrients (The Scotts Company, Marysville, Ohio), respectively. The container substrate was then amended with one of the following CRFs which varied only in P content:18N-0P-10K, 18N-0.4P-10K, 18N-1.3P-10K, or 18N-2.6P-10K (Harrell's Inc., Lakeland, Florida). Each of the four CRFs, was applied at 46 g per container (7.8 lb/yd^3) which supplied P at the respective rates of 0, 20, 60, or 120 $g \cdot m^{-3}$ (0, 15.3, 46, or 92 g/yd^3). Twenty plants were grown with each CRF in a randomized complete block arrangement (one plant per treatment in each of 20 blocks) under natural lighting. Each container was irrigated via one 18-cm-diameter Dribble Ring (Dramm Corp., Manitowoc, Wisconsin) placed on substrate surface. Approximately 400 ml of water was applied when irrigation was needed (once or twice a week after experiment initiation to daily at termination). The experiment was conducted in Gainesville, Florida (82.35 W longitude, 29.69 N latitude). Plants were covered with plastic sheet each evening when there was the potential for frost the following morning. Plastic was removed the following morning after frost dissipated.

The height and widths of all plants were measured once every 2 months. Measurements from the substrate surface to the top of each plant (plant height), the plant width at the widest point, and the plant width perpendicular to the widest point were recorded until plants obtained size specification designated as Florida Fancy according to *Grades and Standards for Nursery Plants* published by the Florida Division of Plant Industry (Anon, 1998). 'Burfordii Nana' is an upright spreading plant that meets Florida Fancy standards when shoots are 46 cm (18 in.) high and

36 cm (14 in.) wide for plant in 10-L (#3) container. 'Helleri' and dwarf yaupon are semi-broad spreading plants that meet Florida Fancy standards when shoots are 18 cm high (7 in.) and 41 cm (16 in.) wide for plant in 10-L (#3) container.

RESULTS AND DISCUSSION

'Burfordii Nana', 'Helleri', and dwarf yaupon fertilized with 18N-0.4P-10K at a P rate of 20 $g \cdot m^{-3}$ (15.3 g/yd^3) were Florida Fancy grade at 13, 11, and 13 months, respectively, after potting and had heights and average widths similar to plants fertilized with 18N-1.3P-10K or 18N-2.6P-10K at P rates of 60 or 120 $g \cdot m^{-3}$ (46 or 92 g/yd^3), respectively. Midcap (2004) found a similar response for hydrangea in that plants grown with P at 71 $g \cdot m^{-3}$ (54 g/yd^3) had similar shoot growth to plants grown in substrate amended with P at136 $g \cdot m^{-3}$ (104 g/yd^3).

Considering these results and those of Midcap (2004), it is suggested that producers evaluate CRFs with 0.4%–1.3% P for different species. In this study, we applied 18N-0.4P-10K and 18N-1.3P-10K at P rates of 20 or 60 $g \cdot m^{-3}$ (15.3 or 46 g/yd^3), respectively. Their use in lieu of a CRF with a higher P content would be considered a best management practice.

DISCLAIMER

Mention of trade names and companies is not an endorsement or discrimination for similar products not mentioned. Information contained herein has not been subjected to scientific peer review, nor has it been incorporated in University of Florida Institute of Food and Agricultural Sciences (UF/IFAS) recommendations.

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Conifers for the Southeast©

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INTRODUCTION

Back in the mid-1990s American Nurseryman magazine ran a series of articles utilizing conifer experts from around the country, but only one of those experts was from the southeastern United States. In the Coastal Plain region, conifers are often thought of as pine trees for forestry or junipers for landscaping, that is it. Due to a lack of information on conifer adaptability for the Lower South, in 1996 I started collecting germplasm for an evaluation project at The University of Georgia campus located in Tifton, Georgia. The Tifton Campus is located 103 km (64 miles) north of the Florida border in south-central Georgia. The station is located in USDA Hardiness Zone 8a and Tifton averages about 100 days per year at or above 32 °C (90 °F).

The initial plantings were installed in January 1997. Individual plants were planted every 3.8 m (12.5 ft) within rows with 6 m (20 ft) between rows. Composted pecan shells were applied as mulch and drip irrigation was installed with an emitter at each plant. Fertilizer is applied at the rate of 50 lbs N per acre in the spring and 25 lbs N per acre in August using 16-4-8 soluble granular fertilizer with micronutrients. The pH of the site at time of planting was 5.5. Weeds were controlled with preemergent applications of simazine and oryzalin in February and September. Glyphosate was applied as needed as a post-emergent herbicide.

FACTORS TO CONSIDER

During the study period the lowest temperature in the winter has been -10 °C (14 °F). Tifton is located in an area where the temperatures never spend 24 h below freezing. Even though temperatures may plummet into the upper teens every winter, temperatures the following day are usually in the low to upper 30s. By adding protection from drying winds, certain conifers from more tropical areas can be grown in the Coastal Plain region of the southeast because temperatures never linger below the freezing mark for days on end.

Photoinhibition can also cause damage or winter browning of foliage under conditions of high light intensity and low temperatures. The response only occurs in leaves exposed to the sun as those on the north side of the plant often remain green. In plants such as *Chamaecyparis, Cryptomeria, Platycladus, Taiwania*, and *Thuja*, foliar browning is due to the production of a pigment known as rhodoxanthin. This pigment is produced to prevent damage to the chloroplasts when light levels are high and temperatures are low or when photosynthesis cannot run efficiently enough to dissipate excessive light energy. In Japan it was discovered that natural polyploids of *Cryptomeria* remained green in the winter due to increased levels of antioxidant enzymes. In 2008 Dr. Ryan Contreras and I initiated a program to develop polyploid Japanese cedars to see if we could create non-browning "evergreen evergreens." After several attempts we successfully produced over 100 polyploid seedlings. These plants are being grown out and will be planted to the field in 2011 for further evaluation.

High temperatures also create problems for conifers in the south. The three main problems are the duration of high temperatures, high nighttime temperatures, and elevated soil temperatures. In south Georgia, we average 90–100 days per year with temperatures at or above 90 °F and summer lasts from early May until mid-October. Depending on their origin, most conifers have an optimum photosynthetic temperature range of 20 to 29 °C (60 to 85 °F). Add in high nighttime temperatures which increase plant respiration and many conifers begin to run a negative carbohydrate balance as they burn up all the sugars made by photosynthesis during the day. Since carbohydrates are needed for plant growth, little to no growth occurs. The Year 2010 was one of the hottest summers on record in Georgia, particularly for nighttime temperatures. It has been fairly common over the past 20 years for temperatures to still be in the upper 80s at 22:00, but this was the first summer where temperatures were in the 90s that late into the evening. Many conifers grow at elevations much higher than those found in the southeast. Due to the adiabatic lapse rate which dictates that temperatures usually decrease about 3 °F for every 305 m (1,000 ft) increase in elevation, many conifers grow in habitats with much cooler night temperatures.

High soil temperatures increase respiratory demands of the root system as well. Throughout much of the southeast, clay soils dominate the landscape. Wet, heavy soils can be a conifers worst enemy since high temperatures and low oxygen availability lead to increased respiratory demands. If sufficient oxygen is not available, this can lead to the death of roots and eventually a decline of the entire plant. Many conifers die during periods of heavy rainfall late in summer since the air pockets in the soil are saturated with water and oxygen is not sufficiently available to meet the demands of the roots. Heavy soils should be amended or raised beds can be utilized. Low oxygen availability is less of a concern on the sandy soils of the Coastal Plain region where there is sufficient drainage. Supplemental irrigation is essential for plant establishment and often helps with survival during the growing season during periods of drought. Plants such a Japanese cedar grow best in coarse, mountain soils in areas that receive upwards of 2,540 mm (100 in.) of rain per year. Much of the southeast gets less than 1,270 mm (50 in.) much rainfall in a normal year.

Soil type (sandy vs. clay), soil pH, and alkalinity of irrigation water all influence nutritional aspects of conifer growth. In south Georgia on our sandy loam soils it is necessary to fertilize most conifers to optimize growth and keep foliage color looking good throughout the winter. On clay soils in the northern part of the state, many collectors only fertilize their collections at planting. The difference — clay soils have sufficient cation exchange capacity to hang onto soil nutrients whereas they tend to leach from sandy soils. Nitrogen seems to be the biggest limiting factor for good growth. Many conifers from Vietnam and southern China grow on acidic limestone karst soils, indicating the need for calcium. Gypsum can be used to increase soil calcium levels without increasing soil pH, otherwise dolomitic limestone can be used. In the highly acidic, leached sands of the Coastal Plain, magnesium deficiency offer occurs on conifers such as *Keteleeria evelyniana* and *Nageia nagi*. Epsom salts (magnesium sulphate) can be used to correct deficiencies of magnesium. Iron deficiency can also occur on alkaline sites or when alkaline irrigation water from limestone aquifers is used for a number of years, particularly with drip irrigation systems.

Hurricanes can wreak havoc on a conifer collection. Many pines snap off at the top or may blow over in shallow soils. In 2004, four hurricanes with winds of in excess of 64 kph (40 mph) came through south Georgia in a matter of months. Many conifers in the collection were not damaged, but all the ones that blew over were in the genus *Cupressus*! In many cases it appears that top growth outgrows the supporting root system.

There are a number of pests that attack conifers in the southeast. In my experience the main pests have been foliar diseases (*Cercosporidium*, phomopsis tip blight), cankers (bot canker and *Seridium*), pine tip moths on two- and three-needled pines, root rot in container and field-grown plants, and spider mites. Wooly adelgids are now problems in the upper south on firs and hemlocks.

CONIFERS FOR CONSIDERATION

Abies firma or Momi fir from southern Japan is the only true fir that can grow across the entire southeastern region. Momi fir has good resistance to phytophthora root rot and is being used as an understock to evaluate other species in the south. In Zones 6 and 7a, *A. homolepis* and *A. nordmanniana* perform well. For conifer enthusiasts along the gulf coast, *Afrocarpus falcatus* has finely textured foliage and makes a large shrub or small tree. New growth is damaged below 18 °F but there has been no stem dieback in Tifton. The Parana pine, or *Araucaria angustifolia*, has been a pleasant surprise in Georgia — performing well in Tifton and next to the conservatory at the Atlanta Botanical Garden. Hybrids between this species and the monkey puzzle tree, *A. araucana*, are being evaluated for resistance to root rot. *Araucaria bidwillii* has also grown well with minimal winter damage to shoot tips in Tifton.

In the Piedmont and mountain regions of the south (Zones 6b and 7), incense cedar (*Calocedrus decurrens*) performs very well, but old trees are rarely seen in the Coastal Plain. Two Asian species, *C. formosana* from Taiwan and *C. macrolepis* from southeastern China have performed exceptionally well in Zone 8a. The Taiwanese incense cedar has dark green foliage which is very attractive. Unfortunately, both species have been fairly difficult to root from cuttings.

Numerous Deodar cedars have been introduced in the past decade. Many growers like *Cedrus deodara* 'Bush's Electra' because it is heavily branched and looks good in a large container. The cultivar 'Gold Cone' has performed well in the Deep South and has nice yellowish foliage during much of the year. Many plants from Taiwan perform well in south Georgia, including *Chamaecyparis obtusa* var. *formosana*. A plant in my trials reached a height of 6.7 m (22 ft) in 10 years. Selections are needed that do not turn brown in the winter time. All dwarf *C. japonica* selections that I have tried over the last 13 years are dead, rarely living more than 7 years. 'Gyokuryu' and 'Rein's Dense Jade' are two intermediate forms that have performed well. I am currently working with a selection from north Georgia that has good form and remains green through the winter.

The genus *Cupressus* is in taxonomic turmoil at the moment. Until a final determination can be made, I will just call them all *Cupressus*. Leyland cypress can be destroyed by several pathogens, including *Cercosporidium* which requires spray treatments every 2 weeks from June to Thanksgiving to prevent the problem. I have an unnamed clone that has shown excellent disease resistance that may be useful for the Christmas tree industry. The selection 'Gold Rider' is the best yellow-foliaged form but it is the poster child for phomopsis tip blight in south Georgia. *Cupressus funebris* is an attractive upright conifer with pendulous foliage that deserves more use while the Arizona cypress selection *C. arizonica* var. *glabra* 'Chaparral' receives positive comments from all who see it. Numerous junipers thrive throughout the southeast. *Juniperus formosana* is an upright grower with weeping branches that does well in Zones 7–8a.

Keteleeria's are fir relatives from southern China and northern Vietnam. *Keteleeria davidiana* is rare in the southeast but well worth the effort if you want a tree that looks like a fir and thrives in the lower south. Another nice species is *K. evelyniana* which has performed well in south Georgia and north Florida. Spruces are not good plants for the Lower South. The only spruce to survive in my trials has been *Picea chihuahuana* from Mexico. At Cox Arboretum in Canton, Georgia (USDA 7a), *P. morrisonicola*, *P. omorika*, and *P. orientalis* have all grown well. *Pinus pseudostrobus* from Mexico is an excellent five-needled pine that has grown well in south Georgia. I have also been pleasantly surprised by the growth of certain *P. armandii* and *P. wallichiana* selections.

Taiwania cryptomerioides, while not a plant with great commercial potential, makes a fantastic specimen conifer for large gardens and public spaces. On the commercial side, *Thuja* 'Green Giant' performs exceptionally well throughout the south and holds up well in the heat of south Georgia with none of the disease problems destroying the Leyland cypresses. Interest in conifers for southern landscapes is increasing. Research is being conducted at University of Georgia Tifton Campus and the Center for Applied Nursery Research in Dearing, Georgia, to bring new introductions to market in the near future.

Feeding the Natives©

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INTRODUCTION

The Southern Highlands Reserve <http://www.southernhighlandsreserve.org>, Lake Toxaway, North Carolina, is a 49-ha (120-acre) private, nonprofit native plant reserve located at an elevation of 1,377 m (4,500 ft) in the Southern Appalachian Mountains of North Carolina. The 8-ha (20-acre) "Core Park" is intensively cultivated while the remaining 41 ha (100 acre) are maintained primarily in a natural state. The objective of the Southern Highlands Reserve is to preserve the various plant communities extant on the property plus to preserve and display a collection of native plants and cultivars of these natives to the Southern Appalachian Highlands.

The Southern Highlands Reserve was never farmed or involved in active horticulture. There is evidence of some logging in the early 20th century but no agricultural activity beyond collecting firewood and wildcrafting. The Core Park forest is primarily high elevation red oak forest (Schafle and Weakley, 1990).

SOIL CONDITIONS

The characteristic soils of the Core Park, the only area where cultivars and hybrids of native species are allowed, are infertile mineral soils with a layer of woodland organic duff as mulch and substrate. The organic layer is rarely more than an inch or two deep except in moist coves where erosion and the accumulation of slowly decomposing organic matter has created deep soils with abundant organic matter, which are relatively infertile according to extensive soil test results from the North Carolina Department of Agriculture (NCDA) Agronomic Division. References to these results will be in the terms and index numbers provided in NCDA soil test reports. Information regarding conversion to other units and how these numbers are derived may be obtained at <http://www.ncagr.gov/agronomi/obt14.htm>.

SOIL AMENDMENTS AND FERTILIZATION

In areas of the Core Park where garden beds were developed as well as areas where recommended "wider but no deeper than the rootball" planting holes could be dug without extensive damage to existing vegetation, NCDA fertilizer suggestions were used. Where appropriate for plants such as *Kalmia latifolia*, various evergreen and deciduous native rhododendrons recommended nutrients were applied. Pine-bark soil amendments were spread to a depth of 8 to 10 cm (3 to 4 in.), and then soils were tilled again at the slowest speed allowed by equipment to thoroughly mix soil amendments and fertilizers with the soil based on research reported by Bilderback (Bilderback et al., 1996). Soils were allowed to settle then planting was commenced.

North Carolina Department of Agriculture recommendations arrive from the lab in suggested nutrient amounts per 1000 sq. ft. and/or as pounds per acre. The phosphorus index (P-I) was often minimal or 0. These mountainous soils "fix" phosphorus, thereby limiting P availability to plants. Treble superphosphate, 0-44-0, was often the source for phosphorus. The source of calcium as well as magnesium was dolomitic limestone applied at the equivalent of tons per acre. However, because of the high soil acidity (Ac in NCDA soil test reports) the soil pH was rarely above 5.0 despite application rates of 2 to 3 tons per acre. Adequate levels of other nutrients existed in the Southern Highlands Reserve soils initially and have been maintained by periodic application of balanced fertilizers as well as the application of composted leaf mulch in the Core Park.

In areas of existing plant communities that appeared to be suffering from excessively low nutrients, perhaps due to high rainfall with acidity in the rainfall leaching already limited nutrients, a very gradual approach was taken to raising nutrients to low to moderate levels of availability, while continually monitoring flora for any negative results. The source of fertilizer used to accomplish this gradual increase in phosphorus was diammonium phosphate, 18-46-0, broadcast to add no more than 0.5 lb of nitrogen per 1000 ft^2 per application. Ground dolomitic limestone was used to provide calcium and magnesium as well as to raise soil pH and increase buffering capacity. Dolomite was broadcast most often at 25 lbs per 1000 ft^2 but occasionally at 50 lbs per 1000 ft^2 per application. These nutrients were applied to noncultivated areas during the winter months.

Soil tests were taken annually with no further fertilization occurring until test results could assess progress, if any. Limestone was applied yearly, while other fertilizer was applied 1–2 times per year.

RESULTS

In cultivated areas of the Core Park, results were as expected based on previous research and results from working with soil analysis done by NCDA Agronomic Division. Plants grew and thrived as if they were in field nursery beds using North Carolina Cooperative Extension recommendations.

The biggest challenge was making improvements to the woodlands without damaging the natural flora of native plants. The initial P-I of 0 has increased to 8–10. Likewise, initial Ca of 10%–20% is now 35%–45%, and initial Mg of 8%–9% is now 12%–15%. *Rhododendron arborescens, R. calendulaceum, R. vaseyi*, and *R. viscosum* are now flowering every year, with major floral displays every few years rather than once per decade. Natural gardens are thriving with no noticed loss of diversity in the existing herbaceous and woody understory. The thousands of trillium, clintonia, galax, and diverse non-rhododendron ericaceous woody species look much healthier and more vigorous than they did when this process started in 2004.

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ET Phone Home, Smart Controllers©

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INTRODUCTION

I installed my first irrigation system in 1976 and have been learning more about the industry ever since. I am here to share my experience with smart controllers and when and how to use them.

What is SWAT? It refers to "smart water application technologies" which encompasses a national initiative with water purveyors and industry representatives that promote new technology and increased efficiency. This includes controllers, sprinkler heads, nozzles, pressure reducers, as well as, non-irrigation-related items.

There are two types of smart (dynamic) controllers; evapotranspiration (ET) based controllers and soil moisture sensors. What is ET? Evapotranspiration stands for the total amount of water transferred from the earth and plants to the atmosphere as a result of local weather.

To understand smart controllers one must understand ET. Evapotranspiration is measured in inches per day and is controlled by humidity, solar radiation, temperature, and wind speed. Smart water management means applying the right amount of water at the right time based on the data collected by a smart controller. For instance, if the day is warm but partly cloudy, it will adjust the amount of irrigation applied. If the following day is very sunny and hot with no clouds, the smart controller may determine that two irrigation events may be needed to replenish the water lost through ET. A third day may be rainy or cloudy all day and no irrigation is applied.

Evapotranspiration smart controllers are weather based, they use local weather and local site conditions. Weather data may be current, daily, or historical. Some units have more data inputs than others. In general the more information you can program into the controller the better the irrigation schedule will be. Some units only work on the existing schedule in the controller and are turned off or on, when a predetermined threshold is met. Developing a water schedule may use a depletion model based on ET or a simulated ET. The operator inputs the parameters such as soil, sun, sprinkler, or inputs a schedule. The controller then calculates the ET and makes changes to an existing schedule, develops a new schedule, or terminates a schedule.

A soil moisture controller measures the amount of water availability in the soil. Measurements may be made in more than one area on a site. The controller waits for the water in the soil to be depleted then water is applied. This is known as the depletion model. A soil moisture controller is site specific and cannot use ET data that may be available in a particular geographic region.

A dumb (static) controller is based on regimented time frame like 15 min per day. The advantage of using smart controllers instead of time-based controllers is water savings. However, smart controllers are not a panacea. They cannot make an inefficient system efficient. Human interaction is still needed to make necessary adjustments.

There are simple and more complex controllers, but all save water. New systems have the most potential for savings water and increasing profits.

Innovative Tips, Tools, and Equipment©

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INTRODUCTION

This talk will present ideas, innovations, and equipment in use at Mortellaro's Nursery. The ideas and equipment used are useful for our operation and should be useful for most other operations. Some of the equipment may need modification for use by other nurseries in order to fit within their cultural practices. As with all ideas that were used to create the equipment and methods in use at Mortellaro's, the main purpose of this presentation is to stimulate thought on how our ideas can be applied to other operations.

DRAMM PORTABLE PULSEFOG

This unit was purchased so that we could more easily treat for insect and diseases during the winter when our houses were covered. It allows our spray applicator to treat a single house and move on to the next house in about 5 min. The unit has the ability to treat up to 100,000 ft^2 in 15 min. For the purpose of safety, we have cut a hole in opposite ends of the house and have a drop down flap. The applicator opens the flap and inserts the fogger through the hole. One-half of the desired chemical is applied and then the applicator goes to the other end of the house and repeats the process. The system is able to distribute the chemical up to 100 ft away, but we prefer to ensure heavy uniform coverage (<http://www.dramm.com/html/main.isx?sub=106>).

DRAMM SPRAYER MS20GAS-66

The Dramm sprayer was purchased primarily for portability. We are able to load this onto a cart or in the back of a truck for transport to another location. We use it for sanitation purposes, treating incoming plant shipments and small infestations. It is a four-cycle engine and uses plain gas. The 20-gal tank is perfect for jobs requiring only a few gallons of spray mix. This unit would be very good on paved or concrete surfaces, but on gravel, it needs weight to balance the unit: (<http://www.dramm.com/html/main.isx?sitesec=8.0.0.0&productRec=3640>).

VERMEER S600TX

We have been using the Vermeer for about a year now and recently purchased our second unit. The primary purpose of the unit was to load 30 gal and larger material into our trucks for delivery. Once the equipment was on site, we found many other uses for it. It is only able to load 45-gal and smaller material into the back of a truck or trailer due to tipping point weights, but it is very useful in tight spaces when we are busy. It became very useful for spacing large trees in the field since it needs less space to maneuver. We use it to pull and load 30-gal and 45-gal material out of the blocks and place on trailers for transport or loading into customers vehicles. The women that move pallets around prefer to use the Vermeer for the smaller size and complete visibility rather than be belted within a skid steer loader. It comes in many options, but we chose a narrow track and Kubota diesel engine (<http://www2.vermeer.com/vermeer/equipment/mini_skid_steers/s600tx>).

VERMEER CHIPPER BC606

In looking for a chipper, our main goal was to not have another engine to maintain. Our first chipper was a Befco, but it was not sufficient for our needs since it only went up to 10 cm (4 in.) diameter. We tried a Vermeer and after less than an hour, we purchased the unit. It handles up to 15 cm (6 in.) diameter trunks and is very easy to service. We mulch all tree limbs and large brush. The ground up wood is used as mulch on our 30-gal and larger containers (<http://www2.vermeer.com/vermeer/equipment/brush_chippers/bc600xl>).

TREE BOSS

We purchased the Tree Boss and used it for several years. As we switched over to wooden and plastic tree boxes, the Tree Boss became more of a hindrance than a useful tool. We decided to combine the best features of the Tree Boss with a set of forks that worked well on boxes. The most difficult part was designing a way to lock the boxes onto the forks to be tilted. This problem was solved by custom designing a nylon strap with multiple loops for different size boxes. The forks are slid under the box and the strap is placed around the box. A hydraulic ram is then used to push the box against the strap and hold it in place. Using the "Super Forks," we are able to lean trees on trailers as well as the Tree Boss did with pots and B&B (<http://www.treeequip.com/treeboss.html>).

ECHO HEDGE TRIMMER HCA-235

We have tried several brands and styles of hedge trimmers. Of all the brands and styles, we have settled on Echo single side shears. The double side is a nice option, but there are problems with material jamming it up. We have had the most life and least mechanical problems using the Echo brand. Issues with other brands are due more to parts availability and suppliers of new equipment rather than direct quality issues (<http://www.echo-usa.com/product.asp?Model=HC-235&Category=HEDGECLIPPER>).

ECHO POLE HEDGE TRIMMER

This model has a 51-cm (20-in.) single-side hedge trimmer on a 1.3-m (51-in.) pole for reaching across blocks or vertical trimming. The head can pivot and lock into seven different positions to top or angle cut a hedge above your head (<http://www.echo-usa.com/product.asp?Model=SHC-265&Category=HEDGECLIPPER>).

