A Comparison of Growth Media for Cyclamens in a Controlled Environment©

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INTRODUCTION

Cyclamens are considered an important crop for winter to supplement the income of enterprises during the cold season. Container grown cyclamens are considered an expensive commercial horticultural crop where growth media is seen as a factor which contributes significantly to the production costs. The economic landscape in South Africa dictates that production costs are kept as low as possible without compromising on quality. Determining the most suitable growth media and maintaining quality would be beneficial for the cyclamen growers. It would not only enhance plant growth, decrease disease, and pest management but allow for competitive prices at the market. The focus of this study was on the comparison of seven growth media in order to determine the most suitable growth media for the South African environment. Existing scholarly and trade literature together with the existing growth media commercially available determined the selection of growth media for the study. The selected growth media included: (1) Cyclamen mix — a commercially imported mixture consisting of coir and perlite, (2) Cyclamen mix - 45 Mix, (3) 49 Mix — a mixture of pine bark and coir, (4) 45 Mix — a mixture of pine bark and coir, (5) 7 Mix — pine bark, (6) course coir, and (7) Klasmann peat substrate 4 — a commercially imported medium consisting of peat. The study involved subjecting container cyclamens to a visual observation measuring instrument which was created from using existing measuring instruments used to compare the growth media of cyclamens in literature. The measuring instrument criteria included the following measurements and observations: Total plant height, plant diameter, fresh plant mass, number of leaves, leave width, foliage fresh weight, number of flowers, diameter of corm, and root mass. Based on the results of the measuring instrument, the most suitable growth media for container cyclamens for South African circumstances will be identified. Recommendations will be made as to the most suitable growth media based on the results of the study.

Research Background

I am currently registered for my M.Sc. in Ornamental Horticulture at University of South Africa (Unisa). The research topic of the comparison of growth media on cyclamen was identified while under the employ of Tuberflora™, a wholesale nursery in Gauteng, as a grower. I started becoming interested in the propagation and production after the realization that the quality and market timing of commercial container cyclamens determines the competitive edge on the market. Where are their ways of speeding up the growing season of the cyclamens in order to provide the market with quality cyclamens ahead of the competitors? This newly found interest lead to an investigation which forms part of my M.Sc. in Ornamental Horticulture.

The motivation for the research project involves identifying a growth medium most suitable in the commercial production of container cyclamen for the South African environment. The commercial growers of cyclamens would benefit from the study as this would allow a commercial nursery to make informed management decisions on the cultivation of a preferred crop for winter/cold season income supplementation. It would assist the commercial growers of cyclamens in determining whether there are any South African growth media alternatives for cyclamens. On an environmental level, it would help determine whether the carbon footprint of the growing medium can be reduced by using the most suitable and cost-effective growth medium for container cyclamens.

Literature Review

Cyclamen in general as an ornamental horticulture crop have acquired the international reputation of being difficult to cultivate. According to Beytes (2003) and Onofrey (2000), in order to successfully cultivate for commercial purposes, *Cyclamen* require advanced growing skills and competencies. This includes specialized growth specifications, dedicated production space, specialized growth medium, disease and pest management programme, and a specialized fertilization programme.

The present economic situation dictates that commercial nurseries economize and focus on more cost effective production strategies. These production strategies involve the cost-effective utilization of available greenhouse production space, and the utilization of the best quality growth medium for propagation at competitive prices.

RESEARCH DESIGN

Research Problem Statement

How do the selected growth media for cyclamens compare in terms of quality in the production of commercially grown container cyclamen in a South African context in a controlled environment?

Research Sub-Problems

- Determining the most suitable growth medium for the cultivation of container cyclamens grown in a controlled environment.
- Identifying the criteria that can be used to create a visual measuring instrument for the comparison of the cyclamen growth media.
- Determining how the commercial cyclamen grower would benefit by using the most suitable growth medium in the production of container cyclamens.

Research Methodology

A comparative study was conducted. The trials were conducted using selected growth media presently being used by commercial growers in the production of cyclamens in South Africa during 2012 and 2013.

The evaluation criteria for growth media were determined to develop a visual measuring instrument for the comparison of the cyclamen growth media. The experiments were conducted with consent of Tuberflora™ management according to the Unisa Ethics requirements.

Experimental Design

Trials were conducted in a greenhouse on the premises of Tuberflora™, a commercial wholesale nursery, located on a plot in Muldersdrift in the province Gauteng, South Africa. The greenhouse a pad and fan structure with double-layered clear plastic (polyethylene - 200 micron ×2) had an area of 3,072 m^2 (48×64 m). Climate control included a mechanized 40% filter screen and plastics to allow for manipulation of light intensity (ideal range between 250-650 lux). Temperature was a critical factor. It was essential to have a "cold house" during production phase. This meant that cyclamen plantlets were transplanted at a cooler temperature during the warm December summers of Gauteng (temperature max 39°C). The trials were arranged in a randomized complete block design with seven pre-selected growth media treatments as suggested by Whitcomb (2003), Nelson et al. (2010), and Widmer (1971). There were five plants per block with 4 blocks and 2 replications (seasonal commercial growth cycles) in a closed environment. The study therefore included a total of 105 plants per replicate and a total of 210 plants over the entire project.