CLUB CARS CARYALL 272

We currently own about 15 Club Cars and have been very pleased with them. They all have aluminum frames, Ingersoll Rand gas engines, and either a flat bed or a bed with sides and a drop tailgate. We use the carts to pull small orders and place the plants on the cart, we pull trailers for larger orders, transport of managers, employees, and customers around the nursery.

The lifespan of the equipment is very good. The engines are only rated for 1,000 h, but with a 100-h maintenance cycle, we have stretched all the engines to 5,000 h or more. The only repetitive repairs we have seen are brakes adjustments and some repairs about every 1,000 h and also most of the front suspensions at about 2,500 h. These carts have about the same reliability as our Kubota tractors (<http://www.clubcar.com/commercialbusiness/utility4x2/pages/carryall272.aspx>).

UPRIGHT SCISSOR LIFT SL30

We purchased the used speed level lift about 6 years ago for the sole purpose of installing plastic on greenhouses. We have found numerous uses for the lift since then. It has been used to repair shade arbors, trim trees for clearance, repair semi trailers, install conduit and lights in buildings, etc. This brand and style had the largest working deck, very stable off road capability, dual fuel capability for indoor use, and was strictly mechanical and hydraulic controlled rather than electronic or computer controlled. Maintenance and repair is similar to a skid steer since the motor controls a hydraulic pump for all motion and lift. Company name has been changed to Snorkle. The type of lift to purchase for off road use is a speed level lift.

BRADY LABEL MAKER

Perfect for outdoor labels on electrical panels, irrigation valves, Emergency signs, and equipment models or ID numbers. We have started making our own bi-lingual signs using the label machine and graphic signs that are only available in English. The machine is available from Grainger (<http://www.bradyid.com/bradyid/catalog/siteSearchResultsView.do?searchTerms=brady+42001&x=0&y=0>).

MY TIME FORCE TIMECLOCK

We have three time clocks in use that are polled by modem. All of the time clocks are polled and the data is imported directly into our payroll program. Timeforce is one of the few companies we found that would modify their software to match the parameters of the payroll program in use at no extra charge. Timeforce is the second company we have used in 12 years. When we replaced clocks and software about 3 years ago, we switched from a barcode badge that needed to be swiped to a magnetic badge that is swiped across the front of the clock (<www.mytimeforce.com>).

CARE TREE SPADE

We researched and chose Care Tree for our tree spades. We own two spades and have been more than pleased with the quality. One of our spades developed a broken weld after about 18 months, and the company came down to inspect the spade and replaced the spade in question after verifying it was not an abuse issue. Both spades are mechanically cable controlled with rear stabilizers (<http://www.care-tree.com/index.php/>).

MULTI-SEAL TIRE SEALANT

We are using a new tire sealant that is in liquid form until exposed to air as it leaks from a tire. We have been using the off highway sealant for about a year and it works in all tires we have put it in. There are formulations for water-filled tires and also highway use tires. We still use solid-foam-filled tires for our skid steers as a weight ballast issue (<http://www.multi-seal.com/>).

BUBCO SPRAYERS

We use the Bubco tractor-mounted sprayers for our pot-in-pot operation. We have been using the equipment for approximately 6 years and have been more than satisfied with the quality of the equipment (<http://www.bubco.com/vineyard.html#tatv>).

SUMMARY

The equipment and ideas that work at one nursery, may not necessarily work at another nursery. Basic equipment will work from nursery to nursery, but highly modified or customized equipment may not. Each nursery has its own unique style of operation and some equipment may not fit that culture. I am not a proponent of changing something that works, but sometimes we have found it best to step back and take a serious look at our operations that we feel could use improvement. Those changes have usually followed an IPPS Conference. Any new equipment or new methods of operation may be useful, if only they can be applied profitably.

Cotton and Other Low to No Bark Alternatives: Getting Past Biomass Crops Assistance Program©

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INTRODUCTION

Bark has been a major component of container substrate since the 1960s. In recent years with the continuous rise in energy prices, the demand for bark as a clean fuel has increased. In 2010 the nursery industry faced a new threat to pine bark availability due to a proposed rule for USDA's Farm Security Administrations Biomass Crops Assistance Program (BCAP). Although pine bark supplies used for container potting substrates were not intended to be included in this program to utilize wood-mill-based residuals, it was not exempted and placed nursery pine bark supplies in jeopardy. One of the most popular areas of university research in recent years has been focused on evaluating alternatives and supplements to pine bark potting substrates since the quantity of timber harvested in the United States has decreased since 1986. Farm Security Administrations Biomass Crops Assistance Program accelerated the quest for new substitutes for commercial growing horticultural crops.

Use of composted materials to replace pine bark in a substrate is not a new idea. Many research studies have investigated the use of industrial and agriculture wastes as substitutes for bark. A comprehensive literature search would yield a very long list. Many alternatives show promise; however, cost, regional availability, and a limited supply of uniform and consistent quality reduce their widespread use.

Cotton is a major agronomic crop in the southeastern United States. In production of no-till cotton, stalks and residue remaining after harvest are very woody and do not easily decompose. This mulch may persist for several seasons and eventually the accumulation interferes with planting and application of fertilizer and herbicides, therefore some of this material must be removed from the field. North Carolina has experienced a tremendous growth in the hog industry, with an increase from 2.7 million hogs in 1990 to over 10 million hogs in this decade, producing over 4,000 tons of hog manure per day. Hog waste has been traditionally managed by open air lagoons and spray-fields. As a result of the documented environmental impacts by hog lagoons and spray-fields, a phase-out plan of anaerobic lagoons and spray-fields has been mandated in North Carolina. Combining these two materials into composted nursery substrate component would appear to be a simple solution to a complex problem. The end product produces an odorless, dark, pine-bark-like substrate. This research study set out to answer the questions: can we use this material to amend pine bark to grow a high quality plant? The use of recycled waste in container production would provide the nursery industry with a reproducible, consistent substrate amendment of unlimited supply. It is not incumbent on the nursery industry to solve the world's waste disposal problems. However, if recycled waste is a valuable substrate amendment then it becomes a win/win situation. Therefore, our objective was to evaluate the physical, chemical, and subsequent growth effects of addition of composted cotton-swine waste (CCSW) to ratios of pine bark.

METHODS AND MATERIALS

To accomplish this objective a study was conducted on a gravel pad at North Carolina State University with pine bark amended with four rates [0%, 15%, 30%, and 45% (by volume)] of cotton stalk/swine compost (CCSW). No micronutrients or dolomitic limestone amendments were added. For comparison to a commercial substrate, 8 pine bark : 1 sand (v/v) was amended on a cubic-yard basis with 2.0 lbs dolomitic limestone and 1.5 lbs MicroMax micronutrient fertilizer. All plants were topdressed with 5 g N per container with a commercial controlled-release fertilizer (Harrell's 17-5-10, 5- to 6-month controlled-release fertilizer).

Uniform rooted cuttings of *Cotoneaster* ×*suecicus* 'Skogholm' were potted into 1-gal. containers on 15 April. Irrigation volume to maintain a 0.2 leaching fraction (LF = irrigation volume leached ÷ irrigation volume applied) was applied via overhead irrigation daily. Leaching fraction for each treatment was determined weekly and adjusted accordingly. After 19 weeks (25 Aug.) tops and roots of all plants were harvested for dry weight determination. Roots were washed with a high-pressure water stream to remove substrate. All plant materials were dried for 5 days at 62 °C (144 °F). After drying, cotoneaster leaves were ground and analyzed for mineral nutrient concentration (N, P, K, Ca, Mg, S, B, Cu, Fe, Mn, Zn, and Na).

An additional 14 containers of each of the pine bark : CCSW substrate combinations were filled at treatment initiation. These fallow containers received similar cultural practices as those with plants. After 9 weeks, particle size distribution along with the physical properties of each pine bark : compost substrate combination were determined for seven fallow containers. Physical properties consisted of total porosity, air space, container capacity, available water, unavailable water, and bulk density. All physical properties analyses were conducted at the Horticultural Substrates Laboratory, Department of Horticultural Science, North Carolina State University. To determine how these properties may change over time, the same analyzes were conducted at the end of the study (19 weeks) for the remaining fallow containers.

To determine the chemical properties of each pine bark : CCSW substrate combination, the substrate solution was extracted from each container via the pour-through nutrient extraction method at 15, 45, 75, 105, and 135 days after treatment initiation (DAI). Electrical conductivity and pH were determined on each sample. The substrate solutions collected at 15, 75, and 135 DAI were analyzed for mineral nutrient concentration (N, P, K, Ca, Mg, S, B, Cu, Fe, Mn, Zn, and Na). All variables were tested for differences using analysis of variance procedures and regression analysis, where appropriate. The control substrate (8 pine bark : 1 sand, v/v) was separated from the CCSW amended substrates via Dunnett's test, $P = 0.05$. Due to page limits and space only growth data and physical properties will be presented.

RESULTS AND DISCUSSION

Top dry weight of cotoneaster increased linearly with increasing rate of CCSW, whereas root dry weight increased quadratically with increasing CCSW (Table 1). In addition, top dry weight of cotoneaster grown in 15%, 30%, and 45% CCSW was significantly greater than cotoneaster grown in (8 pine bark : 1 sand, v/v).

Electrical conductivity (EC) increased with increasing rate of CCSW at all sample times except 75 DAI indicating that CCSW was acting like a slow-release fertilizer (data not shown). This increase in EC was also probably responsible for the increase in top growth with increasing rate of CCSW. The highest EC was 2.81 $dS{\cdot}m^{-1}$ recorded at 15 DAI. During the growing season, an EC range of 0.5 $dS{\cdot}m$ to 2.0 $dS{\cdot}m^{-1}$ is considered appropriate assuming the EC is representative of all essential elements being present.

Table 1. Effect of pine bark substrates amended with cotton stalk/swine compost (CCSW) on top and root dry weight of Skogholm cotoneaster.

CCSW % by volume	Top dry weight (g)	Root dry weight (g)
0	88.0	19.0
15	107.4*[z]	17.8
30	107.3*	18.2
45	121.0*	23.4*
8 : 1[y]	95.3	19.1
Significance[x]		
Linear	***	*
Quadratic	NS	**

[Z*] Significantly different from the control substrate [8:1 pine bark:sand (by vol.)] based on mean separation by Dunnett's test, $P = 0.05$.

[y] 8 : 1 pine bark:sand substrate by vol. The control substrate data not included in regression analysis.

[x]NS, *, **, *** nonsignificant or $P = 0.05$, $P = 0.01$

Total porosity, container capacity, available water, and unavailable water increased with increasing rate of CCSW (Table 2). In addition, all substrates amended with CCSW had greater total porosity and less available water compared to the pine bark : sand, (8 : 1, v/v) control. In contrast, air space and bulk density decreased with increasing rate of CCSW. Air space was greater and bulk density was less in CCSW-amended substrates compared to the control. Air space is critical in substrates for root metabolism and growth; low air space reduces root adsorption capacities. A 20% to 30% air space is preferable for nursery size containers. Thus, the 0% CCSW was very high at 63 DAI and barely inside the range at 135 DAI. In contrast, pine bark : sand was on the low end of the range at both 63 and 135 DAI. Air space values for 15%, 30%, and 45% amended substrate fell between 0% CCSW and the control. Most organic-based substrates including pine bark decrease in air space during production conditions with high irrigation application and fertilizer application.

Table 2. Effect of pine bark substrates amended with cotton stalk/swine compost (CCSW) on physical properties at 63 and 135 days after treatment initiation.

	Total porosity		Air space		Container capacity		Available water		Unavailable water		Bulk density	
	Days after treatment initiation											
Volume (%)	63	135	63	135	63	135	63	135	63	135	63	135
	% vol										g·cm^{-3}	
0	84 *[z]	85*	33*	30*	52	55	22*	22*	29*	33*	0.26*	0.24*
15	84*	86*	29*	28*	55	58	24*	25*	30*	32*	0.25*	0.24*
30	85*	87*	29*	27*	56	60	24*	26*	32*	34*	0.23*	0.21*
45	86*	87*	24	25*	62*	62*	29	27*	33*	36*	0.23*	0.21*
8:1[y]	77	80	23	21	54.0	59	28	29	26	29	0.43	0.44
Significance[x] Linear												
*** ***	***	***	***	***	***	***	***	***	***	***		
Quadratic	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Significantly different from the control substrate [8 : 1 pine bark : sand (by volume)] based on mean separation by Dunnett's test, $P = 0.05$.

[y]8 : 1 pine bark:sand substrate by vol. The control substrate data not included in regression analysis.

[x]NS, *** nonsignificant or $P = 0.001$ respectively.

As air space decreases in substrates during a growing season, a reciprocal increase in container capacity usually occurs. Except for 45% CCSW, which remain unchanged, these substrates increased 3% to 5% in container capacity from 63 to 135 DAI, which was associated with the decline in AS. However, container capacity values remained within normal ranges.

At 63 DAI, 0%, 15%, and 30% CCSW had lower available water compared to the control. At 135 DAI, all CCSW amended substrates had lower available water than the control.

Bulk density decreased linearly with increasing rate of CCSW (Table 2). All CCSW substrates were significantly lower than the control substrate. Changes in bulk density reflect the stability of substrate components. The bulk density of all CCSW-amended substrate decreased 4% to 9% from 63 to 135 DAI indicating the particles were decomposing and reducing the volume of the substrate, whereas the 8 pine bark : 1 sand substrate changes very little from 63 to 135 DAI.

SUMMARY

In summary, composted cotton swine waste used as a supplemental component addition to pine bark has the potential to stretch bark supplies, increase plant growth, replace limestone and micro-nutrients additions, and recycle a waste material.

Annual Crop Growth in Substrates Amended With Sweetgum, Hickory, and Red Cedar©

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Peat has served as an industry standard for greenhouse substrates for over 50 years. Its continued availability, inert characteristics, as well as its ability to stay relatively pathogen-free have all contributed to its success in the horticulture industry. However, due to increased harvesting restrictions, as well as increased shipping costs, the future availability of peat is a largely unknown factor in greenhouse production. Our study evaluated three possible alternative substrates for greenhouse use, including sweetgum (SG), hickory (H), and eastern red cedar (RC). Three greenhouse annual crops (petunia, impatiens, and vinca) were planted in varying ratios of these three wood species mixed with peat. Plants grown with SG and H as amendments did not perform as well as plants in a grower's standard [peat : perlite (3 : 1, v/v)] mix with respect to flower number, growth indices, and plant dry weight. However, plants grown in RC tended to be equivalent to those grown in a peat 75 : perlite 25 (v/v) grower's standard. Data showed that greenhouse producers could amend their standard greenhouse substrate with up to 50% RC with little to no differences in plant growth and overall plant quality.

INTRODUCTION

For the past 40 to 50 years, peat and pine bark have served as industry standards for substrates in the greenhouse and nursery industries because of several inherit qualities; both are readily available and generally pathogen-free. However, due to numerous projected changes, the future availability of these two media is questionable. Peat supplies are decreasing due to increased harvesting regulations, along with increases in fuel costs for the shipping of peat from Canada. This has caused growers to seek alternative greenhouse substrates with equivalent physical characteristics (Greg Young, pers. commun.). Therefore, development of alternative substrates has been a major focus of research efforts.

Hardwoods and hardwood barks have both been evaluated as alternative substrate amendments (Self, 1975; Kenna and Whitcomb, 1985; Broussard et al., 1999). In 1975, results were obtained showing that the best growth of two azalea species was from "pine shavings followed by cedar shavings" (Self, 1975). Kenna and Whitcomb (1985) evaluated hardwood chips of both post oak (*Quercus stellata*

Wangh.) and Siberian elm (*Ulmus pumila* L.) as amendments of container media. *Pyracantha* and *Liquidambar formosana* were the two species used in the study. Addition of Micromax tended to increase height of pyracantha and sweetgum in the elm chips, but not in the oak chips. More importantly, the authors noted that both species grew as well in the hardwood-amended substrates as in the traditional pine bark substrate. Hardwood bark was explored as a possible alternative by Broussard et al. in 1999. They concluded that substrates amended with up to 25% hardwood bark could be used successfully in the production of numerous woody ornamentals.

Recent research has focused on high wood fiber substrates (Boyer et al., 2009; Fain et al., 2008; Jackson et al., 2010). This research has mainly focused on substrates composed of whole pine trees, chipped pine logs, and residual material left on the forest floor after harvesting at pine plantations. Currently, forestry owners are inquiring about the possibility of utilizing low value trees as alternative substrates. Among these are sweetgum (SG) (*Liquidambar styraciflua* L.), hickory (H) (*Carya* spp. Nutt.), and eastern red cedar (RC) (*Juniperus virginiana* L.).

Recent research has evaluated the use of RC in the containerized production of two tree species (Griffin, 2009). Chinese pistache (*Pistacia chinensis*) and Indian-cherry (*Frangula caroliniana*) were potted into one of 24 substrate combinations containing pine bark and varying volumetric ratios of RC. Four fertilizer regimes were evaluated [N at 0.81 $kg{\cdot}m^{-3}$ control release fertilizer (CRF), 1.6 $kg{\cdot}m^{-3}$ CRF, 0.4 $kg{\cdot}m^{-3}$ urea (46-0-0), or no fertilizer at all]. Chinese pistache height was similar to the 100% pine-bark treatment for the substrates amended with 5%, 20%, and 40% red cedar, but less height was seen in substrates amended with 10% and 80% red cedar. Similarly, shoot dry weight was less in the 10% and 80% cedar-amended substrates than in the 100% pine-bark standard, but all the other treatments (5%, 20%, and 40% cedar-amended substrates) performed equally as well as the standard mix. The author reported no problems with substrate shrinkage or visible nutrient deficiencies.

While RC has been evaluated as a substrate amendment in woody ornamental production, no efforts have been made to evaluate it as a greenhouse substrate component. Therefore, the objective of this study was to determine if greenhouse growers could amend their standard substrates with up to 50% SG, H, or RC, without reducing the quality of three annual greenhouse crops.

MATERIALS AND METHODS

Both SG (average caliper = 12.6 cm; 4.97 in.) and H (average caliper = 13.0 cm; 5.10 in.) were harvested from the forest on 16 Feb. 2009, and RC (average caliper = 12.6 cm; 4.95 in.) was cut on 17 Feb. 2009. All trees were de-limbed at the time of cutting. The SG, H, and RC were chipped through a Vermeer BC1400XL chipper on 19 Feb. 2009 and stored in large plastic containers (208.2 L) with lids, until grinding through a 0.6 cm (0.25 in.) screen in a swinging hammer-mill (No. 30; C.S. Bell, Tifton, Ohio) on 7 May 2009. Fresh whole tree (WT) chips were obtained from Young's Plant Farm (Auburn, Alabama) on 7 May 2009.

Nine treatments were evaluated in this study including a grower's standard (GS) control consisting of 75 peat : 25 perlite (v/v). Remaining substrate treatments consisted of 75 : 25 (v/v) and 50 : 50 (v/v) ratios of the different substrates (Table 1). All substrates were amended prior to planting with 1.98 $kg{\cdot}m^{-3}$ (4 lb/yd^3) 15-9-12 (N-

P-K) OsmocotePlus CRF (3–4 month) (The Scotts Company, Marysville, Ohio) and 2.48 kg·m^{-3} (5 lb/yd^3) dolomitic limestone. AquaGro-L® wetting agent (Aquatrols, Paulsboro, New Jersey) was incorporated at mixing at a rate of 124.01 g·m^{-3} (4 oz/yd^3).

Table 1. Substrate treatments evaluated.

Substrate ratios	
75 : 25 (v/v)	50 : 50 (v/v)
P* : PE (control)	
P : SG	P : SG
P : H	P : H
P : RC	P : RC
P : WT	P : WT

*Abbreviations: Peat (P), perlite (PE), sweetgum (SG), hickory (H), eastern redcedar (RC), and fresh whole tree chips (WT).

Three species were used in this study, which was initiated on 8 May 2009 at the Auburn Alabama Paterson Greenhouse Complex at Auburn University. 'Dreams Sky Blue' petunia (*Petunia* Juss. 'Dreams Sky Blue'), 'Cooler Peppermint' vinca (*Catharanthus roseus* (L.) G.Don 'Cooler Peppermint'), and 'Super Elfin Salmon' impatiens (*Impatiens walleriana* Hook.f. 'Super Elfin Salmon') were planted into 1.21-L containers with two plugs (from 288 plug flat) per pot. Plants were placed on greenhouse benches and watered by hand as necessary. The experimental design was a randomized complete block design with eight single-pot replications per treatment. Each species was treated as its own experiment. Data were analyzed using Tukey's Honestly Significant Difference test (p0.05) in a statistical software package (SAS Institute version 9.1.3, Cary, North Carolina).

Growth indices [(height + width1 + width2)/3] (cm) were measured at termination (n = 8). Flower number was also evaluated at termination, where only open blooms and blooms showing color were counted towards the total number on each plant (n = 8). Plant dry weights (PDW) were determined after samples were dried at 170 °F for 72 h (n = 4). Root growth and general health was assessed at study termination on a scale from 1–5, where 1 was assigned to plants with less than 20% root ball coverage, and 5 was assigned to plants with between 80%–100% root ball coverage (n = 8). Pour-through leachates were obtained from 'Super Elfin Salmon' impatiens at 1, 15, 30, and 45 days after planting (DAP) in order to determine substrate pH and electrical conductivity (EC) (n = 4) (Wright, 1986). Physical properties [substrate air space (AS), water holding capacity (WHC), total porosity (TP)] were determined using the North Carolina State University porometer method (n = 3) (Fonteno et al., 1995). Bulk density (BD) was determined from 347.5 cm^3 samples dried in a 105 °C (221 °F) forced air oven for 48 h (n = 3).

RESULTS AND DISCUSSION

Growth Indices. Petunias in the following treatments were similar in size to those in the GS (26.7), 75 P : 25 WT (26.1), 75 P :25 H (24.9), 75 P : 25 RC (26.1), 50 P : 50 WT (26.4), and 50 P : 50 RC (26.3) (Table 1). Both substrate treatments containing SG [75 P : 25 SG (23.2) and 50 P : 50 SG (22.2)] as well as the 50 P : 50 H (18.1) treatment had less growth than that exhibited in the GS. With impatiens, the only 75 : 25 (v/v) treatment not similar to the GS (22.4) was 75 P : 25 H (18.5). When the alternative substrate volume was increased from 25% to 50%, only the treatments containing WT and RC [50 P : 50 WT (21.1) and 50 P : 50 RC (21.8)] remained similar in growth to the impatiens grown in the GS. Vinca growth in the GS (25.6) was similar to three treatments: 75 P : 25 WT (24.0), 75 P : 25 RC (25.6), and 50 P : 50 RC (25.1). These results were similar to those seen in a previous study with eastern redcedar as an amendment in woody tree production (Griffin, 2009). In that study, no differences were observed in height of Chinese pistache in a substrate amended with 40% RC. In the current study, vinca growth indices in SG and H were less than the growth indices of vinca in the GS.

Flower Number. Petunia flower number for all treatments were similar to the GS, with the exception of the 50 P : 50 H treatment (5.4) (Table 1). With impatiens, treatments with RC and WT were similar to the GS (70.3) (both v/v ratios of each), while treatments with H and SG had less flowers. Only two treatments [75 P : 25 RC (27.8) and 50 P : 50 RC (21.6)] were similar to the GS (27.3) with respect to flower number in vinca. Other treatments, including those with WT, H, and SG had fewer flowers than the GS.

Plant Dry Weight. Petunia plant dry weight (PDW) in 75 P : 25 WT (13.4 g) and 75 P : 25 RC (14.4 g), as well as in 50 P : 50 WT (12.3 g) and 50 P : 50 RC (13.3 g) were similar to PDW of plants in the GS (13.2 g) (Table 1). The 75 P : 25 H (10.3 g) treatment was the only treatment from any containing H or SG to be similar to the GS. For impatiens and vinca, the substrate treatments containing RC were the only treatments similar to the GS. The PDW of plants in treatments containing H and SG had the least mass of all.

Root Growth. Root ratings were similar for all treatments compared to the GS (7.4) with respect to petunia (Table 1). For impatiens and vinca, all treatments containing 25% of the alternative substrate material were observed to have similar root ratings to the GS (6.4 for impatiens; 7.1 for vinca). The only two treatments in both plant species to have dissimilar root ratings to the GS were 50 P : 50 SG (1.9 for impatiens; 4.4 for vinca) and 50 P : 50 H (1.5 for impatiens; 3.9 for vinca).

pH and EC. Throughout the experiment, pH levels remained within the BMP recommended range (4.5–6.5) for all treatments at all testing dates with only two exceptions at 30 DAP [50 P : 50 SG (6.6) and 50 P : 50 H (6.7)] (Table 2) (Yeager et al., 2007). The only testing date where pH was similar for 50 P : 50 H (4.9) compared to the GS (5.2) was at 1 DAP. At 14, 30, and 45 DAP, 50 P : 50 H had higher pH levels (6.2, 6.7, and 6.4, respectively) than the GS (5.6, 6.2, and 5.9, respectively). The pH values for 50 P : 50 SG tended to be higher than those for the GS, except at 14 DAP, where the values were similar. Substrate pH values for treatments consisting of 75 P : 25 RC were similar to those of the GS at all testing dates. By the end of the study, treatments with higher percentages of RC tended to have slightly higher pH values than the GS. At 30 and 45 DAP, pH values for 50 P : 50 RC treatments (6.5 and 6.3, respectively) were higher than those for the GS control (6.2 and 5.9, respectively). Treatments containing WT had similar pH values to the GS at each testing date.

Table 1. Effect of substrate on growth indices[z], flower number[y], dry weight[x], and root ratings[w] at termination (47 DAP[v]) of three greenhouse annuals.

	Growth indices			Flower number			Dry weight (g)			Root ratings		
Substrate	Petunia	Impatiens	Vinca	Petunia	Impatiens	Vinca	Petunia	Impatiens	Vinca	Petunia	Impatiens	Vinca
75:25 Peat:Perlite	26.7 a[u]	22.4 a	25.6 a	10.8 ab	70.3 a	27.3 a	13.2 ab	7.8 a	11.6 a	7.4 ab	6.4 ab	7.1 a
75:25 Peat:Wholetree	26.1 ab	21.0 ab	24.0 ab	9.8 abc	53.6 ab	18.0 bc	13.4 ab	4.9 bcd	9.3 bc	8.8 a	6.1 ab	7.4 a
75:25 Peat:Sweetgum	23.2 bc	19.3 ab	20.3 c	9.3 abc	45.1 b	8.6 de	7.6 cd	3.7 cd	7.3 d	7.9 ab	4.5 b	6.5 ab
75:25 Peat:Hickory	24.9 abc	18.5b	20.0 c	11.0 ab	38.1 bc	11.0 de	10.3 bc	3.3 de	6.5 d	8.3 a	4.9 b	5.9 abc
75:25 Peat:Redcedar	26.1 ab	21.9 a	25.6 a	8.3 abc	52.8 ab	27.8 a	14.4 a	5.8 abc	10.9 ab	6.0 b	6.1 ab	6.8 a
50:50 Peat:Wholetree	26.4 ab	21.1 ab	23.2 b	12.3 a	55.5 ab	14.9 cd	12.3 ab	4.5 bcd	8.5 cd	8.6 a	6.8 ab	7.0 a
50:50 Peat:Sweetgum	22.2 c	14.4 c	16.2 d	7.1 bc	18.4 c	6.1 e	7.3 cd	1.1 f	3.1 e	8.8 a	1.9 c	4.4 bc
50:50 Peat:Hickory	18.1 d	13.6 c	14.4 d	5.4 c	16.7 c	6.0 e	5.1 d	1.3 ef	2.3 e	7.3 ab	1.5 c	3.9 c
50:50 Peat:Redcedar	26.3 ab	21.8 a	25.1 ab	9.0 abc	58.6 ab	21.6 ab	13.3 ab	6.6 ab	10.0 abc	8.6 a	7.4 a	7.1 a

[z]Growth index = [(height + width1 + width2) / 3].

[y]Flower number recorded as number of flowers with open blooms and blooms showing color.

[x]Dry weights (g) determined by drying the above-soil portion of the plant in a 76.7°C (170.0°F) forced air oven for 72 hours.

[w]Root growth assessed at study termination (45 days after planting) on 1-5 scale (1 - less than 20% root ball coverage, 5 - between 80–100% root ball coverage).

[v]DAP = days after planting.

[u]Means within column followed by the same letter are not significantly different based on Tukey's Honestly Significant Difference test at $\alpha = 0.05$ (n = 8 for flower number and growth indices; n = 4 for dry weight.

Table 2. Substrate effects on pH and electrical conductivity (EC)[z] in impatiens.

	1 DAP[y]		14 DAP		30 DAP		45 DAP	
Substrate	pH	EC[x] ($mS\cdot cm^{-1}$)[w]	pH	EC ($mS\cdot cm^{-1}$)	pH	EC ($mS\cdot cm^{-1}$)	pH	EC ($mS\cdot cm^{-1}$)
75:25 Peat:Perlite	5.2 bc[v]	1.2 a	5.6 b	2.4 a	6.2 d	0.9[ns]	5.9 b	0.4[ns]
75:25 Peat:Wholetree	5.2 bc	1.1 ab	5.7 b	1.3 abc	6.2d	0.6	6.1 ab	0.4
75:25 Peat:Sweetgum	5.3 abc	1.0 ab	5.7 b	2.2 ab	6.3cd	0.9	6.1 ab	0.5
75:25 Peat:Hickory	4.9 c	1.2 a	5.7 b	2.0 abc	6.4bcd	0.9	6.3 a	0.3
75:25 Peat:Redcedar	5.4 ab	1.1 ab	5.7 b	1.7 abc	6.3cd	1.0	6.1 ab	0.3
50:50 Peat:Wholetree	5.5 ab	0.8 ab	5.9 ab	1.4 abc	6.4bcd	0.5	6.2 ab	0.3
50:50 Peat:Sweetgum	5.7 a	0.9 ab	6.0 ab	1.0 bc	6.6ab	0.9	6.3 a	0.5
50:50 Peat:Hickory	4.9 c	1.1 ab	6.2 a	0.7 c	6.7a	0.7	6.4 a	0.5
50:50 Peat:Redcedar	5.6 ab	0.7 b	5.9 ab	1.4 abc	6.5abc	0.6	6.3 a	0.4

[z]pH and EC of solution determined using pour-through method on 'Super Elfin Salmon' impatiens.

[y]DAP = days after planting.

[x]EC = electrical conductivity.

[v]Means within column followed by the same letter are not significantly different based on Tukey's Honestly Significant Difference test at $\alpha = 0.05$ (n = 4).

[ns]Means not significantly different.

The recommended range for substrate EC levels is between 0.5 to 1.0 $mS \cdot cm^{-1}$ (Yeager et al., 2007). Substrate EC levels for all treatments were similar to the GS (1.2 $mS \cdot cm^{-1}$) at 1 DAP except for the 50 P : 50 RC treatment (0.7 $mS \cdot cm^{-1}$) (Table 1). At 14 DAP, the only treatments dissimilar to the GS (2.4 $mS \cdot cm^{-1}$) were the 50 : 50 blends of both P : SG (1.0 $mS \cdot cm^{-1}$) and P : H (0.7 $mS \cdot cm^{-1}$). All other treatments, including all 75 : 25 blends of P : WT (1.3 $mS \cdot cm^{-1}$), P : RC (1.7 $mS \cdot cm^{-1}$), P : SG (2.2 $mS \cdot cm^{-1}$), and P : H (2.0 $mS \cdot cm^{-1}$), as well as the 50 : 50 blends of both P : WT (1.4 $mS \cdot cm^{-1}$) and P : RC (1.4 $mS \cdot cm^{-1}$) were similar to the GS (2.4 $mS \cdot cm^{-1}$). By 30 DAP, there were no differences among any substrate EC levels for the remainder of the experiment.

Physical Properties. The recommended range for container substrate AS percentage is between 10%–20% (by vol) (Jenkins and Jarrell, 1989). Container substrate AS values in this experiment ranged from 5.9% (75 P : 25 SG) to 15.4% (50 P : 50 RC) (data not shown). Only three treatments had container AS values within the recommended range; 50 P : 50 WT (12.3%), 50 P : 50 H (11.3%), and 50 P : 50 RC (15.4%). Given that most container AS percentages were below the recommended range, it follows that substrate WHC percentages would be higher than normal. No treatment fell within the recommended range for WHC (50%–65%), as they were all higher than 65%. Substrate WHC percentages ranged from 74.9% (50 P : 50 WT) to 84.7% (75 P : 25 SG). With only one exception [50 P : 50 WT (74.9%)], all treatments had similar WHC percentages to that of the GS (82.0%). All percent values for TP of substrates were higher than the recommended range (60%–75%) (Jenkins and Jarrell, 1989). Bulk density values for all treatments were less than the recommended range (0.19–1.70 $g \cdot cm^{-3}$) (Yeager et al., 2007). While all treatments were not similar to the GS (0.15 $g \cdot cm^{-3}$), all BD values fell within a tight range [from 0.13 $g \cdot cm^{-3}$ (75 P : 25 WT, 75 P : 25 SG, 75 P : 25 RC, and 50 P : 50 WT) to 0.16 $g \cdot cm^{-3}$ (50 P : 50 H)]. The 75 P : 25 SG treatment had one of the lowest BD values (0.13 $g \cdot cm^{-3}$).

In general, these data show that while physical properties indicated that these substrates were similar, they performed very differently. Throughout the study, treatments with RC as an amendment tended to perform as well as the traditional GS. Plants in treatments with RC also performed equal to or better than plants in WT. Plants grown with SG and H as amendments differed significantly from the GS with respect to growth indices, flower number, and PDW. Given that plants grown in SG and H appeared to be stunted and smaller than those grown in the GS, WT, and RC, they are not recommended as amendments for annual plant production with current greenhouse practices. However, additional studies are in place to determine if different fertility regimes could improve the potential of using H and SG substrates. While results from this study concerning using RC as an amendment in the GH production of three annual crops were promising, additional trials with a greater number of plant species would be necessary before advising growers to make a switch in their own production practices.

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Effects of Media and Species on Soil CO_2 Efflux in the Landscape©

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Increasing concentrations of greenhouse gases (GHG) including carbon dioxide, methane, and nitrous oxide are widely believed to be the main contributing factors leading to global climate change. The horticulture industry has the potential to improve GHG conditions through sequestering carbon (C) in urban landscapes. In order to determine effects of growth media on soil CO_2 efflux, a study was conducted in which two common landscape species were grown in containers using three different growing media: (1) pine bark [PB], (2) clean chip residual [CCR], or (3) whole tree [WT]; after one growing season they were outplanted into the field. Initial soil samples were collected for C content determinations. Automated carbon efflux systems (ACES) were installed adjacent to three plants of each species in each media for continuously monitoring (24 h/day) of C lost via soil respiration and to determine media C sequestration potential. Increased soil C was primarily noted in the upper soil depth (0–15 cm), where PB was higher than the other media; a similar pattern was observed for the 15–30 cm depth although C values were much lower. Crape myrtle had higher soil CO_2 efflux than magnolia possibly due to crape myrtle having a larger root system or faster growth rate. All media had different soil CO_2 efflux values in crape myrtle (CCR was highest and WT lowest), while for magnolia PB was higher than the other media. Across both species WT had lower efflux than PB and CCR possibly due to its higher wood content causing it to break down slower. Placing containerized plants into the landscape transfers a large amount of C belowground, suggesting that opportunities exist for the horticulture industry and homeowners to contribute positively to mitigating climate change via soil C sequestration. However, further investigation is needed to fully understand the impact of various growing media and ornamental species on soil CO_2 emissions and the residence time of this C in soil when planted into urban and suburban landscapes.

INTRODUCTION

Concentrations of the three most important long-lived greenhouse gases (GHG) in the atmosphere have increased dramatically over the past 255 years. Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) concentrations in the atmosphere have increased by approximately 35% (Keeling and Whorf, 2005), 155%

(Dlugokencky et al., 2005), and 18% (Prinn et al., 2000) since 1750. Annual C emissions have increased approximately 80% from 1970 to 2004 (IPPC, 2007). Fossil fuel combustion along with land use changes such as deforestation, biomass burning, soil cultivation, and drainage of wetlands are the main contributors to increased C emissions. Increased concentration of atmospheric CO_2 and other GHG in widely accepted as the main factor causing global warming (Florides and Christodoulides, 2008). While it has not been proven that GHG are causing global climate change, data has been presented which indicates the earth's surface temperature is increasing which could lead to possible negative environmental impacts (Lal, 2004; IPCC, 2007).

The agriculture industry in the United States is one of the highest contributors to GHG emissions behind only energy production (Johnson et al., 2007). These three (CO_2, CH_4, and N_2O) are the most important GHG because of their atmospheric concentrations and because elevated levels of these gases are primarily due to human activity. Emissions of CO_2, CH_4, and N_2O from agriculture collectively account for an estimated one-fifth of the annual increase in GHG emissions. When land use changes involving clearing of land, biomass burning, and soil degradation are included, the overall impact from agriculture is one-third of the total man-made greenhouse effect (Cole et al., 1997).

Opportunities to reduce GHG in agriculture have been the focus of much research (Hogan et al., 1993; Sommer and Hutchings, 1995; Cole et al., 1997; Kroeze et al., 1999); however, it is widely believed long-term capture and storage of these gases is necessary to mitigate climate change. Unlike many other industries, agriculture has the potential to offset emissions by altering production practices which have the capacity to increase C uptake and storage in biomass and soils, referred to as carbon sequestration (USDA, 2008). Research has shown that row-cropping systems utilizing conservation or "no-till" farming practices can reduce fossil fuel consumption while increasing C storage in soil (Reicosky et al., 1999). Changes in forestry management practices such as nutrient management, density control, and use of genetically improved species has been shown to increase C uptake and storage in biomass and soils (USDA, 2008).

Horticulture is a large-scale industry which impacts the landscape of rural (production facilities) and urban environments. The economic impact of the "green industry" (nursery, greenhouse, and sod) is \$148 billion annually (Hall et al., 2005) and was \$2.8 billion in Alabama alone in 2008 (AAES, 2009). Nationally, the green industry generates 1.9 million jobs, \$64.3 billion in labor income, and \$6.9 billion in indirect business taxes (Hall et al., 2005). While horticulture is one of the fastest growing sectors in agriculture, its potential impacts on climate change (either positively or negatively) have been virtually ignored. Farmers and ranchers in other agricultural sectors are now earning additional income in the emerging carbon trading market in which farmers may be paid to reduce their C emissions or sign contracts pledging to alter production practices which provide C offsets (i.e., C credits) to other industries which want to reduce their C footprint (CCE, 2009; NFU, 2009). In order for the horticulture industry to reduce GHG emissions and benefit from these new emerging programs, baseline estimates of C emissions and the ability of growers/landscapers to sequester C using current production practices must be established. The objective of this research is to develop baseline data to determine the ability of the nursery and landscape industry to mitigate climate change by sequestering C with the planting of ornamental trees and shrubs in the landscape.

MATERIALS AND METHODS

In order to determine the potential that the nursery and landscape industry has for C storage and to begin to understand the effects of growth media on soil CO_2 efflux, two commonly grown nursery crops including crape myrtle (*Lagerstroemia* 'Acoma') and southern magnolia (*Magnolia grandiflora*) were transplanted from 7.6-cm (3-in.) and 10.2-cm (4-in.) liners, respectively, into 11.6-L (3-gal) containers on 25 Mar. 2008. Plants were potted using one of three growing media; pine bark (PB), whole tree (WT), or clean chip residual (CCR). Each substrate was mixed with sand (6 : 1, v/v) and 8.3 $kg \cdot m^{-3}$ (14 lbs/yd^3) 18-6-12 Polyon control-release fertilizer, 3.0 $kg \cdot m^{-3}$ (5 lb/yd^3) lime, and 0.9 $kg \cdot m^{-3}$ (1.5 lb/yd^3) Micromax were added. Whole Tree (Fain et al., 2006) and CCR (Boyer et al., 2008), are by-products of the forestry industry which are currently being investigated as alternative media sources due to decreasing PB supplies (Lu et al., 2006). Plants were grown in the 11.6 L (3 gal) containers for an entire growing season and then outplanted to the field in December 2008. To monitor soil CO_2 efflux, automated carbon efflux systems (ACES, USDA Forest Service, Southern Research Station Laboratory, Research Triangle Park, North Carolina; U.S. patent #6,692,970) were installed adjacent to the two plant species previously mentioned to continuously monitor (24 $h \cdot d^{-1}$) C lost via soil respiration. Three replicate sampling chambers were placed on each potting media/species combination. Belowground soil C was also assessed in Summer 2009, prior to placement of ACES. Two soil cores [3.8 cm (1.5 in.) diameter × 60 cm (23.6 in.) depth] were collected from each treatment within all blocks according to methods described by Prior et al. (2004). Cores were divided into 15 cm (5.9 in.) depth segments, sieved (2 mm), and oven dried at 55 °C (131 °F). Ground subsamples of soil (0.15-mm sieve) were analyzed for C on a LECO TruSpec CN analyzer (LECO Corp., Saint Joseph, Michigan). The experiment was designed as a randomized complete block design. Soil CO_2 efflux data were analyzed using the Proc Mixed procedure and percent soil C was analyzed using the Proc GLM procedure of SAS (SAS version 9.1).

RESULTS AND DISCUSSION

Soil analysis at the beginning of the study period indicated that soil C in the top depth of soil (0–15 cm) was higher for PB compared to WT and CCR for both plant species (Figs. 1 and 2). Soil C for the other two media did not differ in either species. Although soil C was much lower at the 15–30 cm depth, the same treatment pattern was observed for both species. No soil C differences were observed among media in either species at the lower two depths (i.e., 30–45 and 45–60 cm). These initial soil C data indicate that the media were contained in the upper 15 cm of the soil profile with a possibility that some of the pine bark was incorporated slightly below that depth.

Crape myrtle had higher soil CO_2 efflux than magnolia when compared across all media; this was generally true when considering each medium separately (Table 1). This higher efflux may be due to crape myrtle having a larger root system or faster growth rate than magnolia. In crape myrtle, all three media had significantly different soil CO_2 efflux values; CCR was highest and WT lowest. In magnolia, PB was higher than the other media, which did not differ. Across both species, WT had lower efflux than PB or CCR which were similar. Given that all three media had similar C content at potting (49.2, 47.8, and 46.9% for PB, WT, and CCR, respec-

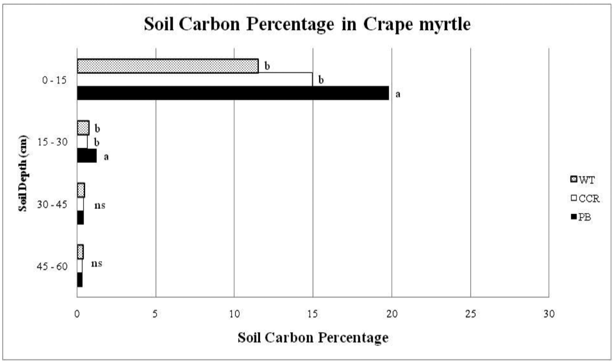

Figure 1. Media effects on soil carbon percentage in crape myrtle. Bars with the same letter are not significantly different according to the Least Significant Differences Test (alpha = 0.05). ns = not significant according to the Least Significant Differences Test. PB = Pine Bark, WT = WholeTree, CCR = Clean Chip Residual.

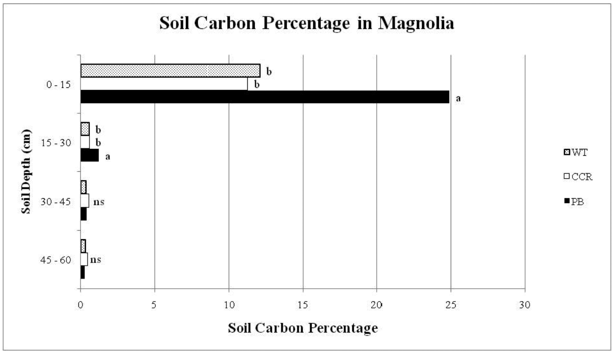

Figure 2. Media effects on soil carbon percentage in magnolia. Bars with the same letter are not significantly different according to the Least Significant Differences Test (alpha = 0.05). ns = not significant according to the Least Significant Differences Test. PB = Pine Bark, WT = WholeTree, CCR = Clean Chip Residual.

tively), the lower efflux for WT may be due to its higher wood content (~90% for WT versus ~40% for CCR) causing it to break down slower. Further, Boyer et al. (2008) reported that PB and CCR had equivalent microbial respiration suggesting that these materials decompose at similar rates which is supported by our findings.

It is interesting to note that, for magnolia, the soil CO_2 efflux data mirrored the initial soil C data; that is, PB had higher soil C values and higher efflux values than the other two media, which did not differ. This was not the case for crape myrtle where soil C followed the same pattern as magnolia but where efflux was highest

Table 1. Effects of species and growth media on soil CO_2 efflux. Means with associated separation statistics are shown.

Species effects on soil CO_2 efflux across all media		
Species[b]	**Soil Flux**	**P-value**
CM	7.68	<0.001
MG	7.01	
	% Difference	
MG vs CM	9.6	
Media effects on soil CO_2 efflux across both species		
Media[c]	**Soil Flux**	**P-value**
PB	7.46	<0.001
WT	7.01	
CCR	7.57	
	% Difference	**P-value**
PB vs WT	-6.0	<0.001
PB vs CCR	1.5	0.265
WT vs CCR	8.0	<0.001
Media effects on soil CO_2 efflux within Crape Myrtle		
Media	**Soil Flux**	
PB	7.68	
WT	7.12	
CCR	8.24	
	% Difference	**P-value**
PB vs WT	-7.3	<0.001
PB vs CCR	7.3	<0.001
WT vs CCR	15.7	<0.001
Media effects on soil CO_2 efflux within Magnolia		
Media	**Soil Flux**	
PB	7.24	
WT	6.89	
CCR	6.90	
	% Difference	**P-value**
PB vs WT	-4.8	0.016
PB vs CCR	-4.7	0.018
WT vs CCR	0.1	0.977
Species effects on soil CO_2 efflux within media		
	% Difference	**P-value**
MG vs CM in PB	6.1	0.002
MG vs CM in WT	3.3	0.099
MG vs CM in CCR	19.4	<0.001

[a]Efflux in µmol CO_2 $m^{-2} \cdot s^{-1}$; [b]CM = Crape Myrtle, MG = Magnolia

[c]PB = Pine Bark, CCR = Clean Chip Residual, WT = Whole Tree

for CCR, followed by PB, then by WT, with each being significantly different. The reason for this is not know but may involve interactions of media and root growth; this will be investigated at study termination.

It has been shown that changes in agricultural management practices which minimize soil disturbance (i.e., no-tillage) and increase surface crop residues (including use of cover crops) can enhance soil C sequestration potential (Smith et al., 1998; Lal, 2007), however this may be true only in the long term (Six et al., 2004). In the present study, soil C ranged from 11%–25% in the upper soil profile of the planting area compared with about 3% found in field soils (Simmons and Derr, 2007). These data clearly show that planting containerized ornamentals into the landscape transfers a large amount of C belowground instantly, suggesting that opportunities exist for the horticulture industry to contribute positively to soil C sequestration. However, uncertainty remains regarding how long this C will remain sequestered. Further investigation is needed to fully understand the impact of various growing media and ornamental species on soil CO_2 emissions and the residence time of this C in soil when planted into urban and suburban landscapes. These data will not only prepare the horticultural industry for possible future legislation, they also provide homeowners a means of directly contributing to the mitigation of climate change via soil C sequestration.

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Effect of Coffee Grounds on Seed Germination©

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Aqueous coffee extracts (ACE) and spent coffee grounds (SCG) were evaluated for effects on seed germination of *Trifolium repens* (white clover), *Lolium perenne* (perennial rye), and *Amaranthus palmeri* (palmer amaranth). In Experiment 1, five different percentage ACE treatments (0%, 25%, 50%, 75%, and 100%) were mixed and added to petri dishes. Each petri dish had 25 seed of each weed species. White clover started germinating 1 day after seeding (DAS) in all treatments. By 8 DAS, nearly all white clover seed had germinated. However, visually the seedling size decreased as percentage ACE increased, suggesting that ACE might contain properties that deter seed from germinating. Furthermore, perennial rye seed had a lower germination rate, regardless of percentage ACE compared to the 0% ACE treatment. In Experiment 2, SCG and pine bark (PB) were evaluated as container mulch at five different depths (0, 0.5, 1.0, 1.5, and 3.0 inches). Results indicated that SCG as container mulch, have similar weed control to PB mulch by 14 DAS, at respected depths. Additionally, use of either SCG or PB at 0.5 and 1.0 inches depth, had less weeds compared to the nonmulched containers at 14 DAS.

INTRODUCTION

In 2005, individuals consumed 24.2 gal of coffee per year in the United States of America alone (Buzby and Haley, 2007). While this per capita is based on liquid consumption it does not account for the solid waste or coffee residue leftover after the brewing process. It is estimated that the daily volume of coffee residue is 0.91 kg for each kilogram of soluble coffee (Yen et al., 2005). In 2006/2007 world coffee production was estimated at 134.3 million bags, over 8 billion kg (USDA, 2007). Spent coffee grounds (SCG), which are the coffee residue after brewing, are considered municipal solid waste and normally end up in landfills. Once in a landfill, they take up space until they are degraded and due to the high presence of organic material, there needs to be adequate oxygen in order to be degraded or they can ferment and spontaneously combust (Silva et al., 1998). The amount of SCG is surprisingly overwhelming, for example, extension agents in Lane County, Oregon, collected 53 tons of coffee grounds from 13 local coffee shops in 2007 estimating that in 1 year Lane County produced around 500 tons of coffee grounds (62.5 large dump trucks) (Woods, 2008).