A randomized complete block design (suggested by Whitcomb, 2003; Nelson et al., 2010; Widmer, 1971) used during the study.

Plant Population
There were 210 plants in the trial. The focus would be on only one cultivar of cyclamen for a homogenous plant population. It was decided to focus on *Cyclamen persicum* F_1 standard, cultivar Grandola deep rose seeds from the supplier, Hemgenetics™. Each trial container cyclamen would be clearly marked with a sticker indicating the plant as part of trial and not to be sold commercially.

Growth Media
The growth media used for the study is listed in Table 1.

Table 1. List of growth media.

Growth media name	Growth media
1. Cyclamen mix	Cyclamen mix consists of course coir and perlite (9:1, v/v), growth medium supplied by MEEGAA™
2. Mix 2	Cyclamen mix and 45 Mix (1:1, v/v), this mixture consists of a mixture of two exciting mixtures
3. 49 Mix	The 49 Mix consists of pine bark and coir (4:1, v/v)
4. 45 Mix	The 45 Mix consists of pine bark and coir (3:2, v/v)
5. 7 Mix	This mix consists of 100% pine bark
6. Coir	This mixture consists of 100% course coir
7. Klasmann peat substrate 4	This imported medium is 100% peat from the Netherlands

Data Collection
The following guidelines were adhered to:
- The temperature and humidity were recorded with data logger on hourly basis.
- The light intensity was measured and recorded hourly using a Lux data logger.
- The growth media analysis was conducted by Eco Analytica (North West University). The growth media nutrients were recorded on regular intervals using an EC meter and administered with Dosatron® system.
- A pest and disease management programme was designed specifically for the cyclamen production, AVONROD Plant protection® and used by Tuberflora.
- The measuring instrument developed as evaluation tool would be used for the visual observation and measurements of the cyclamens.
- The visual observations and measurements were recorded in three sessions over two seasons.

Measuring Instrument
The measuring instrument criteria included the following measurements and observations: Total plant height, plant diameter, fresh plant mass, number of leaves, leave width, foliage fresh weight, number of flowers, diameter of corm and root mass.
The following information will be captured on the data capturing spread sheet (Table 2).

Table 2. Measuring instrument.

	Parameters/ criteria	Sub parameters	Source
1)	Total plant	Plant height (canopy height)	Widmer (1971), Van der Gaag et al. (2007), Nelson et al. (2010), Cativello et al. (1997) and Mao et al. (2006)
		Plant diameter	Widmer (1971), Cativello et al. (1997), Van der Gaag et al. (2007), Trelka and Szczepaniak (2009) and Nelson et al. (2010)
		Fresh plant mass/ weight (with corm/ tuber)	Cativello et al. (1997), Van der Gaag et al. (2007), Trelka and Szczepaniak (2009) and Nelson et al. (2010)
2)	Leaves	Number of leaves	Mao et al. (2006), Trelka and Szczepaniak (2009) and Nelson et al. (2010)
		Leaf width	Mao et al. (2006)
		Foliage fresh weight	Cativello et al. (1997)
3)	Flowers	Number of flowers	Cativello et al. (1997), Van der Gaag et al. (2007) and Nelson et al. (2010)
4)	Corms/tubers	Diameter of corm/ tuber	Mao et al. (2006) and Trelka and Szczepaniak (2009)
5)	Roots	Root mass/weight	Cativello et al. (1997)

RESULTS AND DISCUSSION

The results would include the visual observations and measurements recorded during the data collection of three separate sessions during two growing seasons.

Table 3. Mean values for season 1 and 2 combined. Growth media mix comparison.

Measuring schedule per production week	Mix 1: cyclamen Mix	Mix 2: cyclamen mix and 45 Mix	Mix 3: 49 Mix	Mix 4: 45 Mix	Mix 5: pine bark	Mix 6: 100% coir mix	Mix 7: Klasmann peat mix
First measurement							
Plant height	6.2	5.1	4.4	4	4	4	4.9
Plant diameter	17	17	15	13	16	14	20
Plant mass	12.6	12.1	11	10.5	10.5	10.6	12.4
Number of leaves	35	31	24	25	26	36	53
Leaf width	5.9	9.4	5	5	4.8	5.5	5.8
Folaige fresh weight	18.9	10.9	10.6	10.9	11.9	12	19.4
Number of flowers	*	*	*	*	*	*	*
Diameter of tuber	1.5	1.7	1.6	1.5	1.7	1.7	1.6
Roots fresh weight	11	11	9	9	9	20	29
Second measurement							
Plant height	12	9.4	7.4	7.9	7.2	9	9.8
Plant diameter	29	33	21	25	25	29	28
Plant mass	23.4	20.6	16.2	17.7	15.5	19.5	20
Number of leaves	134	115	59	78	58	122	200
Leaf width	8.5	8.2	7.5	7.9	6.9	8.4	8.2
Folaige fresh weight	75.9	69.8	33.8	41.3	31.5	47.8	57.8
Number of flowers	18	16	12	14	13	14	17
Diameter of tuber	1.9	2.1	2	1.9	1.9	1.9	1.9
Roots fresh weight	36	27	17	26	19	52	123