Previous research has suggested that SCG can be used as alternative fuels (Silva et al., 1998), soil additives (Yen et al., 2005), metal adsorbents (Utomo and Hunter, 2006), vermicompost (Orozco et al., 1996), landscape compost (Morikawa and Saigusa, 2008), mulch (Eshetu et al., 2007), and weed control (Sciarrappa et al., 2008). Morikawa and Saigusa (2008) composted ferrous sulfate with SCG for 60 days in plastic bags. Their findings showed that this compost combination decreased pH in alkaline soils, increasing plant available Fe. Additionally, mulching with coffee husk has shown to conserve soil moisture enough to significantly promote vegetative growth in pineapples when moisture is a limiting factor (Eshetu et al., 2007). Subsequently, coffee husk mulch had 85.5% weed control compared to their non-weeded/non-mulched control. Studies conducted by Sciarrappa et al. (2008) showed that mulching with coffee grinds to a depth of 1.6–3.1 in. provided 95% weed control in organic blueberry production.

Since SCG are a low cost by-product and there is more than 80 million tons produced a year, SCG could be an option for the green industry. Our objective for this study was to evaluate aqueous coffee extracts (ACE) on germination of three commonly found weed seeds and evaluate SCG as potential mulch for containers.

MATERIALS AND METHODS

For this study the local Starbucks® coffee shops in Starkville, Mississippi, provided SCG.

Experiment 1: Effect of ACE on Seed Germination. Treatments included four concentrations of ACE and reverse osmosis water (RO) was used as control. Stock ACE was developed by mixing 231 g of spent coffee grounds with 600 mL of water and stirring for 48 h on a stirrer plate (Corning Stirrer/Hotplate). The coffee solution (pH 5.39, EC 1.69 $dS{\cdot}m^{-1}$) was then filtered through cheese cloth. The ACE of various concentrations were formulated in 100 mL beakers as following: 25% ACE consisted of 10 mL of the stock ACE and 30 mL of RO, 50% consisted of 20 mL of stock ACE and 20 mL of RO, 75% consisted of 30 mL of stock ACE and 10 mL of RO, and 100% was 40 mL of stock ACE. Captain fungicide was added to each treatment based on recommended label rate of 1½ tbs/gal (0.088 g per 40 mL). Whatman® #1 filter paper was placed on the petri dishes. An aliquot of 4 mL of solution, was added to each petri dish to saturate the filter paper and 25 seeds of *Amaranthus palmeri* (palmer amaranth), *Lolium perenne* (perennial rye), and *Trifolium repens* (white clover) were placed in one petri dish (three species, 25 seeds per plate). There were five Petri dishes for each of the four ACE treatments and the control, and there were a total number of 25 Petri dishes in the experiment. All Petri dishes were placed in a growth chamber with 20 °C/15 °C (day/night temperatures) and 16-h photoperiod. Petri dishes were monitored daily, adding an additional milliliters of corresponding ACE solution to each plate as needed to keep seed from drying out. Data collected included the germination rate and germination development (white clover only; presence of radicle, 1 leaf cotyledon, 2 leaf cotyledon). A seed was considered germinated once change in the seed was noticed (break in seed coat, radicle emerging). Data were analyzed utilizing SAS 9.2 generalized linear model, with mean separation according to least significant difference test, alpha = 0.05.

Experiment 2 : Effect of Spent Coffee Grounds and Pine Bark on Seed Germination in Containers. Trade gallon containers were filled with Sunshine #1 potting mix to 3 in. below the top of the container and watered accordingly. *Trifolium repens* and *A. palmeri* were overseeded at 15 seed per container (one species per container) and then mulched with either spent coffee grounds (SCG) or pine bark (PB) to a depth of 0, 0.5, 1.0, 1.5, or 3 in. and watered accordingly. Data collected included the number of visible weeds at 3, 6, 10, and 14 days after seeding (DAS). Data were analyzed utilizing SAS 9.2 generalized linear model, with mean separation according to least significant difference test, alpha = 0.05.

RESULTS

Experiment 1. White clover started germinating in all treatments 1 DAS (Table 1) and the 75% ACE had statistically less white clover germinate (22%) compared to the control (17%). At 2 and 4 DAS all ACE-treated dishes had less germination compared to the control. At 5 DAS, all percent ACE treatments had less white clover germination compared to the control with the exception of the 25% ACE treatment. At 6 and 7 DAS all percentage ACE treatments had similar white clover germination compared to the control with the exception of the 100% ACE solution. By 8 DAS nearly all white clover had germinated in all treatments and were statistically similar. While statistically there were no differences in treatments 8 DAS, there were visual differences. As the percentage of ACE increased, the progression of seed growth was less advanced (Table 2). On 9 DAS, 77% of the seed treated with 75% and 100% ACE only had emerged radicles. Only 3% of the seed had 1 or 2 cotyledons in 100% ACE treatment. On the other hand, 14% of the seed were in the 1-leaf-cotyledon stage and 38% in 2-leaf-cotyledon stage for the control.

Perennial rye seed started germinating 4 DAS in the 0%, 25%, and 50% ACE treatments (Table 3). However there were no significant differences regardless of ACE treatments. At 6, 7, and 8 DAS all treatments with ACE had significantly less perennial rye than the control. Number of germinated perennial rye seeds tended to decrease as percentage ACE increased, respectively.

Palmer amaranth treated with higher percentage of ACE had lower seed germination rate than the control (Table 4). However, germinated seeds were short lived, more than likely due to the small seeds being over saturated.

Experiment 2. For white clover there was significantly less seedlings in all treatments with mulch than the control regardless of the depth or type (Table 5). Our results were similar to Sciarappa et al. (2008) who reported that mulching with SCG is an effective weed control option in field blueberry production. Comparing mulch types, 0.5 and 1.0 in. SCG were not significantly different from 0.5 and 1.0 in. PB treatments, respectively. At 14 DAS white clover started emerging in the 1.5-in. PB treatment, however statistically there is no difference compared to the zero emergence in 1.5-in. SCG treatment. No weed emergence was observed in 3-in. mulch 14 DAS. As of 14 DAS only a few of palmer amaranth had only germinated in the 0 in. mulch (data not shown).

DISCUSSION

In conclusion, initial white clover germination was observed in all ACE treatments however development of the seedlings at 8 DAS were different, respectively. These results suggest that ACE might have some properties that inhibit white clover and perennial rye growth. Mulching with either SCG or PB had less seedlings than the non-mulched treatment. Moreover, mulching in containers is a technique used by Oregon growers especially in areas or crops susceptible to herbicide damage (Altland and Lanthier, 2007). Utilizing SCG as mulch in containers can provide an organic alternative to weed control in the nursery industry. These results are ongoing and future research will focus on evaluating container plant growth with SCG mulch and evaluating spent coffee grounds as a weed barrier.

Table 1. Effect of varing concentations of an aqueous coffee extract (ACE) on germination of *Trifolium repens*.

		Germination rate (%)						
Treatment	ACE	1 DAS[z]	2 DAS	4 DAS	5 DAS	6 DAS	7 DAS	8 DAS
1	0%[y]	17 a[x]	35 a	56 a	60 a	73.2 a	85.2 a	82.4 a
2	25%	10 ab	17 b	36 b	52 ab	61.2 ab	84 ab	80 a
3	50%	8.8 ab	18 b	26 bc	37 bc	58.4 ab	83.2 ab	86.4 a
4	75%	3.2 b	8 b	17 c	26 c	61.6 ab	81.6 ab	83.2 a
5	100%	7.2 ab	13 b	22 c	36 c	44 b	48.8 b	76.8 a

[z]DAS = days after seeding.

[y]Percent ACE stock solution. Stock solution was obtained by mixing 231 g of coffee grounds with 600 mL of water and stirring for 48 hours on a shaker plate.

[x]Means (within a column) with different letters are significantly different, according to Least Significant Difference test (α=0.05).

Table 2. Differences in *Trifolium repens* grown under aqueous coffee extracts (ACE), 9 days after seeding.

		Seed germination development (%)		
Treatment	ACE	Radicle[z]	Cotyledon[y]	Leaf[x]
1	0%[w]	32.0 b[v]	14.4 a	37.6 a
2	25%	52.0 ab	8.8 ab	27.2 ab
3	50%	64.8 a	12.0 a	12.0 bc
4	75%	76.8 a	8.0 ab	6.4 bc
5	100%	76.8 a	3.2 b	3.2 c

[z]Radicle = only the radicle had emerged.

[y]Cotyledon = 1 leaf cotyledon stage.

[x]Leaf = 2 leaf cotyledon stage.

[w]Percent ACE stock solution. Stock solution was obtained by mixing 231 g of coffee grounds with 600 mL of water and stirring for 48 hours on a shaker plate.

[v]Means (within a column) with different letters are significantly different, according to Least Significant Difference test (α=0.05).

Table 3. Effect of varing concentations of an aqueous coffee extract (ACE) on germination of *Lolium perenne*.

		Germination rate (%)						
Treatment	ACE	1 DAS[z]	2 DAS	4 DAS	5 DAS	6 DAS	7 DAS	8 DAS
1	0%[y]	-	-	1.6 a[x]	10 a	32 a	42.8 a	52 a
2	25%	-	-	0.8 a	4 a	11.2 b	24 b	28 b
3	50%	-	-	0.8 a	0.8 a	8 b	18.4 bc	28 b
4	75%	-	-	0 a	0 a	3.2 b	10.4 cd	15.2 bc
5	100%	-	-	0 a	0 a	0 b	0.8 d	3.2 c

[z]DAS = days after seeding.

[y]Percent ACE stock solution. Stock solution was obtained by mixing 231 g of coffee grounds with 600 mL of water and stirring for 48 hours on a shaker plate.

[x]Means (within a column) with different letters are significantly different, according to Least Significant Difference test (α=0.05).

Table 4. Effect of varing concentations of an aqueous coffee extract (ACE) on germination of *Amaranthus palmeri*.

		Germination rate (%)						
Treatment	ACE[z]	1 DAS	2 DAS	4 DAS	5 DAS	6 DAS	7 DAS	8 DAS
1	0%[y]	0.8 a[x]	5.6 a	18 a	27 a	14.4 a[w]	24 ab	20 a
2	25%	1.6 a	5.6 a	8 b	13 b	9.6 a	29.2 a	14.4 a
3	50%	0.8 a	3.2 a	9.6 ab	6.4 b	10.4 a	8.8 ab	7.2 b
4	75%	2.4 a	2.4 a	1.6 b	5.6 b	5.6 a	4 b	8 b
5	100%	3.2 a	2.4 a	4 b	4.8 b	7.2 a	4 b	6.4 b

[z]DAS = days after seeding.

[y]Percent ACE stock solution. Stock solution was obtained by mixing 231 g of coffee grounds with 600 mL of water and stirring for 48 hours on a shaker plate.

[x]Means (within a column) with different letters are significantly different, according to Least Significant Difference test (α=0.05).

[w]Means lower than the value in the previous day was due to seed mortality which may have been caused by over saturation of the seeds.

Table 5. Efficacy of spent coffee grounds (SCG) and pinebark (PB) used as mulch for control of *Trifolium repens*.

	Mulch		Seedling emergence			
Treatment	Depth (inches)	Type	3	6	10	14
1	0.0	-	2.5 a[z]	7.0 a	7.5 a	9.0 a
2	0.5	SCG	0.8 b	3.0 bc	3.8 bc	4.0 bc
3	1.0	SCG	0.0 b	0.5 d	0.8 de	1.5 de
4	1.5	SCG	0.0 b	0.0 d	0.0 e	0.0 e
5	3.0	SCG	0.0 b	0.0 d	0.0 e	0.0 e
6	0.5	PB	0.5 b	3.8 b	5.3 b	5.8 b
7	1.0	PB	0.0 b	1.3 cd	2.5 cd	2.5 cd
8	1.5	PB	0.0 b	0.0 d	0.0 e	0.3 e
9	3.0	PB	0.0 b	0.0 d	0.0 e	0.0 e

[z]Means (within a column) with different letters are significantly different, according to Least Significant Difference test (α=0.05).

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Growth of *Pistacia chinensis* in a Red Cedar–Amended Substrate©

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INTRODUCTION

Pine bark (PB) continues to be the industry standard material for container grown plant production of woody ornamentals throughout the Southeast U.S.A. (Yeager, 2007). However, because of the closing and relocation of timber mills, as well as increased use of PB as a fuel source for power mills, PB has become less available and more costly for use in the nursery industry (Laiche and Nash, 1986; Lu et al., 2006). This has lead to a demand for alternative substrates to supplement PB particularly in regions that lack indigenous pine species (such as the Great Plains). Abundant tree species in the Great Plains could potentially be used in a similar manner to Clean Chip Residual (CCR) and WholeTree (WT) which have been used in the Southeast U.S.A. Eastern red cedar (*Juniperus virginiana*) grows in most areas of the Great Plains. Once held back by grazing and wild fires from fully entering the grasslands, community development and farming have reduced these natural control measures. Additionally, the use eastern red cedar as windbreaks, erosion control, and wildlife cover since the 1960s has increased the seed population (Ganguli et al., 2008; Ownesby et al., 1973).

Movement of eastern red cedar into the Great Plains can impact the environment by affecting soil moisture, blocking incoming solar radiation, decreasing soil temperature, and altering litter dynamics by increasing litter size and slowing decomposition creating a mechanical barrier that prevents germination. Even isolated trees can have a negative effect on species composition well beyond its canopy diameter affecting stem density, species richness, forb cover, and grass cover. As a tree becomes older and larger the understory environment becomes unfavorable for most herbaceous plants and rapid recovery to the original species composition (prairie) seems unlikely the longer a single tree is in place. Nonetheless tree stands full of eastern red cedar exist across the Great Plains (Linneman and Palmer, 2006; Gehring and Bragg, 1992). In addition to decreasing species diversity, eastern red cedar increases livestock handling costs and decreases forage area (Ortmann et al., 1998). In Oklahoma an estimated 762 acres of land are lost to eastern red cedar infestation per day (Drake and Todd, 2002).

Utilization of eastern red cedar chips as a component of nursery potting substrates could alleviate PB demand in the Great Plains with a sustainable, local resource while providing economic incentive to decrease the eastern red cedar population and its effect on the Great Plains ecosystem and economy. Previous work has demonstrated that red cedar may be an acceptable substrate for production of some woody species (Griffin, 2009). The purpose of this investigation was to determine if red cedar could act as a substrate or PB extender for containerized nursery crop production of ornamental species.

MATERIALS AND METHODS

Eastern red cedar chips were obtained from Queal Enterprises (Pratt, Kansas). Whole trees were harvested from Barber County, Kansas, and aged for 6 months. Trees were then processed into chips using a horizontal woodgrinder (Rotochoper, St. Martin, Minnesota). Further processing occurred through a hammermill (Model 5–2 0–4 WW Grinder Inc., Wichita, Kansas) to pass a 3/4 inch screen at the John C. Pair Horticultural Research Center (Haysville, Kansas). Red cedar was then used to create six substrates containing 0%, 5%, 10%, 20%, 40%, or 80%, red cedar (by vol.). Sand (20% by volume) was incorporated into each substrate and the remaining volume contained PB. Each substrate treatment was pre-plant incorporated with 1.5 lbs/yd^3 of Micromax (The Scotts Company, Marysville, Ohio) and either a low (7.5 lbs/yd^3) or high (15 lbs/yd^3) rate of controlled-release fertilizer (Osmocote 19-6-12; 12 to 14-month release; The Scotts Company, Marysville, Ohio) resulting in 12 treatments on 19 and 20 May 2009. Chinese pistache (*Pistacia chinensis*) seeds were collected at the Haysville station, germinated in Spring 2008, and grown in 2-in. by 2-in. by 6-in. bottomless bands in a PB and sand (8 : 1, v/v) mix with controlled-release fertilizer (Osmocote Plus 15-9-12, The Scotts Company, Marysville, Ohio) incorporated at the high label rate (12 lbs/yd^3). Seedlings were overwintered in an unheated polyhouse. On 20 May 2009 1-year-old Chinese pistache seedlings were planted into 3-gal. containers (Olympian Heavy Weight-Classic 1200, Marysville, Ohio) containing the treatment substrates and placed on a gravel production pad where they received 1 inch of irrigation water daily via overhead sprinklers. The experiment was terminated on 9 Sept. 2009, 113 days after planting (DAP). The experimental design was a randomized complete block with a factorial arrangement of treatments. There were six substrate blends and two fertilizer rates. The experiment was replicated eight times. Substrate physical properties were determined using North Carolina State University porometers (Raleigh, North Carolina) which measured substrate air space (AS), water holding capacity (WHC), substrate bulk density (BD), and total porosity (TP) (Fonteno and Bilderback, 1993). Data collected included pH and electrical conductivity (EC) using the PourThru technique and leaf greenness as measured with a SPAD meter at 15, 29, 43, 57, 71, 85, 99, and 113 days after planting (Wright, 1986). Shoot dry weight (SDW) and root dry weight (RDW) were recorded at the conclusion of the study (113 DAP) by drying in a forced air oven at 160 °F for 7 days. Tree caliper was measured at termination. Data was analyzed using SAS (Version 9.1 SAS Institute Inc. Cary, North Carolina).

RESULTS

Substrate pH of the fertilizer treatments did not differ but the differences between red cedar content was significant. Water pH used for irrigation ranged from 7.46 to 7.96 with an average of 7.61. Substrate pH of 0% red cedar increased by 27% to 7.20 from 15 DAP to 113 DAP while pH of 5% red cedar increased by 25% to 6.95 at 113

DAP. Substrate pH of 10% red cedar increased by 28% to 7.01 at 113 DAP and the pH of 20% red cedar increased by 23% to 7.18 at 113 DAP. Substrate pH for 40% red cedar increased less than other treatments, 7% to 7.28 at 113 DAP. Substrate pH of treatments containing 80% red cedar decreased by 3% to 7.48 at 113 DAP. The high pH of substrates containing larger amounts of red cedar changed less over time most likely due to having a higher starting pH with red cedar alone having a pH of 6.60. Both fertilizer level and red cedar content was significant for EC. Low fertilizer treatments with 0% red cedar decreased by 51% to 0.59 $\mu S \cdot cm^{-1}$ at 113 DAP and 5% red cedar decreased by 47% to 0.60 $\mu S \cdot cm^{-1}$ at 113 DAP. Substrates with 10% red cedar decreased EC by 52% to 0.61 $\mu S \cdot cm^{-1}$ at 113 DAP while 20% red cedar decreased EC by 51% to 0.66 $\mu S \cdot cm^{-1}$ at 113 DAP. In containers with 40% red cedar EC decreased 17% to 0.75 $\mu S \cdot cm^{-1}$ at 113 DAP while 80% red cedar decreased EC by 8% to 1.04 $\mu S \cdot cm^{-1}$ at 113 DAP. High fertilizer rate with 0% red cedar decreased EC by 63% to 0.72 $\mu S \cdot cm^{-1}$ at 113 DAP and 5% red cedar decreased by 53% to 0.87 $\mu S \cdot cm^{-1}$ at 113 DAP. Substrates with 10% red cedar decreased by 46% to 0.86 $\mu S \cdot cm^{-1}$ at 113 DAP while 20% decreased by 42% to 0.77 $\mu S \cdot cm^{-1}$ at 113 DAP. In containers with 40% red cedar EC decreased by 34% to 0.81 $\mu S \cdot cm^{-1}$ at 113 DAP while 80% red cedar decreased by 51% to 0.77 $\mu S \cdot cm$ at 113 DAP. Water EC ranged from 0.86 $\mu S \cdot cm^{-1}$ to 0.94 $\mu S \cdot cm$ with an average of 0.91 $\mu S \cdot cm^{-1}$ (data not shown).

Plants exhibited no differences in height based on fertilization at 113 days after planting and there were no significant differences between red cedar content except 80% red cedar, which had less growth (115 cm for 0% to 40% red cedar; 95 cm for 80% red cedar) (Table 1). Fertilizer had a significant effect on caliper with the higher rate producing larger caliper trees (1.61 cm low, 1.72 cm high). Within the low fertilizer treatment there were no significant differences in caliper between red cedar content. The high fertilizer treatment, however, had slightly more variability between treatments with 0% and 20% red cedar having thicker trunks and 80% red cedar having the smallest trunk size while 0%, 5%, and 40% red cedar were similar. Fertilizer level also affected shoot dry weight with the low fertilizer level having similar shoot growth in 0% to 20% red cedar and 40% to 80% red cedar having less growth. The high fertilizer shoot dry weight had had similar shoot growth from 0% to 40% red cedar with 80% red cedar being smaller than the others. Root dry weight did not differ between fertilizer levels. However red cedar content did influence root dry weight with 0% to 10% red cedar being similar and 80% red cedar being the lowest with 20% and 40% red cedar similar to both levels (Table 1). Leaf greenness was measured on four new fully expanded leaves every 2 weeks. Leaf greenness was significantly different between fertilizer levels at 29 and 43 DAP and within those two treatment dates leaf greenness varied greatly between red cedar treatments. However, at 57 DAP through the end of the study neither fertilizer level nor red cedar content had a significant effect on leaf greenness (data not shown).

Substrate physical properties for container capacity and total porosity remained within recommended levels with the exception of the container capacity of 80% red cedar container (39.3%) which fell slightly below the recommended range of 45% to 65%. Two red cedar treatments fell below recommended ranges for air space as well (5% and 10% red cedar) with, respectively, 9.1% and 8.2% (recommended air space: 10% to 30%) (Table 2) (Yeager, 2007).

Table 1. Main effects of pine-bark- and *Juniperus virginiana*-based substrates and fertilizer treatment on the growth of *Pistacia chinensis* 113 days after planting.

	Plant height (cm)[z]	Caliper (mm)[y]		Shoot dry weight (g)[x]		Root dry weight (g)[w]
Substrate[v]		Low[u]	high[u]	Low	High	
80% PB: 0% red cedar	109.78 a[t]	1.60 a[t]	1.69 ab[t]	94.74 a[t]	114.91 ab[t]	54.56 a[t]
75% PB: 5% red cedar	115.41 a	1.70 a	1.73 ab	94.86 a	122.96 ab	68.76 a
70% PB: 10% red cedar	120.03 a	1.70 a	1.88 a	113.38 a	138.66 a	64.32 a
60% PB: 20% red cedar	116.75 a	1.57 a	1.79 a	95.64 a	129.13 a	56.07 ab
40% PB: 40% red cedar	113.16 a	1.57 a	1.75 ab	74.35 b	116.63 ab	51.36 ab
80% red cedar	94.99 b	1.53 a	1.51 b	57.40 b	79.18 b	34.77 b

[z]Plants were measured from the top of the substrate to the apical meristem (1 cm = 0.397 in.).

[y]Plants were measure six inches from the top of the substrate.

[x]Shoots were harvested at the container surface and oven dried at 70 ˚C for 48 h (1 g = 0.0035 oz.).

[w]Roots were washed of substrate and oven dried at 70 ˚C for 48 h (1 g = 0.0035 oz.).

[v]Substrate treatments were: PB = pine bark, red cedar = *Juniperus virginiana* chips (1 in. = 2.54 cm). Substrates mixed by volume basis with each treatment containing 20% sand.

[u]Substrates were pre-plant incorporated with either a low or high rate of controlled release fertilizer Osmocote (The Scotts Company, Marysville, Ohio; 19-6-12; 12 to 14 month release) consisting of either a low rate (7.5 lbs/yd3) or a high rate (15 lbs/yd3).

[t]Means within column followed by the same letter are not significantly different based on Waller-Duncan k ratio t tests ($\alpha = 0.05$, n = 3).

CONCLUSION

Plants grown in substrates containing 0% to 40% red cedar had similar growth while plants grown in 80% red cedar consistently (with the exception of caliper on the low fertilizer treatment) had less growth. This decrease in plant growth may be due to the physical properties in the 80% red cedar treatments. Substrates containing 80% red cedar had more air space and a lower than recommended container capacity which resulted in less available water than plants grown in other treatments. Eastern red cedar can be used to supplement but not replace existing PB supplies though a 100% red cedar substrate may be viable with further particle size manipulation (chipping and processing) to increase available water. Additionally, Chinese pistache is an adaptable plant suited to growing in substrates with high pH. Other ornamental crops could exhibit more variability of responses depending on their sensitivity to pH. However, savings on substrate costs by using eastern red cedar to grow pH-adaptable species could make up for crops that must be grown in a more acidic substrate. This data is encouraging for nursery growers in the Great Plains, as they will have more options for affordable substrates for container-grown plants in the future.

Table 2. Physical properties of pine bark- and *Juniperus virginiana*-based substrates.

Substrates[z]	Air space[y] (% Vol)	Container capacity[x] (% Vol)	Total porosity[w] (% Vol)	Bulk density (g·cm^{-3})
80% PB: 0% red cedar	12.6 c[v]	63.0 b[v]	75.5 a[v]	0.51 bc[v]
75% PB: 5% red cedar	9.1 cd	66.5 a	75.6 a	0.50 c
70% PB: 10% red cedar	8.2 d	62.0 b	70.2 b	0.52 b
60% PB: 20% red cedar	10.4 cd	63.9 ab	74.3 a	0.51 bc
40% PB: 40% red cedar	20.8 b	55.2 c	75.9 a	0.51 bc
0% PB: 80% red cedar	29.9 a	39.3 d	69.1 b	0.58 a

[z]Treatments were: PB = pine bark, red cedar = *Juniperus virginiana* chips. Substrates mixed on by volume basis with each treatment containing 20% sand.

[y]Recommended air space: 10 to 30%.

[x]Recommended container capacity 45 to 65%.

[w]Recommended total porosity 50 to 85%.

[v]Means within column followed by the same letter are not significantly different based on Waller-Duncan k ratio t tests ($\alpha = 0.05$, n = 3).

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Nursery Crop and Landscape Systems Plant Evaluations by SERA-27 in the Southeastern U.S.: 2010 Update©

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INTRODUCTION

Many new woody and herbaceous plants are introduced every year with extensive marketing programs, exclusive growing agreements, protective plant patents, and extensive distribution. However, there also exists a wide range of plants that fall outside of this circle that, although lesser known, may be quite worthy of use in the landscape for specific regions. When information is not available on the performance of these plants in different regions, a coordinated system of independent evaluation, along with dissemination of the resulting information to nursery and landscape professionals, becomes invaluable. In the southeastern U.S.A., the SERA-27 group was formed to serve this purpose.

The Southern Extension and Research Activities/Information Exchange Group 27 (SERA-27) for Nursery and Landscape Systems was established in 1994. The group is composed of research and extension faculty working in the commercial nursery and landscape disciplines from among fourteen 1862 land grant universities in the southeastern U.S.A., along with scientists from the USDA-Agricultural Research Service.

Since its inception, over 40 plants have been evaluated, or are currently under evaluation, by the group. A number of the plants evaluated by the group in past years have found useful application in today's southeastern U.S.A. landscapes, including *Cephalotaxus harringtonia*, *Lagerstroemia* 'Pocomoke', *L.* 'Chickasaw', *Illicium mexicanum* 'Aztec Fire', *Styrax japonicus* 'Emerald Pagoda', *Conradina ca-*

nescens, *Ceanothus* ×*delilianus* 'Gloire de Versailles', and several *Hemerocallis* cultivars. Some of the newer plants currently under evaluation are *Arisaema dracontium* (green dragon), *Callicarpa dichotoma* 'Duet' ('Duet' beautyberry; NA 72235), *Eucalyptus neglecta* (Omeo gum), *Hypericum olympicum* (St. John's wort), *Syringa* 'Betsy Ross' ('Betsy Ross' lilac; NA 62973), and *Tagetes nelsonii* (Mayan marigold).

OBJECTIVES OF THE SERA-27 GROUP

The objectives of the SERA-27 group are as follows:

- As a group, identify underutilized ornamental landscape plants with superior environmentally sustainable qualities that can enhance the ornamentals industry in the southeastern U.S.A.
- Using multistate cooperators, evaluate these selected plants at multiple trial locations over a 5-year period. (Depending upon the plant, this period could be shorter or longer.)
- Meet annually to share and discuss quantitative and qualitative results collected from the multiple trial sites.
- At the end of the evaluation period, summarize the regional results with quantitative data, qualitative comments, and an overall rating for the plant.
- Collectively and individually disseminate information gained from the plant evaluation system, such as cold hardiness, heat tolerance, growth rate, and environmental adaptation limits, to a wide variety of audiences.

Morphological Characteristics of Seeds With Physical Dormancy©

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INTRODUCTION

Seed dormancy is a condition where seeds will not germinate even when the environmental conditions (water, temperature, light, and aeration) are permissive for germination (Hartmann et al., 2011). Not only does seed dormancy prevents immediate germination, it also regulates the time, conditions, and location where germination will occur. In nature, different kinds of dormancy have evolved to aid the survival of a species by programming germination for particularly favorable times in the annual seasonal cycles (Baskin et al., 1998).

The major seed dormancy categories include:

- Primary dormancy
  - exogenous dormancy (physical)
  - endogenous dormancy (physiological and morphological)
  - combination dormancy (physical plus physiological)
- Secondary dormancy

The focus of this paper will be to describe the morphological characteristics associated with physical dormancy and indicate how specialized structures on the seed called water gaps function to coordinate dormancy release.

PHYSICAL DORMANCY

Exogenous physical dormancy is imposed upon the seed from factors external to the embryo including the outer seed coat or parts of the fruit coverings (Hartmann et al., 2011). Seeds with physical dormancy fail to germinate because the seed is impermeable to water. Physical dormancy is found in at least 15 plant families, including horticulturally important families like the Fabaceae, Malvaceae, Cannaceae, Geraniaceae, and Convolvulaceae (Baskin et al., 2000). For horticultural crop production, seeds are scarified to mechanically abrade the seed coverings or seeds are treated with concentrated sulfuric acid to alleviate physical dormancy. In nature, exposure to high temperature or fluctuating temperatures is the most likely cause of dormancy release (Geneve, 2003).

Two features characterize seeds with physical dormancy. Physically dormant seeds have an outer seed or fruit cell layer comprised of macrosclereid cells and there is also a surface feature within the outer seed layers that functions as a water gap to allow water imbibition.

MACROSCLEREID CELL LAYER

Macrosclereid cells form the outer cell layer in the seed coat or fruit wall in physically dormant seeds and are responsible for preventing water uptake (Fig. 1). These cells belong to a plant cell type called sclereids. Sclereids are characterized by extensive secondary wall formation and are usually non-living at maturity. This cell layer is also referred to as the Malpighian or palisade cell layer. Malpighian cells

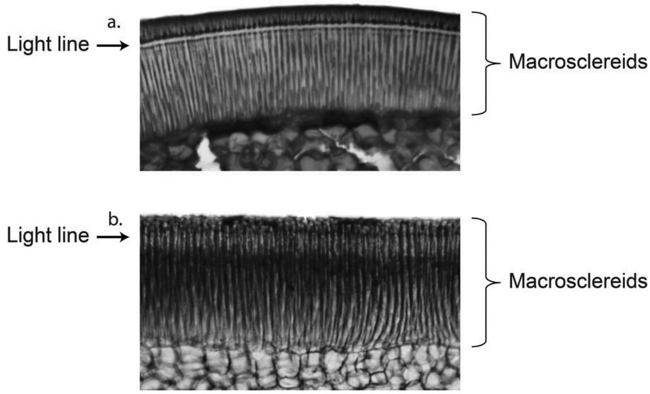

Figure 1. Macrosclereid layer and light line in (a.) eastern redbud (*Cercis canadensis*) and (b.) canna (*Canna indica*).

is an older term no longer in common use and refers to the early 17th-century Italian plant anatomist Marcello Malpighi. During the later stages of seed development, cells of the outer integument coalesce and deposit water-repellant materials within and on the surface of the macrosclereid cells. This seals the seed and makes it impervious to water. These materials include lignin, suberin, cutin, and waxes (Rolston, 1978).

Most macrosclereid cells have a single light line that appears to form a continuous layer across cells (Fig. 1). The light line does not actually extend between cells but occurs at nearly the same location in adjacent macrosclereid cells giving the appearance of a continuous layer. This layer is apparently at the location in the macrosclereid cell where there is a change in the cell's chemical composition that refracts light in a way that appears to form a line in the cell. The light line has been implicated in helping to maintain physical dormancy, but it appears to be secondary to the water repellant materials in the cuticle and sub-cuticle outer layers of the macrosclereid cells.

THE WATER GAP

There is usually a single area of the seed coat that acts as a water gap to relieve physical dormancy and initiate imbibition. It is thought that water gap structures act as environmental sensors to detect appropriate times for germination based primarily on temperature (Baskin et al., 2000). Water gap structures are usually associated with areas of the seed coat where there were natural openings in the ovule during seed development such as the hilum, micropyle, and chalaza. The morphological characteristics of water gaps can vary significantly between physically dormant seeds, but is reasonably similar within a plant family. A list of the known water gap structures are listed in Table 1.

For many seeds, temperature is the environmental signal that relieves physical dormancy (Hartmann et al., 2011). High temperature or temperature fluctuations

Table 1. Water gap structures and associated plant families.

Bulge gap	Convolvulaceae
Chalazal blister gap	Malvaceae, Malveae
Chalazal opening	Malvaceae, Gossypieae
Endocarp slit	Anacardiaceae
Hilar slit	Convolvulaceae, Fabaceae
Hilum associated gap	Sapindaceae
Hinged valve gap	Geraniaceae
Imbibition lid	Cannaceae
Lens gap	Fabaceae

physically alters the water gap, which opens to permits water uptake (Baskin et al., 2000). For example, treating mimosa (*Albizia julibrissin*) seeds with moist heat [50 °C (122 °F)] for 24 h causes the eruption of a plug located in the lens region of the seed (Fig. 2). As the plug separates from the seed, it provides a gap in the otherwise impermeable macrosclereid layer permitting imbibition. Another example of a temperature-sensitive water gap structure is the imbibitonal lid that forms in *Canna* seeds after being submerged in boiling water for 1 min (Fig. 2). The lid separates from the seed again allowing water to enter the seed.

CONCLUSION

Physical dormancy is thought to provide several ecological advantages to the seed. First, since the seeds remain dry until released from dormancy, seeds have the potential to remain viable for many years. Some of the longest-lived seeds have been those with physical dormancy including sacred lotus (*Nelumbo nucifera*) documented to be viable after 1000 years (Shen-Miller et al., 1995). Secondly, the water gap acts as an environmental sensor to fine-tune germination to coincide with an environment that provides the best chance for seedling survival and ecosystem colonization. Temperature is postulated to be a way for seeds to detect differences in the seasonal year or whether they are in an open or protected area. Therefore, a species such as *Ipomoea lacunosa* that has seeds that require moist temperatures above >30 °C (86 °F) for dormancy release would germinate in the summer in open areas when the soil temperature would be high (Jayasuriya et al., 2009).

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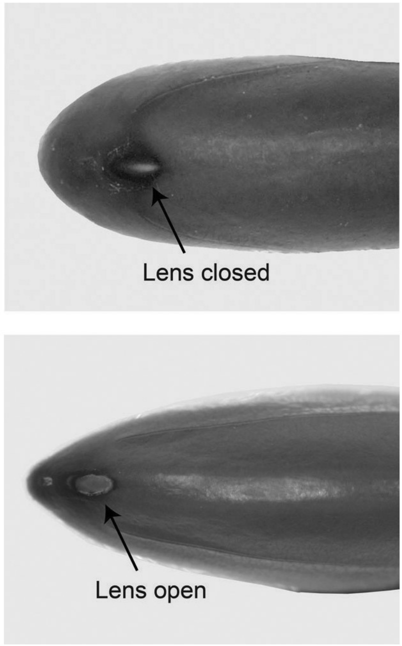

Figure 2. Dormancy release in mimosa (*Albizia julibrissin*) treated with moist heat at (50 °C; 122 °F) for 24 h showing the eruption of the lens plug to open the water gap.

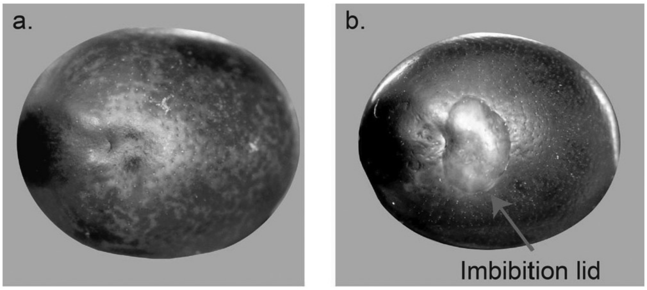

Figure 3. Dormancy release in canna (*Canna indica*) before (a.) and after (b.) treating the seed in boiling water for 1 minute.

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The situation surrounding Japan's agriculture today is extremely severe. It is full of problems such as adjustment and liberalization of rice production, expansion of abandoned cultivated land, aging of farmers, lack of successors, reduction in agricultural income, reduction in food self-sufficiency, overflow of biological waste, and uncertainty about food safety. Above all, the situation is especially severe with respect to rice-growing agriculture. With the hourly wage as low as 200 yen, the migration of young generations away from agriculture and the resulting expansion of land left idle is progressing.

In the case of industrial products, if the necessary materials are supplied to a manufacturing plant under appropriate conditions, products of constant quantity and quality are systematically produced at planned timings. But in the case of field-crop agriculture, even if materials such as seeds and seedlings, agrochemicals, and fertilizers are supplied to a field, the crop is greatly influenced by climate, soil quality, coexisting organisms, etc., resulting in a variation in the harvesting season, production volume, and product quality. In addition, agricultural products are highly perishable. To solve these problems, it is necessary to cultivate crops under a protected production environment like factory production, and further development of greenhouse horticulture and plant factories is expected.

Toyohashi City in Aichi Prefecture is said to be the birthplace of Japan's greenhouse horticulture, with a history of more than 100 years, and it recorded the largest value of agricultural production in Japan before a municipal merger. Since the merger, the value of agricultural production of Tahara, a neighboring city of Toyohashi, has become the largest in Japan, and that of Hamamatsu the fourth largest, with Toyohashi the sixth largest, all belonging to a horticultural area, topping the list. However, the value of agricultural production in Higashimikawa, where Tahara and Toyohashi are located, peaked at 165 billion yen in 1995; it has now fallen by 10 billion yen.

In consideration of the severe agricultural situation in Japan and in order to reestablish agriculture as a business in which young people can securely engage, it is necessary to convert traditional seat-of-the-pants agriculture into data-based agriculture by introducing leading-edge information technology in agriculture. In addition, it will be necessary to promote cooperation between agriculture, commerce, and industry to establish agriculture as the sixth industry.

Toyohashi University of Technology, an engineering and technology university, in 2006 established the Research Center for Advanced Agrotechnology and Biotechnology in celebration of the 30th anniversary of its foundation, with the aim of sharing its systematic engineering technology with the agriculture of the

Higashimikawa area, which is one of Japan's leading farming areas. The university not only transfers engineering technology to agriculture, but also develops human resources as leaders of information technology in agriculture and coordinators as planners of plant factories.

Focusing on greenhouse horticulture as a profitable agriculture to which systematic engineering technology can be applied, this program introduces problems in relation to soil and fertilization; information technology in agriculture takes into consideration production, distribution, and sales of products; the development of human resources for plant factories; and cooperation with other industries in order to discuss a restoration of Japan's agriculture as a business.

A Challenge to Make a Blue Rose©

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It is rare for a single plant species to have a broad range of flower colors. Roses, carnations, and chrysanthemums lack blue/violet color. Morning glories and pelargoniums lack yellow. In particular, blue roses are regarded as the “Holy Grail” by rose fanciers and have been sought after. Blue flowers achieve their color by a combination of various factors including:

1) Production of delphinidin, a pigment that most blue flowers contain
2) Modification of pigments by aromatic acyl groups
3) Accumulation of flavones or flavonols that cause bluing of pigments
4) Elevation of vacuolar pH where pigments localize
5) Accumulation of ferrous or aluminum ion

Non-blue flowers rarely have these abilities. Among these factors, molecular mechanism of delphinidin production is most well studied. Flavonoid 3’,5’-hydroxylase (F3’5’H) is the critical enzyme for delphinidin biosynthesis (Fig. 1).

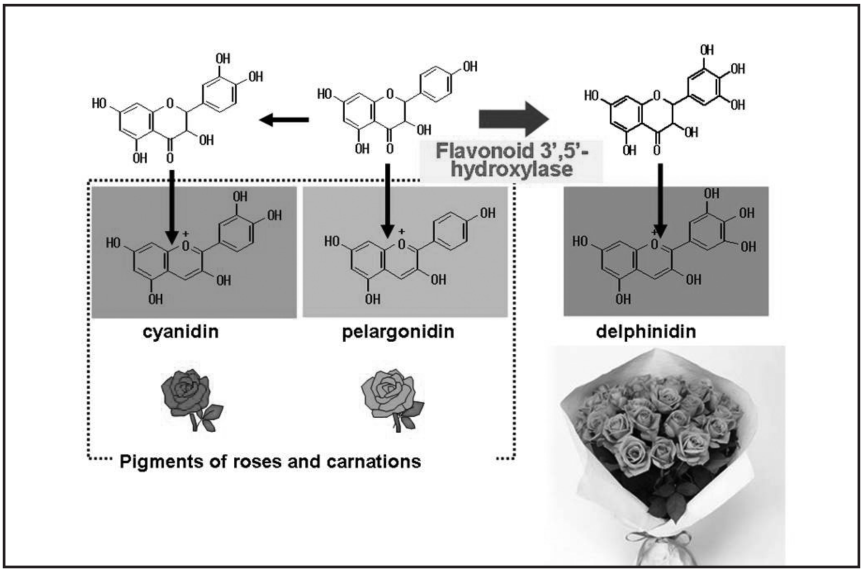

Figure 1. Biosynthetic pathway of floral pigments.

In order to obtain blue roses, it is necessary to introduce F3'5'H gene into roses with genetic engineering. Development of genetically modified blue flowers requires:

1) Isolation of a F3'5'H gene
2) Development of a rose transformation protocol
3) Regulation of transgenes in transgenic plants

For commercialization, it is necessary to obtain permission by the government on the basis of "Law Concerning the Conservation and Sustainable Use of Biological Diversity through Regulations on the Use of Living Modified Organisms" (Cartagena Protocol domestic law).

One plant species contains tens of thousands of genes. We isolated the F3'5'H gene from petunia. Transgenic carnations harboring the F3'5'H gene had novel bluish flower by producing delphinidin. The carnations, 'Moondust', are produced in Colombia and Ecuador and sold in U.S.A., Europe, and Japan.

A pansy F3'5'H gene was introduced to about 40 rose cultivars selected from several hundred cultivars. Transgenic rose lines accumulating delphinidin at high content percentage and having a novel blue hue were obtained. General release permission was granted to the selected line after showing the release of the transgenic rose would not affect biodiversity in Japan. The rose, 'Suntory Blue Rose Applause', was launched in Japan on 3 Nov. 2009. Efforts to yield bluer roses are on-going by incorporating the various factors affecting flower color in addition to delphinidin production.

Effects of Stock Plant, Rooting Medium, and Time of Cutting Collection on Rooting and Growth of Cuttings of a Dwarfing Rootstock for Kaki©

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INTRODUCTION

We have developed cutting propagation of kaki (*Diospyros kaki* Thunb.) by using single-node stem cuttings (Tetsumura et al., 2000, 2001, 2003, 2009), although it was thought to be difficult to propagate kaki by cuttings (Tao and Sugiura, 1992). The single-node stem cuttings collected from root suckers rooted easily when put in a greenhouse installed with a mist system.

Kaki tends to grow to a large tree. Therefore, the necessity of vegetative propagation of dwarfing rootstocks has been urged for 60 years (Ito, 1988), but nursery stocks grafted on the dwarfing rootstocks have not been available yet. We collected the single-node stem cuttings from root suckers of the 'Saijyo' tree showing sub-dwarfing habit (1 m in height) in the orchard of Okayama Prefectural Agriculture Center, in which the height of normal-sized 'Saijyo' trees were 4.5 m, and propagated them by using a propagation fame (Tetsumura et al., 2003). The rooted cuttings were grafted with the scions of 'Fuyu' and 'Hiratanenashi', and then the investigation for over 7 years on the growth, flowering, and fruiting showed that the rootstock, 'Rootstock-b' (R-b), made both cultivars' trees dwarfed and improved their flowering and yield efficiencies (Tetsumura et al., 2010). Hence, we plan to develop sustainable mass-propagation of R-b for its practical use supported by the Ministry of Agriculture, Forestry and Fisheries of Japan.

In general, the earlier the time of cutting collection is, the higher the survival rate of the rooted cuttings in the following year is; the more vigorous the growth of the rooted cuttings is, because the longer growth period between rooting and defoliation brings more photosynthates to the rooted cuttings. However, an early collection of cuttings decreases leaves of the mother stocks during the growth season, and this reduction in the photosynthetic organ may make sustainable cutting-propagation difficult. Hence, the objective of this study is to investigate effects of time of cutting collection on rooting of R-b cuttings and growth of the rooted cutting in the following year, by using cuttings from root suckers and hedges and using rooting medium of Metro-Mix® 360 and Bora soil.

MATERIALS AND METHODS

The nursery stocks derived from the single-node stem cuttings of R-b were planted in March 2001 and were cut back to a height of 40 cm each winter for establishment of the hedges. In April 2006, some of the hedges were cut down just above ground level, and then the surface soil about 0.25 m^2 around the stump and 20 cm in depth was removed. Each winter, all suckers were removed for production of new root suckers.

In 2009, single-node stem cuttings with one bud and leaf were prepared from the root suckers and the hedges, dipped at their bases in 50% aqueous ethanol with 3000 ppm indole-3-butyric acid (IBA) for 5 sec, planted in plug trays (200 ml/plug) which were filled with Metro-Mix 360 and Bora soil (volcanic tuff, 2 to 3 mm diameter), and then placed under a vaporized aluminum netting in a propagation frame covered with plastic film. The propagation frame was intermittently misted (30 sec mist and 15 min stop in the daytime) and was ventilated with fans when the ambient air reached 38 °C. Ten cuttings per type for each treatment were planted on 15 June, 20 July, and 15 August.

The percentages of survival and rooting, and the number and the length of roots were investigated 2 months after planting. The rooted cuttings were transplanted to plastic pots filled with 300 ml of Metro-Mix 360. The pots were placed in a propagation frame covered with plastic film but opened at the sides. The percentages of survival, the length of shoots and the number of leaves of the rooted cuttings were investigated on 23 April 2010.

RESULTS AND DISCUSSION

The cuttings collected from the R-b root suckers tended to root better than those from the hedges (Table 1). However, cuttings from the root suckers and hedges rooted well (90% or more) when collected on 15 June and 15 August and planted in Metro-Mix 360. The previous report (Tetsumura et al., 2009) showed that only 45% of R-b cuttings from the hedges rooted. The improvement in rooting of cuttings from the hedges, which need easier maintenance than the roots for production of root suckers, may contribute mass-propagation of R-b. However, the roots from cuttings from the root suckers developed better than those from the hedges (Fig. 1) as reported previously (Tetsumura et al., 2009). Since the reason of poor rooting of cuttings collected on 20 July is unclear, we must continue to conduct the same experiments. As for rooting medium, Metro-Mix 360 was superior in rooting to Bora soil, which might be too porous for kaki cuttings to root well.

The rooted cuttings with short stem, 3–5 cm in length, scarcely sprouted during current year of cutting, and then overwintered. The rooted cuttings from root suckers survived and grew better than those from hedges (Table 2). The percentages of survival of rooted cuttings collected from root suckers and planted in Metro-Mix 360 were more than 75% irrespective of the time of cutting collection, while the average of those from hedges and in Metro-Mix 360 was 33%. It seemed that the rooted cuttings with developed root system survived and grew well.

CONCLUSION

Cuttings from root suckers of R-b rooted well when collected in mid-June and mid-August. We need further investigation of the effect of the time of cutting collection on growth of mother stocks in the following year. Improvements in the development of roots of cuttings from the hedges and their survival in the following year will also contribute to sustainable cutting-propagation of R-b.

Acknowledgements. This work was partially supported by the research and development projects for application in promoting new policy of Agriculture Forestry and Fisheries from the Ministry of Agriculture, Forestry and Fisheries of Japan.

Table 1. Effects of stock plant, rooting medium and time of cutting collection on the survival, rooting and development of roots of R-b single-node stem cuttings 2 months after planting.

Factor	Survival (%)	Rooting (%)	No. of roots per rooted cuttings	Total length of roots (cm)
Stock plant (SP)				
Root	100	72	3.1	49
Hedge	98	57	2.0	29
Time of cutting collection (T)				
15 June	100	83	2.8	47
20 July	100	40	2.4	27
15 August	98	70	2.9	42
Rooting medium (RM)				
Metro-Mix® 360	100	75	2.8	44
Bora soil	98	53	2.4	34
Significance				
SP	ns[z]	ns	ns	*
T	ns	*	ns	ns
RM	ns	*	ns	ns
SP × T	ns	ns	ns	ns
T × RM	ns	ns	ns	ns
RM × SP	ns	ns	ns	ns

[z] ns, * : nonsignificant or significant by LSD at $P < 0.05$, respectively.

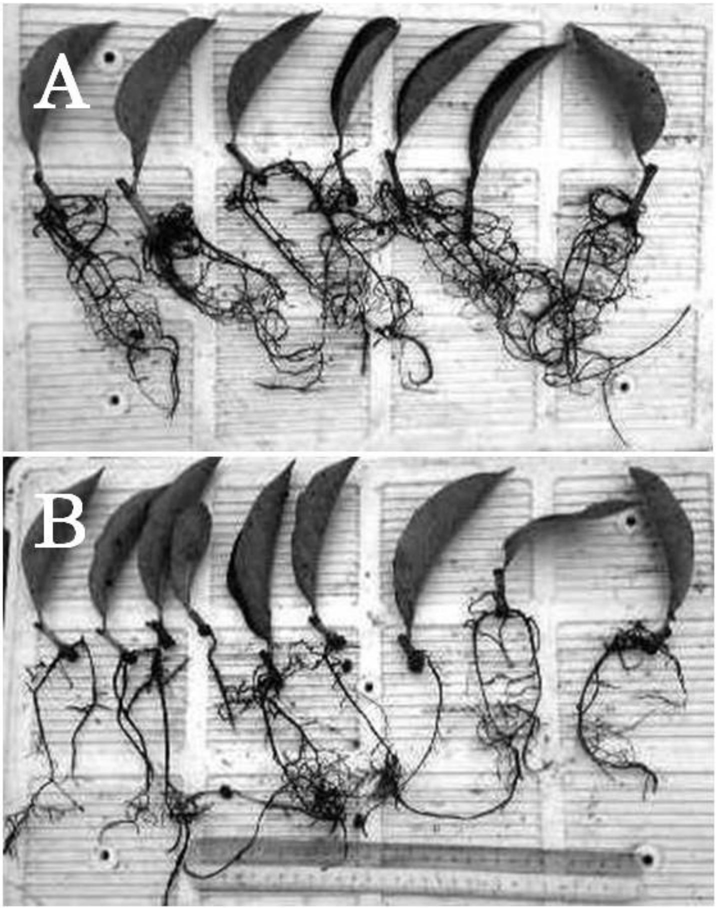

Figure 1. Rooted cuttings 2 months after planting on June 15 and in Metro-Mix® 360. (**A**) Cuttings from root suckers. (**B**) Cuttings from hedges. The ruler = 31 cm.

Table 2. Effects of stock plant, rooting medium and time of cutting collection of R-b single-node stem cuttings on the survival, length of shoots, and number of leaves of the rooted cuttings in the following year.

Factor	Survival (%)	Length of shoots (cm)	Number of leaves
Stock plant (SP)			
Root	77	7.7	5.2
Hedge	34	4.1	3.3
Time of cutting collection (T)			
15 June	65	7.0	5.5
20 July	33	3.8	2.0
15 August	70	6.8	5.1
Rooting medium (RM)			
Metro-Mix® 360	59	6.6	4.4
Bora soil	53	5.2	4.0
Significance			
SP	*[z]	*	*
T	ns	ns	*
RM	ns	ns	ns
SP × T	ns	ns	*
T × RM	ns	ns	ns
RM × SP	ns	ns	ns

[z] ns, * : nonsignificant or significant by LSD at $P < 0.05$, respectively.

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In Vitro Propagation of Mango (*Mangifera indica*)©

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INTRODUCTION

A Japanese leading and monoembryonic mango (*Mangifera indica* L.) cultivar, 'Irwin', is propagated by grafting onto seedling of polyembryonic mango. The grafted nursery stocks of tropical fruit trees sold in Japan are very expensive mainly because of heating cost in winter. Hence, in vitro propagation of mango will provide a stable supply of nursery stocks and a shortening of raising period possible. However, establishment of tissue culture of mango has been very difficult because of browning of medium and contamination. Therefore, reports on tissue culture of mango are few. Thomus and Ravindra (1997) reported that the solidified medium caused better survival of explants than a liquid medium and the longer explants established better. We made preliminary experiments by using explants from seedlings and succeeded in proliferation of shoots without browning of medium. The objective of this study was to explore the best basal medium for propagation of in vitro shoots from mango seedlings. In addition, we tried to minimize contamination of in vitro culture establishment of explants from mature trees.

MATERIALS AND METHODS

Effect of Basal Medium on Growth of In Vitro Shoots. The in vitro shoots used in this experiment were proliferated from explants obtained from mango seedlings, and were planted in 5 basal media: Murashige and Skoog (MS) (Murashige and Skoog, 1962), ½ MS, wood plant medium (WP) (Lloyd and McCown, 1981), ½ WP, and Ganborg (B5) (Gamborg et al., 1986). All media were supplemented with 10 µM zeatin, 0.2% Plant Preservative Mixture (PPM™, Plant Cell Technology, Washington D.C., U.S.A.), 3% sucrose, and 0.8% agar (pH 5.8). The shoots were planted singly in a 100-ml conical beaker containing 20 ml of culture medium autoclaved at 121 °C for 15 min. All cultures were maintained at 28 °C under 16-h photoperiod. The shoot length and number of leaves were measured every 5 days. Data were subjected to ANOVA.

Prevention of Contamination in In Vitro Culture Establishment. Growing shoots of potted 'Irwin' plants in a greenhouse were collected, and the leaves were removed. The explants were surface-sterilized for 30 min in 1%, 2%, and 3% sodium hypochlorite solutions, containing 0.1% Tween 20 each, and washed three times with sterile water. Before the chlorine treatments, half of the explants were immersed in 70% ethanol for 1 min and the rest were not. The explants, 2–3 cm long, were placed on WP medium with 10 µM zeatin. The culture conditions were the same as those of the basal medium test. The contamination rate of the explant was investigated every day.

RESULTS AND DISCUSSION

The basal medium influenced the in vitro shoot growth. It was on the MS medium that the shoots elongated most. The average of shoot elongation on the MS medium for 2 months was 1.6 cm. However, because some shoots withered and died on the MS medium, the WP and ½ WP media seemed to be the most suitable ones for the in vitro propagation (Fig. 1). The shoots grew the poorest on the ½ MS medium. Browning was not observed in any media. Thin and long explants, producing less phenol, were reported to be better ones for in vitro establishment (Thomus and Ravindra, 1997). We used thin and long explants and shoots, and these materials probably brought the success of shoot proliferation in this study.

Figure 1. Mango shoots derived from ' Irwin' seedlings, developing after 30 days in culture in ½ WP medium with 10 μM zeatin.

Contamination occurred in most explants in in vitro culture establishment regardless of the concentration of sodium hypochlorite solutions. The 70% ethanol treatment delayed the occurrence of contamination, but it did not completely prevent the occurrence. Contamination did not occur in 33% of the explants sterilized by 70% ethanol + 1% sodium hypochlorite.

CONCLUSION

Both WP and ½ WP media were effective basal ones in in vitro propagation of mango. The relationships between the size and age of explants and the browning of medium and withering of shoots should be investigated. As for prevention of contamination, a further improvement using ethanol treatments is necessary. In a preliminary experiment, we also succeeded in rooting of mango shoots (Fig. 2) and acclimatization of rooted shoots (Fig. 3). However, because the roots developed

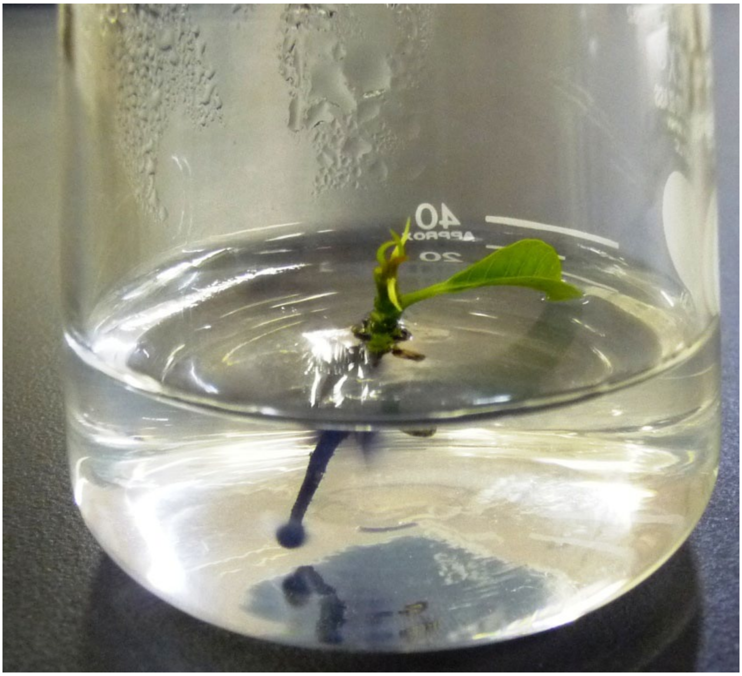

Figure 2. A mango shoot derived from ' Irwin' seedlings, rooting after 20 days in culture in $^{1}/_{4}$ WP medium.

Figure 3. Mango micropropagules derived from 'Irwin' seedlings, being acclimatized after 60 days in culture in Jiffy pots filled with fine vermiculite.

poorly, the rooting treatment must be improved. We now use the root development medium, which improved rooting of Japanese chestnut (*Castanea crenata* Sieb. et Zucc) (Tetsumura and Yamashita, 2004).

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Effective Methods for Controlling Chrysanthemum Stunt Viroid©

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INTRODUCTION

The disease caused by chrysanthemum stunt viroid (CSVd) is the most important viral disease in chrysanthemum plants. It causes stunting of growth and reduced flower quality (Fig. 1). Damage caused by CSVd has been increasing since its discovery in Japan in 1977.

A viroid is the minimum pathogen composed of only RNA. Chemical treatments are ineffective against the solid molecular structure. Growers must improve production by preventing infection in plants, thus, maintaining the concentration of CSVd at low level in the environment. Viroid-free plants and resistant cultivars are required for the study.

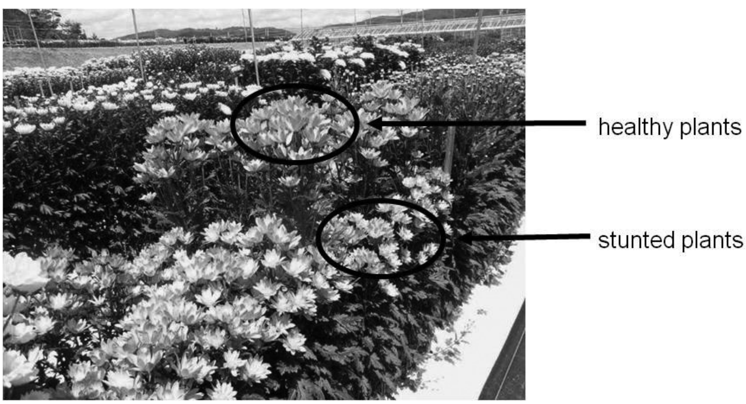

Figure 1. Typical symptom of disease caused by *Chrysanthemum* stunt viroid.

DETECTION OF CHRYSANTHEMUM STUNT VIROID

The symptoms of the disease caused by CSVd in chrysanthemum plants include stunted growth, chlorosis in the leaves, and a change in the time of flowering (early in many case). Chrysanthemum stunt viroid can be detected to identify the disease caused by it. Methods of detection include a bioassay using a test cultivar, return-gel electrophoresis of CSVd RNA, Dot-blot hybridization, reverse transcription polymerase chain reaction (RT-PCR), and reverse transcription loop-mediated isothermal amplification (RT-LAMP). The author of this review has developed a method of wooden toothpick/direct RT-PCR, RT-LAMP. This method obviates RNA extraction and decreases the risk of contamination with CSVd. As shown in Fig. 2, a wooden toothpick is used to prick the leaf blade or petiole several times and is then soaked in a reaction buffer contained in a microtube. Then RT-PCR or RT-LAMP was performed directly. Thus, easy and sensitive detection of CSVd is possible.

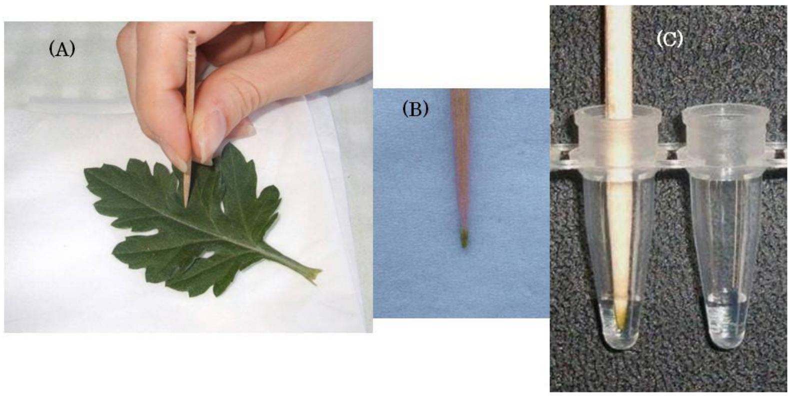

Figure 2. Method of 'wooden toothpick/direct RT-PCR, RT-LAMP' (Ohishi et al., 2005). (A) Pricking leaf blade or petiole several times. (B) Toothpick stained with sap. (C) RT-PCR or RT-LAMP is performed directly in a reaction buffer contained in a microtube.

LATENT INFECTION OF CHRYSANTHEMUM STUNT VIROID

Some cultivars infected with CSVd express no symptoms. The author investigated 79 symptomless plants around 10 years ago, and CSVd was detected in about 90% of samples by RT-PCR/nested PCR, which was the most sensitive detection method at the time. The data thus obtained suggests that CSVd was widespread in Japan.

CONTROLLING CHRYSANTHEMUM STUNT VIROID

Results obtained in the author's experiments until now have indicated that the concentration of CSVd was either very high or very low, in many cases. The concentration of CSVd in susceptible cultivars mostly remains at a low level for some time after infection, but certain factors triggered an increase in the concentration of CSVd and the cultivars begin to show symptoms (Fig. 3). Once the concentration of CSVd increases, the diseased plants never recover. Controlling the factors that raise the concentration of CSVd is difficult. Resistant cultivars, in which the CSVd concentration rarely increases after infection, have been found recently. In the future, resistant cultivars will contribute immensely to reducing the damage of the disease.

Effective Methods for Controlling CSVd Are as Follows.

Application of Resistant Cultivars. All cultivars are likely to be infected with CSVd. However, some cultivars in which the concentration of CSVd dose not increase have been found (Omori et al., 2009). It is possible to estimate resistance to

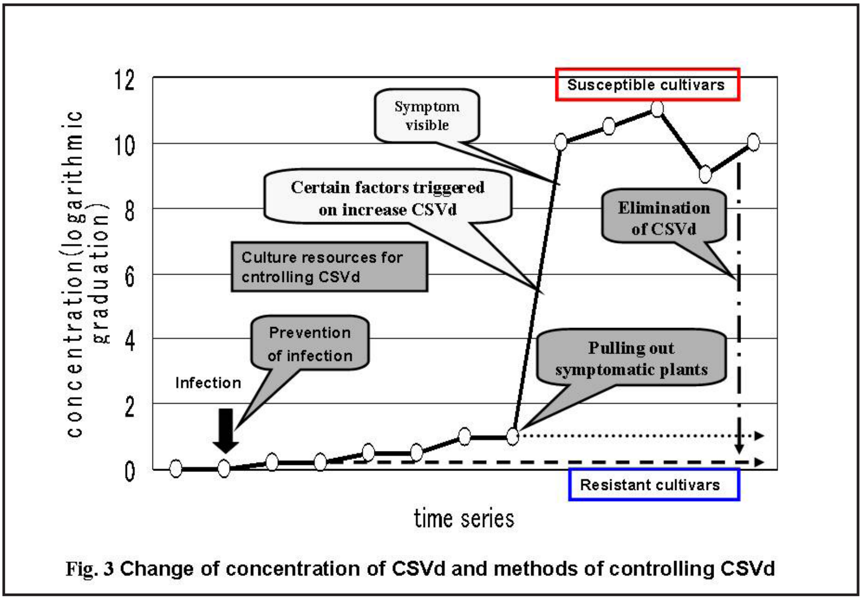

Figure 3. Change of concentration of CSVd and method of controlling CSVd.

CSVd by grafting the assay cultivars onto viruliferous stocks (Fig. 4). Plant breeding companies should inform growers about the resistance of certain plants to CSVd by printing relevant information in a catalog, coupled especially with cultivars that show strong resistance. Improving resistance to CSVd by crossbreeding is a valid approach because the resistance is hereditary (Omori et al., 2009).

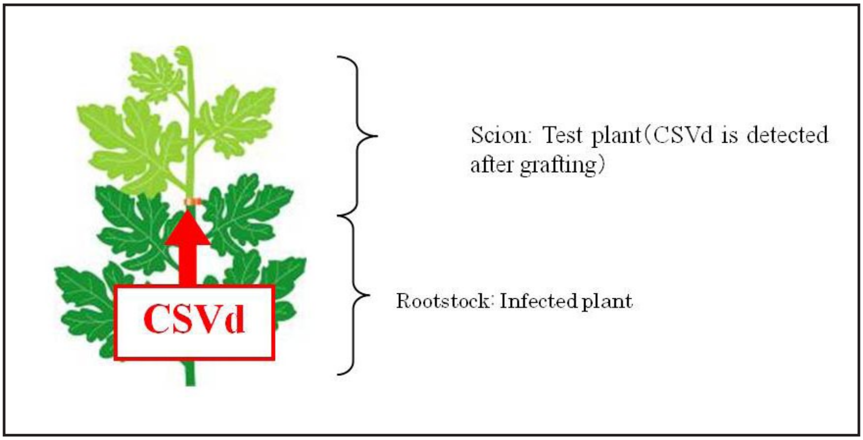

Figure 4. Estimate of resistance to CSVd by grafting (Omori et al., 2009.

Prevention of Infection. It is very important to disrupt the routes of infection to prevent the spread of CSVd. Although it is believed that CSVd is transmitted only by sap, seed transmission should also be considered (Fig. 5). Because CSVd is likely to be transmitted through ovules and pollen, symptomatic plants should never be used as parents. Tools such as pruning scissors should be sterilized thoroughly to prevent infection. Chrysanthemum stunt viroid RNA is heat resistance and can be detected after boiling (Ohishi et al., 2003). For complete sterilization, it is necessary to heat tools until they become red hot. Effective chemicals for sterilization include sodium chlorate, sodium chlorate, sodium hydroxide, and formalin. Among the above mentioned chemicals, sodium chlorate is the easiest to obtain and use; for example, a solution of 5% of active chlorine is used to prepare a bleaching agent.

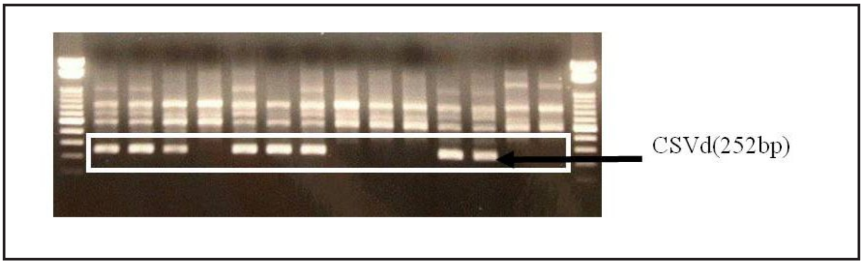

Figure 5. Seed transmission of CSVd (Ohishi et al., 2001). RT-PCR analysis of CSVd in seedlings of infected plants with high concentration crossed with infected plants with low concentration.

Culture Resources for Controlling Chrysanthemum Stunt Viroid. As shown in Fig. 3, the concentration of CSVd in susceptible cultivars increases rapidly and the symptoms become visible thereafter. Although the major factors responsible for the disease caused by CSVd are high temperature, solar radiation, and pinching, the details are unclear. It is important to investigate the factors causing the disease and find the culture resources necessary to control it.

Reduction of Damage Caused by CSVD Pulling Out Symptomatic Plants. Radical steps for controlling CSVd include improvement of resistance of the plants to CSVd and cultivation of CSVd-free plants. Pulling out symptomatic plants is recommended. The damage caused by CSVd can be reduced by pulling out the stunted plants with small-sized leaves in a field or nursery bed as soon as the symptomatic plants are spotted. It is recommended that the symptomatic plants should be burned. Spraying herbicide on the stunted plants and burying them are also considered effective methods.

Elimination of CSVD from Infected Plants. Raising CSVd-free plants from susceptible cultivars is the most effective way of controlling the disease. It is difficult to eliminate CSVd by a shoot apical meristem culture. Recently, Hosokawa et al. (2004) reported that CSVd-free chrysanthemum can be obtained by shoot regeneration from a leaf primordium-free shoot apical meristem dome attached to a root tip of cabbage (Fig. 6).

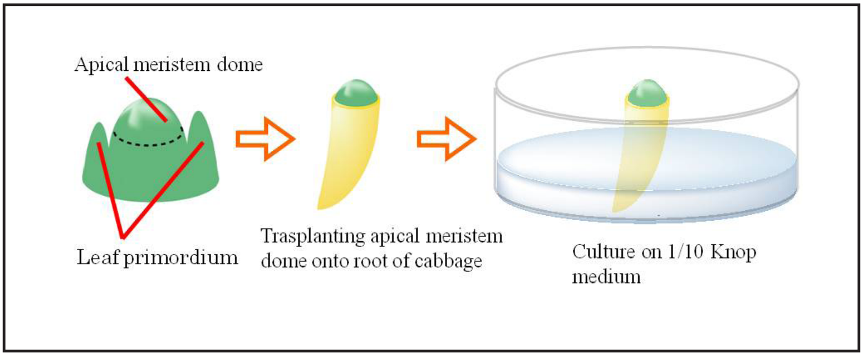

Figure 6. Elimination of chrysanthemum stunt viroid from an infected chrysanthemum cultivars (Hosokawa et al., 2004).

CONCLUSION

Damage due to CSVd has spread all over Japan and it is feared to increase if effective measures are not taken. It is recommended that growers and nurseries sterilize their tools, pull out symptomatic plants, and use resistant cultivars.

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Genetic Resources of Roses and Their Conservation©

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INTRODUCTION

The genus *Rosa* belongs to Rosaceae and is widely distributed throughout the temperate and subtropical regions of the Northern Hemisphere, from Ethiopia to Siberia. Number of species is between 150 and 200, although there is much variation in number of species by taxonomists. Among these species, there are 12 species and three varieties native to Japan.

THE ORIGIN OF CULTIVATED ROSES AND VARIETAL DIFFERENTIATION

The cultivation of roses started for perfume and medicinal use. The origin goes back to ancient Persia. In Greek and Roman time, roses were widely cultivated and the people of Roman used many rose flowers. And then, roses were developed as ornamental plants because of the elegant flowers. Cultivars were bred from wild species both in Europe and China. Since the 19th century, European cultivated roses were hybridized with Chinese taxa and a new phase of breeding was developed. As ornamental plants various cultivars have been developed for ornamental garden, cut flower, and potted plant uses. According to *Modern Roses XI* published by the American Rose Society as the international rose register, there are more than 24,000 cultivars listed. In the *Combined Rose List* printed in U.S.A., there are about 15,000 cultivars listed on the market.

CONSERVATION OF GENETIC RESOURCES

These cultivars and species are planted and conserved in various rose gardens and private gardens throughout the world. In Japan, about 7,000 taxa are planted in Flower Festival Commemorative Park of Gifu Prefecture and these collections were greatly contributed to by an Italian rose collector. The most famous rose garden is Sangerhausen Rosarium in Germany and there are about 8,000 taxa in the garden. There also are some important rose garden especially in France and Australia. In the United Kingdom the National Council for the Conservation of Plants and Gardens plays an important part in conservation of plant genetic resources and it conserves some special rose collections.

In order to support such conservation activities, the World Federation of Rose Societies (WFRS) organize the Heritage Roses Committee and the Conservation Committees established a database of genetic resources and hold international heritage rose conferences every 3 years. The 12th International Heritage Rose Conference will be held in Sakura, Japan, in 2011 under the auspices of WFRS.

Tetraploids Induction by Colchicine Treatment in *Hibiscus mutabilis*©

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Tetraploid plants of *Hibiscus mutabilis* L. with pink flower were obtained by colchicine treatment. Self-pollinated seeds were dipped into sulfuric acid for 360 minutes to break the impermeable seed coats. Seedlings with a root of 1–2 mm were treated by dipping into 0, 0.1, 0.3, or 1.0 mM colchicine solution for 12 or 24 h, respectively. Survival rate decreased according to colchicine concentration, and tetraploid induction increased according to colchicine concentration significantly. Many tetraploid plants were acquired with 0.3 mM colchicine regardless of treatment time. The width/length ratio in petal and sepal, the thickness of petal, the length of guard cell, and the pollen size in tetraploids were significantly larger than those of diploids. We decided that this tetraploid *H. mutabilis* is suitable as a garden plant.

INTRODUCTION

Cotton rose (*Hibiscus mutabilis* L.), which has white or pink flower, is a native woody plants in China and it has been planted widely in gardens as a summer flowering plant. However, the breeding of new cotton-rose selections is not progressing and there are few cultivars besides *H. mutabilis* var. *versicolor*. Although interspecific hybridization with other *Hibiscus* species has been tried, the breeding was not advanced because many are sterile. Tetraploid plants are able to produce fertile interspecific hybrids and tetraploid plants often show enlargement of various plant parts such as flowers and leaves. In this study, we tried tetraploid induction by colchicine treatment in cotton rose in order to breed new cotton-rose cultivars with high ornamental value.

MATERIALS AND METHODS

Plant Materials. Self-pollinated seeds of cotton rose with pink flower, which are planted in Gifu University, were collected in November 2009. Sixty seeds per treatment were dipped into sulfuric acid for 0, 5, 15, 30, 60, 120, 180, 240, 300, 360, 480, 600 min to scarify the impermeable seed coat. After sulfuric acid treatment the seeds were rinsed in running water for 1 h and placed on the moist filter paper in covered plastic Petri dishes. Two weeks later germinated seeds were counted.

Cholchicine Treatment. Germinated seeds with root length of 1–2 mm were dipped into colchicine solution (0, 0.1, 0.3, or 1.0 mM) containing 10% dimethyl sulfoxide (DMSO) for 12 or 24 h, respectively. Each treatment comprised 200 seedlings. After treatment the seedlings were rinsed in running water for 1 h, planted in plug trays which have 200 holes filled with peat moss and perlite (2 : 1, v/v), and grown in the greenhouse. Six weeks later the number of sprouting shoots was counted.

Tetraploid Analysis by Flow Cytometry. Ploidy analysis was carried out on the plantlets after five leaflets by flow cytometry (FCM) (Partec Ploidy Analyser, PAII). Nuclei were collected by chopping up the leaf segment of 0.5 cm around using sharp razor blade in 0.2 ml of Partec CyStain UV solution A. Subsequently nuclei were stained with 0.8 ml of Partec CyStain UV solution B containing 4'-6-diamidino-2-phenylindole (DAPI) and were filtered through a 30 µm mesh. *Hibiscus mutabilis* leaves from controls were used as the diploid standard.

Morphological Analysis. Fully expanded leaves and flowers of plants which were determined as diploid or tetraploid by FCM were used for morphological analysis. The leaf width/length ratio, the length of guard cells, the petal width/length, the sepal length/width, the petal weight/area and the pollen length were measured. The length of guard cells was measured by SUMP method (Suzuki's universal micro-printing method) (Kawai, 1969).

RESULTS AND DISCUSSION

Germination Rate by Sulfuric Acid Treatment. In the relation between germination rate and sulfuric acid treatment (Fig. 1), no seeds germinated at 0 and 5-min sulfuric acid treatment. For sulfuric acid treatment times greater than 15 min, the germination percentage increased up to 360 min when a rate of 69.5% was reached. In treatment times longer than 360 min the germination percentage fell with increasing treatment time.

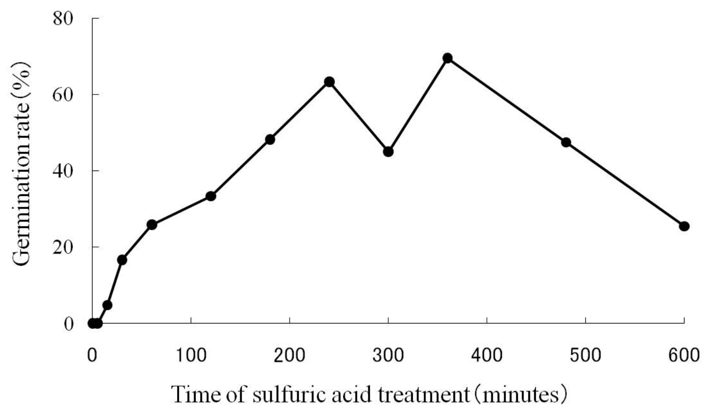

Figure 1. Relation between germination rate and time of sulfuric acid treatment.

Hibiscus genera have a hard seed coat and germination is inhibited by impermeability. Sakhanokho (2009) indicated that *H. dasycalyx* and *H. acetosella* seed germination was enhanced by sulfuric acid treatment for 10 to 20 min. In this study, however, only 16.7% of *H. mutabilis* seeds germinated by a 30 min sulfuric acid treatment, and the optimal time of breaking the impermeable seed coats was the 360 min treatment. Therefore, we decided that the seed coat of *H. mutabilis* was

Table 1. Survivals and polyploids induction by colchicine treatment.

Treatment (h)	Concentration of colchicines (mM)	Sprouting (%)	Number for FCM analysis	2x (%)	4x (%)		Others (%)	Remarks*
12h	0	142 / 200 (71.0[x]) d[z]	129	129 (100.0) d[z]	0 (0.0[y]) a	(0.0[y]) a[z]	0 (0.0[y]) a[z]	
	0.1	118 / 200 (59.0) c	118	102 (86.4) c	7 (5.9) b	(3.5) b	9 (7.6) b	(2x+4x : 9)
	0.3	79 / 200 (39.5) b	91	24 (26.4) b	56 (61.5) c	(28.0) d	11 (12.1) b	(2x+4x : 11)
	1.0	46 / 200 (23.0) a	44	3 (6.8) a	33 (75.0) c	(16.5) c	8 (18.2) b	(2x+4x : 3, 4x+8x : 2, 8x : 3)
24h	0	125 / 200 (62.5) BC	125	125 (100.0) C	0 (0.0) A	(0.0) A	0 (0.0) A	
	0.1	129 / 200 (64.5) C	111	82 (73.9) B	25 (22.5) B	(12.5) B	4 (3.6) A	(2x+4x : 4)
	0.3	104 / 200 (52.0) B	106	12 (11.3) A	81 (76.4) C	(40.5) C	13 (12.3) B	(2x+4x : 5, 4x+8x : 4, 8x : 4)
	1.0	23 / 200 (11.5) A	38	5 (13.2) A	25 (65.8) C	(12.5) B	8 (21.1) B	(4x+8x : 3, 8x : 5)
12h	-	385 / 800 (48.1)	382	258 (67.5)	96 (25.1)	(12.0)	28 (7.3)	
24h	-	381 / 800 (47.6)	380	224 (58.9)	131 (34.5)	(16.4)	25 (6.6)	
-	0	267 / 400 (66.8)	254	254 (100.0)	0 (0)	(0.0)	0 (0)	
-	0.1	247 / 400 (61.8)	229	184 (80.3)	32 (14)	(8.0)	13 (5.7)	
-	0.3	183 / 400 (45.8)	197	36 (18.3)	137 (69.5)	(34.3)	24 (12.2)	
-	1.0	69 / 400 (17.3)	82	8 (9.8)	58 (70.7)	(14.5)	16 (19.5)	
Total number		766 / 1600 (47.9)	762	482 (63.3)	227 (29.8)	(14.2)	53 (7.0)	

[z]Different letters indicate a significant difference according to Tukey's multiple range test ($P<0.05$).

[y]Number of plants/number of sprouting.

[x]Number of plants/number of treated plants.

*Remarks indicate the kind of ploidy and that number.

thicker than those of *H. dasycalyx* and *H. acetosella*. The growth of germinated seedlings was not increased by sulfuric acid treatments over 360 min. This may indicate that sulfuric acid treatments over 360 min injured the embryo and germination was inhibited.

Effect of Colchicine Treatment. Germination rate was high for control (12 h: 71%, 24h: 62.5%) and decreased with increasing concentration of colchicine (Table 1). The treatment of 1 mM colchicine inhibited sprouting of seedlings significantly. The seedlings which did not elongate had normal opened cotyledons but no elongated root. The high concentration of colchicine strongly inhibited cell division of the shoot and root apical meristems. It therefore appears that the seeds treated with a high concentration of colchicine could not elongate root and differentiate leaves after treatment.

Tetraploid Analysis by Flow Cytometry. Flow cytometry analysis showed that a lot of polyploid plants were produced (Table 1 and Fig. 2). All plants in 0 mM colchicine treatment were diploid and the percentage of diploids decreased with increasing colchicine concentration. The tetraploid percentages within seedlings in 0.3 and 1.0 mM colchicine treatments were over 60% regardless of treatment time, but in 0.1 mM colchicine treatment were significantly lower (12 h: 5.9%, 24 h: 22.5%). The tetraploid percentage within treated plants in 1.0 mM colchicine treatment were lower than that in 0.3 mM, and the octoploid plants and chimeras with 8x were observed in 1.0 mM. From these results, we decided that 0.3 mM colchicine was the optimum concentration for tetraploid induction regardless of treatment time.

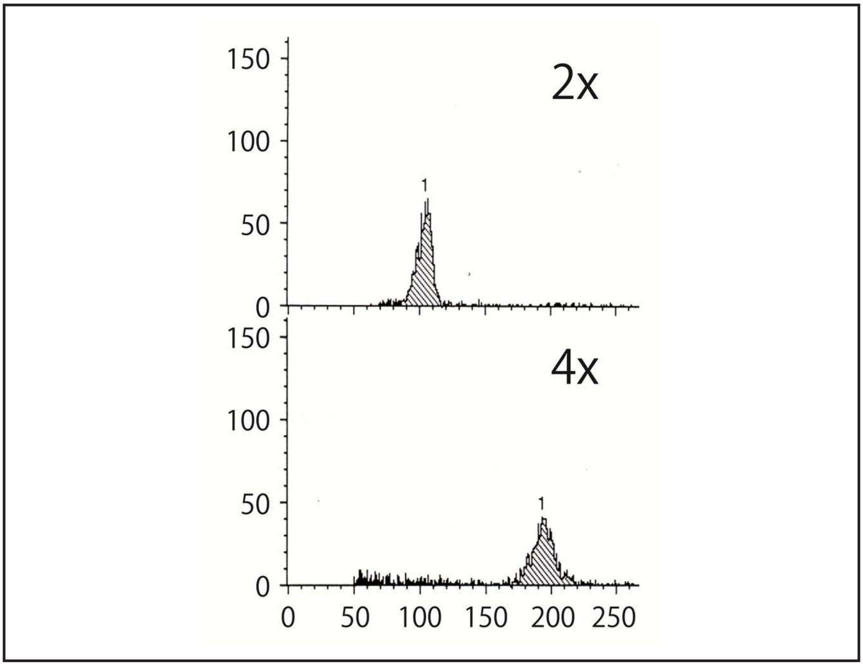

Figure 2. Flow cytometric histograms of 2x and 4x plants.

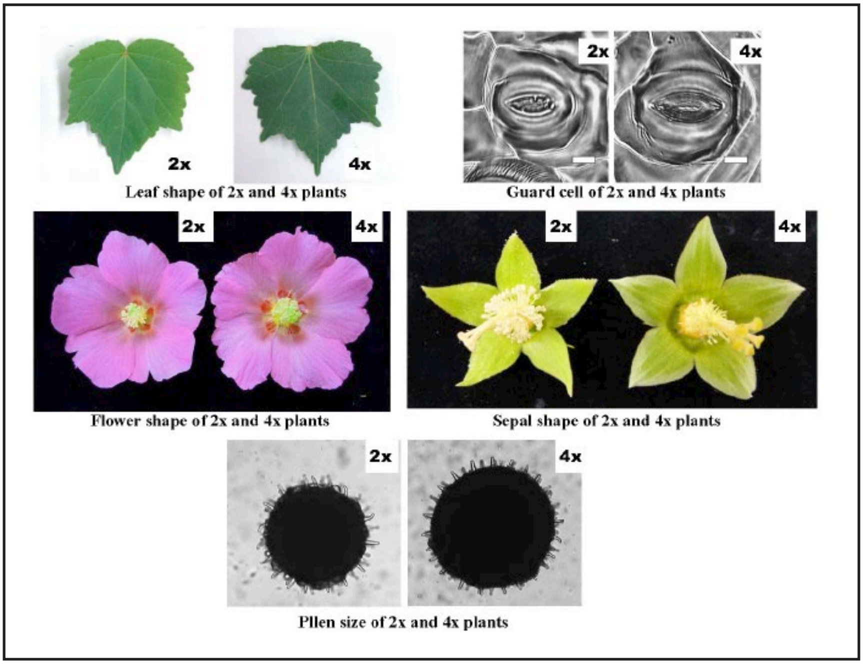

Figure 3. Shape of leaf and flower in 2x and 4x plants.

Table 2. Comparison of diploid and tetraploid plants.

	2x		4x		Test of significance
	Average	Standard deviation	Average	Standard deviation	
Length of guard cell (μm)	4.58	±0.58	5.49	±0.66	**
Length/width ratio in petal	0.90	±0.08	0.98	±0.10	*
Petal weight (g/cm^2)	16.14	±0.75	30.19	±1.55	**
Length/width ratio in sepal	0.69	±0.06	0.80	±0.09	**
Pollen size (μm)	140.23	±12.29	173.61	±7.48	**

Significant differences (** : p = 0.01, * : p = 0.05, NS : No significant)

Although the gains of tetraploid in *Rosa* species were 0.2% to 0.3% in our past reports (Fukui and Yokota, 2007; Sugimoto et al., 2010), the tetraploid percentage within treated plants at dipping treatment of colchicine in 1.0 mM for 24 h was high with 40.5% in this result. Therefore, we considered that the seed of *H. mutabilis* had higher activity of cell division in shoot apical meristem than those of *Rosa* species.

Morphological Analysis. The results of morphological analysis are shown in Figure 3 and Table 2. The tetraploid leaf looked thicker and darker than the diploid leaf, but there were no differences in size and shape. The lengths of guard cells of tetraploids were significantly larger than those of diploids (Fig. 3 and Table 2). Plant height for tetraploids was about 1m and was shorter than diploids.

Tetraploids bloomed in September 2010. The petal of tetraploids was wider in comparison with diploids, and the flower shape was roundish because parts of the petals overlapped (Fig. 3 and Table 2). The petals of tetraploids were thicker than that of diploids. The sepals of tetraploids were wider in comparison to diploids, and pollen grains were larger than that of diploid pollen.

From these results, the characteristics of *Hibiscus* tetraploid plants were a more compact shape, deeper green leaves, and overlapping and thicker petals. We, therefore, decided that this tetraploid *H. mutabilis* is suitable as a garden plant. Additionally the tetraploid *H. mutabilis* has ability to make triploid plants by cross-pollination with diploid plants and interspecific hybrids by cross-pollination with other *Hibiscus* species.

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Micropropagation of Flying Spider-Monkey Tree Fern and Crocodile Fern From Rhizome Segments©

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Flying spider-monkey tree fern [*Cyathea lepifera* (J. Sm. ex Hook.) Copel.] and crocodile fern (*Microsorum musifolium* Copel.) were propagated through tissue culture by a procedure using green globular bodies (GGBs) as an intermediate propagule. Green globular bodys were induced from rhizome segments on half strength Murashige-Skoog (½ MS) medium supplemented with 1 mg·L^{-1} benzyladenine (BA), 20 g·L^{-1} sucrose, and 8 g·L^{-1} agar (pH 5.6). The GGBs of both species were able to multiply on the full strength MS medium supplemented with 1 mg·L^{-1} BA, 20 g·L^{-1} sucrose, and 8 g·L^{-1} agar (pH 5.6). In *Cyathea lepifera*, the regeneration of sporophytes from GGBs was promoted by the addition of 1 mg·L^{-1} 1-naphthaleneacetic acid (NAA) to the full strength MS medium supplemented with 20 g·L^{-1} sucrose and 8 g·L^{-1} agar (pH 5.5). Rockwool cube was the best supporting materials for sporophyte regeneration to obtain high quality transplants for pot plant production.

INTRODUCTION

Flying spider-monkey tree fern [*Cyathea lepifera* (J. Sm. ex Hook.) Copel.] is a species of tree fern and endemic to Taiwan, Philippines, and Japan. Young small sporophytes of *C. lepifera* have become a popular ornamental pot plant recently. Crocodile fern (*Microsorum musifolium* Copel.) is a member of the polypodies and endemic to Malaysia, Philippines, Indonesia, and New Guinea. *Microsorum musifolium* has a prominent network of dark veins which looks like crocodile skin, and is very decorative as a pot or basket plant (Jones, 1987).

Murashige (1974) described the availability of adventitious shoot multiplication as the commercial mass propagation system for ferns. Padhya (1987) reported that the meristematic region of *C. gigantea* had the ability to regenerate new adventitious shoots through the tissue culture procedure. However, the system required great effort and skill for division and subculture of multiplied adventitious shoots. Previously, we have proposed a simple micropropagation system (Amaki and Higuchi, 1991) which consists of two processes, that is, the first process of GGB induction and the second process of the sporophyte regeneration. Green globular body induction from rhizome segments and its multiplication are able to occur on a benzyladenine (BA) containing medium. In this paper, we report the micropropagation method of *C. lepifera* and *M. musifolium* using GGBs.

MATERIALS AND METHODS

Initial Culture of Rhizome Explant and Multiplication of Green Globular Bodies. Tips of rhizomes (about 3cm long) were prepared from *C. lepifera* and *M. musifolium* sporophytes. The rhizome tips were washed with a detergent, and then rinsed under tap water for 20 min. The tips were immersed in 70% ethanol (EtOH) for 5 min, and then 2% NaClO for 10 min. After washing in sterilized distilled water three times, the tips were dissected to cubic explants (4 mm long). Those explants were inoculated on a medium for the induction of GGBs [Amaki, 1997: $^1/_2$ MS + 1 mg·L^{-1} BA + 20 g·L^{-1} sucrose + 8 g·L^{-1} agar (pH5.6)]. After GGBs were obtained, they were subcultured every 3 months on the same medium for maintenance and multiplication.

Effects of Medium Constituents on GGB Multiplication and Organogenesis. For the determination of basal medium for GGB multiplication of respective species, MS medium strength ($^1/_1$, $^1/_2$, $^1/_3$, $^1/_4$, $^1/_8$), sucrose concentration (0, 20, 40, 60, 80 g·L^{-1}), and medium initial pH (4.5, 5.0, 5.5, 6.0, 6.5) were examined. In addition, the effects of various concentrations of BA and NAA on organogenesis from GGB explants were also examined. Each basal medium for *C. lepifera* [$^1/_1$ MS + 20 g·L^{-1} sucrose + 8 g·L^{-1} agar (pH 5.5)] and *M. musifolium* [$^1/_1$ MS + 40 g·L^{-1} sucrose + 8 g·L^{-1} agar (pH 6.0)] was supplemented with each combination of BA and NAA at the concentrations of 0, 1.0, 2.0 mg·L^{-1}. In these experiments, 10 GGB cubic explants (3 mm long) were put on 10 mL of each medium in a glass test tube (ϕ20 × 120 mm) and cultured at 24±2 °C and 16-h light with cool white fluorescent lamps (40 μmol·m^{-2} s^{-1} PPFD) / 8-h dark for 3 months. Before inoculation of explants, all media were poured into test tubes which were closed with aluminum foil and autoclaved at 120 °C for 15 min. After 3 month culture, the numbers and fresh weights of fronds and roots produced on the GGB explants were recorded.

Effects of Supporting Material on the Regeneration and Growth of Sporophyte. For the determination of effective supporting material for sporophyte regeneration from GGB segments, vermiculite (SS-type, Asahi-Kogyo Co., Ltd., Japan), rockwool cube (Grodan X-TRA, Grodania A/S, Denmark), 2 g·L^{-1} gellan gum (Wako Pure Chemical Industries, Ltd., Japan), and 8 g·L^{-1} agar (Kanto Chemical Co., Inc., Japan) were examined. Each of the supporting materials with the medium constituents for sporophyte regeneration (BA-free medium) was put into a glass test tube (ϕ40 × 130 mm) to 30 mL in capacity. Ten GGB cubic explants (3 mm long) were cultured at 24±2 °C and 16-h light with cool white fluorescent lumps (40 μmol·m^{-2} s^{-1} PPFD) / 8-h dark for 3 months. Before inoculation of explants, vermiculite and rockwool cubes in respective test tubes were autoclaved in a dry state at 120 °C for 20 min, and then, autoclaved medium were poured into the test tubes which were closed with aluminum foil. After 3 months of culture, the numbers and fresh weights of fronds and roots produced on the GGB explants were recorded.

RESULTS AND DISCUSSION

Rhizome tip explants of *C. lepifera* and *M. musifolium* produced GGBs the same as other fern species (Amaki, 1997; Amaki and Kadokura, 2010). The GGBs were multiplied and maintained on a medium containing 1 mg·L^{-1} of BA. However, the growth rate of the two ferns was markedly different. Rhizome explants of *C. lepifera* produced GGBs 1 month after inoculation. On the other hands, GGB production from *M. musifolium* explants was observed after more than 3 months from inoculation.

In *C. lepifera,* the maximum multiplication rate of GGBs was obtained on the medium of 1/1 strength of MS, 20 g·L^{-1} of sucrose, pH of 5.5 (Fig. 1) and 2 mg·L^{-1} of BA (Table 1). The addition of BA markedly inhibited the frond and root forma-

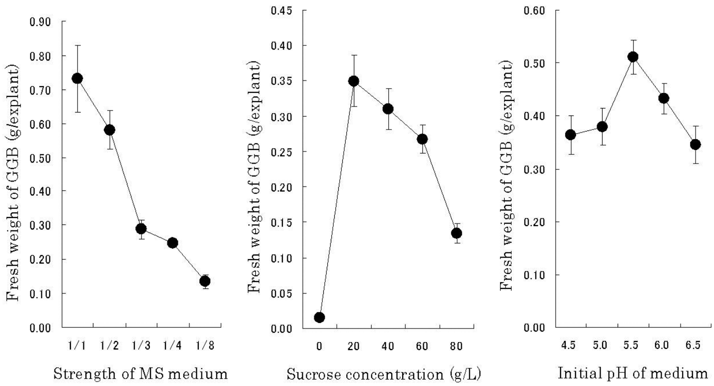

Figure 1. Effects of MS salts strength, sucrose concentration and initial medium pH on the growth of BBG explants in *Cyathea lepifera*.

tion from GGB explants. Frond formation was promoted by the addition of NAA to BA-free medium. The maximum frond growth was obtained at 2.0 mg·L^{-1} of NAA (Table 1). *Cyathea lepifera* showed the same response to NAA as *Rumohra adiantiformis, Adiantum raddianum, Davallia mariesii* (Amaki, 1997) and *Diplazium nipponicum* (Amaki and Kadokura, 2010). In comparison with supporting materials for the sporophyte regeneration, the best growth of fronds and roots from GGB segments was observed on agar and/or gellan gum (Table 2). However, the start of sporophyte regeneration was observed earlier when the GGB segment was inoculated on the rockwool cube than on agar and gellan gum. The sporophyte regenerated on the rockwool cube grew up to transplantable size within 2 months. From the above results the rockwool cube is the best supporting material for sporophyte regeneration among materials used in this experiment, because of rapid regeneration and growth of sporophyte and labor saving for acclimatization procedure. After acclimatization, the regenerated sporophytes grew normally in a greenhouse.

For *M. musifolium* the maximum growth rate of GGBs was obtained on the medium of 1/1 MS medium + 40 g·L^{-1} of sucrose (Fig. 2). Experiments on effects on the initial medium pH, BA and NAA concentration on GGB growth and organogenesis are now in progress because of the slow growth rate of *M. musifolium* GGBs compared with that of *C. lepifera*.

Table 1. Effects of BA and NAA on the growth and organogenesis from GGB explants in *Cyathea lepifera*. (n = 10. Values in table are means ± SE.)

Concentration (mg/L)		Fresh weight (g/explant)			No. of fronds	No. of roots
BA	NAA	Fronds	Roots	GGB	per explant	per explant
0	0	2.51±0.29	0.15±0.05	0.23±0.02	36.4±5.45	22.4±4.43
	1.0	2.60±0.38	0.29±0.04	0.27±0.03	36.8±3.98	25.0±2.57
	2.0	2.80±0.14	0.35±0.06	0.33±0.02	47.6±1.44	23.8±2.84
1.0	0	0.00±0.00	0.00±0.00	0.28±0.01	0.00±0.00	0.00±0.00
	1.0	0.00±0.00	0.00±0.00	0.29±0.02	0.00±0.00	0.00±0.00
	2.0	0.00±0.00	0.00±0.00	0.35±0.04	0.00±0.00	0.00±0.00
2.0	0	0.00±0.00	0.00±0.00	0.11±0.01	0.00±0.00	0.00±0.00
	1.0	0.00±0.00	0.00±0.00	0.19±0.03	0.00±0.00	0.00±0.00
	2.0	0.00±0.00	0.00±0.00	0.30±0.03	0.00±0.00	0.00±0.00

Table 2. Effect of supporting material on the regeneration and growth of sporophytes from GGB segment.

	Fresh weight (g/explant)			No. of fronds	No. of roots
Supporting material	Fronds	Roots	GGB	per explant	per explant
Vermiculite	0.18±0.05	0.00±0.00	0.41±0.12	12.8±3.88	0.4±0.22
Rockwool cube	0.63±0.08	0.12±0.04	0.93±0.09	72.7±9.94	19.2±5.06
Gellan gum (2g/L)	3.15±0.38	0.20±0.07	1.00±0.14	119.5±12.7	40.3±8.79
Agar (8g/L)	3.51±0.14	0.36±0.04	1.70±0.13	138.3±6.48	72.5±7.83

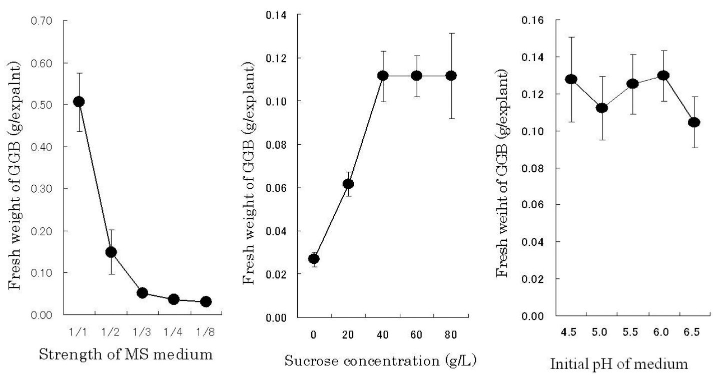

Figure 2. Effects of MS salts strength, sucrose concentration and initial medium pH on the growth of BBG explants in *Microsorum musifolium*.

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Development of a Low Cost Plant Culture Method Utilizing Coconut-Husk Chips in a Bag©

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INTRODUCTION

Plant culture experiments using coconut husks in a bag (coco-bag culture) were started in 2002 at our company research farm. Many hydroponic systems were available at that time, and they had advantages of pest control and stable harvests. However, we started development of coco-bag culture with the following goals:

1) Low costs
2) Easy set up
3) Availability of current culture techniques

This system has been introduced at the farm level to about 100 tomato farms.

GOALS ACHIEVED

Toyohashi area, Aichi Prefecture and we consider that our goals have been achieved:

1) Low costs.
   a. Final products are on sale in bags. These bags can be used as culture beds and culture can start simply and at reasonable cost.
   b. Coco bag is made of coco peat (coconut husk chips). Coco peat is a cheap and stable resource compared with traditional organic media. Furthermore, shipping costs can be saved because coco peat can be compressed and packed in a bag.
2) Easy set up.
   a. Structure of culture beds can make simply by adding pressure and drip controller to drip tube for supply of nutrient solutions.
   b. Bags are not heavy and work for set up is not hard.
3) Availability of usual culture techniques.
   a. Coco bag culture system is based on rock wool system, which is used much in this area, so it is possible to exchange information with growers of other crops.
   b. Risk of root rot by excess wet is reduced because coco peat is a gaseous phase rich medium.

FUTURE DEVELOPMENT

Inquiries and inspections of coco bag culture are increasing domestically. Requests for the system differ regionally and a flexible service system is required from now. We will spread this system with meticulous attention and after-sales service.

Aim at Stabilization of the Management by "Green Servicizing"©

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Thirty years ago in 1981 I started a plant tissue culture business. I built the production system for the plants produced by tissue culture. And I made the grower's group organization to establish the relay cultivation system for "right crop for right land." For the stable sale of pot plants produced by the grower's group organization, I developed a sales company and began direct delivery from the farm sale.

By this process, for the stabilization of company management, I felt the necessity for both the standardization of the pot soil and the establishment of the method of plant factory production, and started hydroculture production (method of growing plants without the use of soil). Our business came to a turning point 22 years ago, and using hydrocultured plants, I diversified into a number of enterprises, such as rental, indoor tree planting, and wholesale for retail stores. Currently, I am developing an environmental tree-planting enterprise in cooperation with growers for rooftop gardening and "eco-walls."

Moreover, this business is a high-service-type business model that adds value, it promotes conversion into active shape of the green business which is new as a higher effect of the reduction of negative environmental impact can be expected by aiming at the 2Rs ("reduction" and "reuse"). By both the "urban green-culture service" and "Vegetakul" business models, our company was admitted as "the green servicizing enterprise" (company of environmental concern for plants rental business) from the Ministry of Economy, Trade and Industry, Japan. Green servicizing is a new business model in an increasingly environmentally conscious and cost-conscious world (Rothenberg, 2007). Urban green culture service is a service business which carries out circulation use of the plants which produced on rooftop garden or on eco-wall (greening of building on wall) as the indoor greens. In a conventional decorative plant renting business, plants are periodically exchanged (recycled) by trucking. This periodical exchange by a truck changes the plant's growth environment, and, as a result, the plant's rate of damage becomes high and waste increases. In addition, the exhaust gas and heat which are generated by transportation in a track also increases environmental impact. In urban green culture service, the roof of a building plays the role of a farm. The incorporation of plants into the inside and outside (rooftop) of a building and use of a water supply system utilizing collected rainwater reduced environmental impact items in a number of ways, and high LCA evaluation in ISO14040/44 was obtained. Since the building roof and walls, which generally do not have value, now have high added value the administrative expenses of a building are reduced.

Vegetakul is a business in which the propagator cooperates with the consumer by growing plants in an on-demand system throughout the year. A build-to-order system enables stable production and stable sales for a propagator. In addition, Vegetakul is the business model of a network-type considered environment. Vegetables are being produced on the veranda in the current kitchen-garden boom in Japan. However, in cultivation on a veranda, there are problems, such as dirt from the growing soil, management of the soil after plant cultivation, continuous cultivation methods, and the situation that the kitchen-garden boom has not stabilized. Because of these problems, I developed the Vegetakul business model <http://www.vegetakul.com>. This cultivation system won the Good Design Award (new domain section) by Japan Industrial Design Promotion Organization (JIDPO).

Moreover, I have expanded this system from consumers to welfare institution for the aged and vegetable gardens on railroad stations and business complex roofs. The plants grown not only contain vegetables but herbs, medicinal herb, various flowering trees, etc.

The development of a method for enjoying horticulture continuously throughout the year is presented. Japan in the future should value the environment, health, and welfare. Vegetakul is a new system which leads to an expansion of consumer's horticulture experience and vegetable production at home. I think that it is a business model which is harmonious with consumers.

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Export Business of Toyoake Kaki Co., Ltd.©

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Our company is a pot-plant wholesale marketer in Aichi, the biggest flower production area in Japan. Products are gathered from all over Japan and sold to buyers throughout Japan. Our export business to the Chinese mainland began in the lunar New Year of 2004. At that time the production of *Cymbidium* in China was increasing. However, compare to Japanese *Cymbidium* plants, Chinese production was of low quality. Our company has selected and exported the Japanese *Cymbidium* which is highly valued in China. Up to the current lunar New Year we have exported *Cymbidium* plants and have established our plants under the Toyoake brand name became they are famous for high quality (there are pirated editions of Toyoake products). Currently the Chinese market is a core part in our exporting business but we have an eye on expanding this business.

Beginning in 2008 we started to export to the United Arab Emirates. Our business to the United Arab Emirates has its base in Dubai. In Dubai 80% of the population are migrant workers and the remaining 20% of the population are native inhabitants and they are a very rich class. Our exported products are mostly orchids, and they have to be sent by air to keep their freshness, so shipping charges are expensive. Our business has to be targeted for the rich locals. Therefore, we must have a large network of local people and this required having a local partner company.

Fortunately, from the beginning of the business, our company has had a local partner company that is very cooperative and has a great interest in Japanese products. Through this partnership we were able to exhibit our orchids at IPM (International Plants Expo Middle East) Dubai in 2009 and 2010. The IPM Dubai is a exhibition similar to IPM Essen in Germany which is the largest yearly exhibition in the flower business. In IPM Dubai, the buyers were mainly from the United Arab Emirates, Kuwait, Saudi Arabia, Iran, Palestine, Lebanon, Syria, and Cyprus. Perhaps, many of these people saw Japanese orchids for the first time and they were astonished and took photos of the orchids. Currently our business still has much to learn about doing business in Dubai. This year we are planning to invite a buyer from our partner company in Dubai to come to Japan and hope that he can feel and understand the high quality and great range of Japanese orchids available. We are hoping this year will be the year for expanding our exports to the United Arab Emirates.

Outside the United Arab Emirates, we began exporting in 2009 to the United States and in 2010 to Russia and Singapore. At IPM Essen 2010 we displayed our orchids in the Japanese Pavilion. As a wholesale marketer our exporting business has a close partnership with the producers in Japan. We wish to show good product sales to those producers by coordinating the sales of their great orchids, to not only inside Japan, but also to the world.

Effort to Market in Both the Domestic and Foreign Floricultural Industry©

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INTRODUCTION

Kaneya Co., Ltd. Japan has produced and sold plastic flowerpots and trays for 40 years in Japan. These days, the floricultural industry is changing rapidly. We would like to introduce our efforts that we are undertaking in both the domestic and foreign markets during this period of change in the markets.

OUR EFFORTS IN THE DOMESTIC MARKET

For the Pot-Plant Growers. In the pot-plants market, we are recommending the use of the "slit pot" to Japanese growers (Fig. 1A). We have been supplying the slit pot to Japanese markets for more than 10 years. If you use and grow plants using the slit pots, the root systems of the plants will grow very well and you will get better shaped plants. You will avoid the root circling problem and damage during the growing period for a long time and your plants growth will be healthy (Fig. 1B). Specially, many growers who are growing fruiting plant, roses, clematis, helleborus, and others are using the slit pot increasingly.

We provide services for the slit pot users which we call "Slit Plants Members." If a grower becomes a member, we do the promotion for them to the market and the buyers (Fig. 1C).

For Cut Flower Growers. We started to provide a new system for the cut flower industries about 10 years ago, named Eco Line Flower (ELF) system. The system is a cut flower bucket system. At the same time, we started Japan Elf System Association. Kaneya Co. makes an effort to increase the use of cut flower bucket system to keep the quality of the cut flower distribution system from the grower to the consumer (Figure 1 D).

For Vegetable Growers. We have started to introduce a new vegetable growing system for vegetable propagators. The name of the system is called the "Pot Farm System." The idea for this system is coming from research at the Agriculture Technology Center in Gifu Prefecture. We develop this system idea and have started to supply Pot Farm System to the vegetable market (Fig. 1E).

OUR EFFORTS TO FOREIGN MARKET

We started a sales promotion program to foreign market. The plastic pot for the flower grower is our main product line in this promotion. Currently our program is underway in the U.S.A. and the E.U. markets with promotion of the slit pots. Our staff are visiting U.S.A. and E.U. growers and doing this promotion face to face and

Figure 1. Introduction of approaches of Kaneya Co., Ltd.: (A) "Slit pot." (B) Plant roots showed fine growth in the 'slit pot' (upper side). Lower side is a control which grew in a usual pot. (C) Commercial paper of 'slit pot' in Japan. (D) Commercial paper of 'ELF system' in Japan. (E) Commercial paper of 'POT FARM System' in Japan. (F) Test of 'slit pot' with *Mandevilla*. (G) Result of the pot test with *Mandevilla*. (H) Pot supply to Chinese market

have booths at trade exhibitions. Growers are showing interest in our slit pots and some have started to use the slit pot. For example, a grower who is producing *Mandevilla* used the slit pots in production tests. Their results were very good because of the good plant-root systems which promoted an increase in the volume of the plants and reduced growing cycle length. After many tests the grower understands the characteristic of the slit pot (Fig. 1F and G).

We also have started to supply flowerpots to the Chinese market. The Chinese market is developing well. We did select the plastic pot for the flower which has been sold in Japanese market and started the sales promotion. We feel that Chinese market will increase rapidly like Japanese flower markets did (Fig. 1H).

From Japan to Foreign Markets. Kaneya Co., Ltd., Japan would like to introduce our products, which are made in Japan more, to foreign markets. Last year we received authorization via government projects and trying to start to introduce Japanese breed plants to foreign markets; for example, we attended exhibitions both in the U.S.A. and E.U. markets.

We are seeing a decrease in the floricultural industry in Japan. Because of this we are now focusing on foreign markets for growth and will try to export our Japanese products to these new markets. We think that it will be very important action to stimulate the floricultural industry.

Demonstration of CO_2 Emission Reduction in a Double Layered Greenhouse

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INTRODUCTION

In greenhouse horticulture heating a greenhouse during winter costs quite a lot and has become a serious problem for growers due to the steep rise in heavy oil price. To heat a greenhouse by burning heavy oil emits CO_2 to the air and this causes environment problems. By applying two layers of roof covering material for higher heat insulation we were able to demonstrate a reduction in the usage of heavy oil and CO_2 emission.

RESEARCH OUTLINE

Research period: 6 Feb. 2009 to 19 Feb. 2009.

Location: Ishiguro Nozai Co., Ltd., experimental farm. This trial was conducted in two greenhouse (width 9 m × length 27 m = 243 m^2) in the same area.

Double layered greenhouse: Covered by F-Clean® [ethylene tetrafluoroethylene (ETFE) film] with double layers (thickness: outer layer 0.08 mm; inner layer 0.05 mm).

Control greenhouse: Covered by F-Clean with single layer (thickness: 0.08 mm).

Method: Exactly the same heating temperature settings were applied in both the double layered greenhouse and the control greenhouse.

Heating temperature settings: 16 °C (6 Feb.–10 Feb.), 14 °C (10 Feb.–14 Feb.), 12 °C (16 Feb.–19 Feb.).

Data recorded: Outside temperature, greenhouse temperature, and usage of heavy oil.

RESULT

Reduction rate of usage of heavy oil and CO_2 emission by a double layered greenhouse was 27.4%–30.5% and these results proved its effectiveness (Table 1).

PROSPECTIVE DEVELOPMENT

A double layered greenhouse can possibly save a heating cost of more than 1 million yen per year for average size growers who grow crops which require higher temperatures during production (current cost is more than 3 million yen per year per grower). Reduction of CO_2 emission is an important theme for our company which is involved in greenhouse horticulture.

Table.1 Comparison of the usage of heavy oil at different heating temperature settings between double layered greenhouse and single layered (control) greenhouse

Heating temperature setting		Usage of heavy oil (L)			Ratio compared with Control per degree hours**	Estimated burning hours per day
		Per each period	Per day	Per degree hours*		
16 °C	Double layered	129.7	32.4	0.231	70	6.8
	Control	187.5	46.9	0.330	100	9.8
14 °C	Double layered	62.4	15.6	0.174	69.5	3.3
	Control	94	23.5	0.251	100	4.9
12 °C	Double layered	82.7	27.6	0.207	72.6	5.7
	Control	107.7	35.9	0.286	100	7.5

*Degree hour was calculated in order to revise influence of daily differences of outside temperature. First cumulative temperatures in each period were calculated by adding temperature differences between greenhouse temperature and outside temperature in each day, and then the usage of heavy oil was divided by the calculated degree hours in each period.

**Ratio of usage of heavy oil per degree hours when the usage of heavy oil per degree hours in Control is 100.

A Report on the IPPS Exchange Program Between New Zealand and Japan©

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This is a report on the first IPPS exchange program held between New Zealand Region and Japan Region. For about a month from 15 May to 14 June 2010, I participated in the program. While staying in South Island (New Zealand) until 30 May and then in North Island for the remainder of the time. I attended the New Zealand IPPS annual conference as a member of "4-Pack."

The IPPS conference was held in Blenheim. From 27 to 30 May there was a workshop in the morning and a nursery tour in the afternoon. The workshop was a valuable experience for me because I first studied at a workshop abroad. I was particularly interested in many presentations on the plants native to New Zealand (NZ), which were very different in species diversity and growth environment from those in Japan. The tour was also rewarding because I had a chance to visit a range of agricultural and cultural places such as nurseries, greenhouses, agribusinesses, commercial facilities, and museums. The large tomato production company which I visited was larger in scale than I had expected (Fig. 1). I also visited garden centers that dealt with small rare flowers like *Acmadenia tetragona* 'Star Blush' (Fig. 2), Nelson Nursery, which gave us a grubbing presentation (Fig. 3), and Yealanad Winery, which arranged a tasting event (Fig. 4).

Figure 1. Visiting a tomato greenhouse at HOPS Ltd. (May 26).

Figure 2. 'Starblush' at a garden store (May 26).

Figure 3. A grubbing machine at Nelson Nursery (May 27).

Figure 4. Wine tasting at Yealanad Winery (May 28).

During the conference, I met a range of horticultural people including tree/flower nurserymen and horticulturists, and was able to get valuable information from them. At the banquet held at night, all the participants livened up the party, enjoying humorous performances. I took great pleasure in the friendly atmosphere.

I found NZ had its own plants and cultivation methods. I was able to see many plants native to NZ. They had different features in size and type from those in Japan. For example, some native ferns were tall while others small, and some had green leaves on the upper side and silver on the lower side. Many trees were best suited to the unique terrain known to be windy, and were used as windbreaks. I also saw many production methods such as producing plants efficiently by using giant machines and selecting plants appropriately for weather conditions.

My host family took good care of me. With them, I went cycling in the mountains, watched soccer games, worked together, and discussed cultural difference between the two countries while dining.

For a short period of 1 month, I met a lot of people and had a lot of unforgettable experiences in NZ. I would like to thank Murray Mannall, president of IPPS New Zealand Region. He was kind enough to meet me at the airport and made all my stay happy and comfortable. Thanks also go to the staff of IPPS NZ Region for their warm welcome. And lastly, I also thank IPPS Japan Region for supporting this exchange program. I hope the program will promote exchanges between the two regions through a long-lasting relationship.

Field Tours in Aichi Prefecture, Aichi Agricultural Research Center Course©

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On the second day of the 17th Annual Conference of IPPS Japan Region, 57 participants enjoyed the field tours.

Toyoake flower auction market trades only pot plants and the volume of trade is the largest in Asia. On this day there were about 880,000 pots traded. The market uses the reverse Dutch flower auction system. Many buyers bid silently, looking at the images of the plant on five separate screens (Fig. 1). In addition, the market has worked on not only trading of plants but also to recycle the plastic trays used in transporting the pot plants. The plants traded in the market are sold all over Japan.

Figure1. We were able to tour auctions in the observation deck called the Skywalk.

Twenty-eight participants visited Aichi Agricultural Research Center. Aichi prefecture is one of the major agricultural regions and a leading producer of many crops in Japan such as, flowers (chrysanthemum, commercial orchid, rose, and cyclamen), foliage plants, cabbage, green beefsteak plants, Japanese butterbur, and fig. The center conducts research on many topics, such as field crop, horticulture, and livestock, and has a 152-ha field. We visited the horticulture section, which conducts research on rose, carnation, and fig topics. In the rose and carnation greenhouse crop area, research is being conducted on the breeding and selection for flower size, production, and powdery mildew resistance (Fig. 2).

Figure 2. The selection greenhouse of rose in Aichi Agricultural Research Center.

In the research in the fig section, they have been studying not only breeding for production but also resistant rootstock for ceratocystis canker (*Ceratocysts* sp.) and labor saving cultivation. I was interested in the container culture research. I think that the main advantage of this culture system is isolation of the plant from soil contaminated with *Ceratocysts* sp. Moreover, it was very important technically for labor saving cultivation of other plants.

The next visit was a commercial grower of figs in Anjo city. The Anjo and Hekinan regions are well known as one of the largest production centers for figs in Japan. Fig trees fruit in the season following planting; this does not occur with many other fruit crops. A number of labor saving technologies are effectively used at many fig farms, especially, straight-line training and wide alleyway for efficient working. The visited farm used the same methods and rain protected culture by a simple greenhouse (Fig. 3). The farmer noted that no serious problems occur during production of figs except from thrips from nearby home gardens. The participants went back to the Nagoya station, said good-bye, and promised to meet again next year in Ehime.

Figure 3. The fig trees were controlled straight-line training and wide alleyway.

Field Trip in Aichi Prefecture, Chita Peninsula Course©

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On the second day of the 17th Annual Conference of IPPS Japan Region, 57 participants enjoy the field tours. First we visited to Toyoake Kaki Co., Ltd. (Pot Flower Auction Market) and then the participants were split into two groups (Chita Peninsula tour and Aichi Agricultural Research Center tour). I joined with 29 participants and enjoyed Chita Peninsula tours.

First, we visited Hayakawa Engei Co. Ltd., which sells potted plants all over Japan. This producer has a 3-ha greenhouse producing 229,000 potted plants, including *Cyclamen, Begonia, Primula, Gerbera, Boronia, Astartea,* and *Erica,* produced with bottom irrigation (Fig. 1). Hayakawa Engei is famous as a breeding company of *Cyclamen, Gerbera*, and *Primula,* and this company supplies good F_1 seeds to Japanese potted-plant growers. This year it was unusually hot in summer. But it seemed that the potted *Cyclamen* grew vigorously in their greenhouse, because the F1 *Cyclamen* of Hayakawa Engei have good resistance to heat.

At lunch time, we ate a Japanese-style meal at Maruha restaurant on the seashore. We enjoyed fresh fishery products and a big fried prawn.

Next we visited Kaneya Co., Ltd., a famous supplier of plastic growing pots, especially the "slit pot" (Fig. 2). The slit pot inhibits root circling during long term

Figure 1. Hayakawa Engei Co.Ltd. *Cyclamen* grew vigorously in greenhouse.

Figure 2. KANEYA CO., LTD. (A) Plastic planting pots ware produced. (B and C) Many cut flower buckets were washed (ELF system).

cultivation and promotes shoot growth. This effectiveness has been known by not only Japanese growers but also growers in the U.S.A. and the E.U. Kaneya Co. is a producer of a wide range of horticultural materials and equipment such as seedlings, substrates, fertilizers, and equipments. They are developing the Eco Line Flower (ELF) system, which is a recycling system for cut flower bucket. This same flower a bucket is used from the cut flower grower to retail store and recycled.

Our last visit was the Uotaro fish market where attendees bought some souvenirs such as local fresh fishery seafood, dried fish, and fish senbei (typical Japanese rice cracker). The participants went to the Nagoya station of Japan Railway, promised to meet again next year and said good-bye.

NON-PRESENTED PAPERS

INTERNATIONAL AT LARGE MEMBERS

The Use and Preparation of a Homemade Conditioner for Vegetables©

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INTRODUCTION

I am glad to introduce and share the results of my learning along with the other members of IPPS. Together with my brother, I grow roses, chrysanthemum, and hypericum, among other flowers. This year we started with about 400 ha for growing grains at 23° latitude and 630 m altitude, where the subtropical climate predominates with annual pluviometric indexes (pluviometer = instrument for measuring the amount of precipitation at a given location over a specified period of time) around 1500 mm, mostly during the summer. The soil is a red latosoil, typically acid and poor in phosphorus; thus some corrections have to be made to bring the soil to an appropriated status for plant growth. Therefore, I am not able to guarantee the efficiency of this method to other members of IPPS due to the variability in the growth conditions. However, for those who are experiencing problems with their plant growth or development and with frequent infestation by pests such as spider mites or thrips, it is worthwhile to try this method mostly due to its easiness to work out and low cost. Additionally, in my view, the method allows me to partially restore the earlier organic conditions present in the soil that were spoiled by the continuous and systematic use of soluble fertilizers and pesticides.

COMPOST TEA PRODUCTION AND USE

This method was first introduced to me by a company that sold a compost-based product containing different herbs — it seems that company became inspired by biodynamics to achieve that product. In the preparation to use this product the company recommended the use of a plastic container with a volume of 1000 L with 200 kg of cow manure added and 50 kg of their product. The container was then filled with water and left to ferment for 15 days. The reader will realize it is a compost tea. This tea is diluted by 10% for pulverization or it is used in a 200 L per ha rate when added to the irrigation water. When we tried this method, we did not realize any change in the plant culture at first, but this changed when I had the idea of adding a small amount of humic and fulvic acids from leonardite to the tea. We were surprised with the results regarding the improvement in the plant culture and the reduction in pests like spider mites and thrips. After 5 years we are still using this method and we are ready to use it also in the culture of grains and cotton which are irrigated through a circular irrigating system. I have noticed that the best results are obtained when we use the method in rotation cultures from the winter to the summer with appropriate temperatures for the growth. Under these conditions it is possible to use less fertilizer or even no fertilizer at all, but this depends upon the soil and the culture under growth. If one of these conditions isn't present, fertilizer is recommended in order to achieve higher output. This compost tea can also be made in large tanks for larger areas where, for each 1000 L, I use about 200 kg of fresh cow manure plus 25 kg of old and dark compost and 25 kg of old vegetative plant remains found in the ground of natural woods where a range of species grow. It seems that the presence of the vegetative plant remains has a stimulating effect in the radicular system of the plant. After 15 days of fermentation it is possible to collect every day 100 L of tea from a 1000 L container and refill the box with water again. We collect the tea only when the solid portion is very well settled because we are interested only in the liquid portion near the surface. The solid is used in order that the microorganisms can remain in the aqueous medium in their activity of producing different types of organic molecules which are necessary for a plant's metabolism. After the collection and refilling with water, I stir the bottom of the tank with a shovel to release carbonic gas. If I notice that the solid material in the bottom is diminishing I add cow-manure and compost with plant vegetative remains. For each hectare I use 200 L of the tea at the time of irrigation when I add only 150 g of leonardite in a weekly basis. The producer starts to see the effect only in the 3rd week. Depending upon the climatic conditions I believe that the method can be applied every 14 days. A different source of humic and fulvic acids can be used, however those acids are more concentrate in leonardite. For those who want to pulverize it is necessary to know if the plant species has a good absorption by the leaves, otherwise irrigation is indicates. For every 10 L of water 1 L of tea should be used and I additionally add a 1/4 teaspoon of leonardite. The pulverization has to be done weekly. This is the method I use and I believe that who try it will be very satisfied with its results.

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