Table 3. Continued.

Measuring schedule per production week	Mix 1: cyclamen Mix	Mix 2: cyclamen mix and 45 Mix	Mix 3: 49 Mix	Mix 4: 45 Mix	Mix 5: pine bark	Mix 6: 100% coir mix	Mix 7: Klasmann peat mix
			Third measurement				
Plant height	15	14.3	10.7	11.4	9.5	11	12.4
Plant diameter	28.1	23.1	20.3	21	17	20.8	24.5
Plant mass	373.8	263.8	158.8	203.4	101.5	161	391.4
Number of leaves	50.3	46.5	33.2	45.3	26.3	30.5	50.5
Leaf width	9.75	8.7	8.3	8	7.4	8.6	8.7
Folaige fresh weight	153	115.6	64.7	88.1	52.8	85.8	98
Number of flowers	28.5	26.8	21.1	23.7	14.4	17.7	27.3
Diameter of tuber	1.9	2.5	2.2	2.3	2	2.1	1.8
Roots fresh weight	135.5	87.1	35.1	68.6	29.1	41	244.5

*No flowers present.

Statistical Comparisons for Season 1 and 2

This section contains the statistical comparisons conducted. Parametric and as well as non-parametric methods were used to compare Mix means and were followed up with post-hoc analysis to identify which Mix differed significantly. The assumptions of normality, constant variance and independence were tested in considering the appropriate method: Parametric and non-parametric data.

1. Parametric Data. For the parametric data namely plant height; diameter of tuber; number of leaves and leaf width, was used for group comparisons and Tukey HSD for the post-hoc analysis.

2. Non-Parametric Data. The non-parametric data namely plant diameter; plant mass; number of flowers; root fresh weight and foliage fresh weight were tested using Kruskall Wallis for a comparison between Mix means followed by Mann-Whitney U test for the post-hoc analysis. In order to accommodate the objective of the research, the post hoc tests were conducted with a top-down approach. The mean values were ranked and the highest Mix mean was compared with the second highest value until a significant difference was obtained.

Table 4. Measuring instrument parameters.

Measuring instrument parameters	Sub parameters	Year 2012			Year 2013		
Total plant	1. Plant height	ANOVA p=0.00232	Mix 1 & 2	Tukey HSD p=0.03	ANOVA p=0.014	Mix 1 & 3	Tukey HSD p=0.014
	2. Plant diameter	Kruskal Wallis p=0.056	Mix 1 & 5	Mann-Whitney p=0.01	Kruskal Wallis p=0.005	Mix 1 & 7	Mann-Whitney p=0.039
	3. Fresh plant mass	Kruskal Wallis p=0.026	Mix 7 & 6	Mann-Whitney p=0.024	Kruskal Wallis p=0.007	Mix 7 & 4	Mann-Whitney p=0.01
Leaves	4. Number of leaves	ANOVA p=0.07			ANOVA p=0.107		
	5. Leaf width	ANOVA p=0.0003020244	Mix 2 & 3	Tukey HSD p=0.041	ANOVA p=0.011	Mix 6 & 3	Tukey HSD p=0.051

Table 4. Continued.

Measuring instrument parameters	Sub parameters	Year 2012			Year 2013		
Leaves	6. Foliage fresh weight	Kruskal Wallis p=0.032	Mix 1 & 2	Mann-Whitney p=0.126	Kruskal Wallis p=0.118		
Flowers	7. Number of flowers	Kruskal Wallis p=0.293			Kruskal Wallis p=0.651		
Tubers	8. Diameter of tuber	ANOVA p=0.005	Mix 2 & 5		ANOVA p=0.015	Mix 2 & 5	Tukey HSD p=0.059
Root	9. Weight	Kruskal Wallis p=0.005	Mix 1 & 7	Mann-Whitney p=0.05	Kruskal Wallis p=0	Mix 7 & 6	Mann-Whitney p=0.018

This Section Contains the Explanation of the Statistical Comparisons Conducted (Year 2012 and Year 2013 Hereafter Referred to as 2012 and 2013)

1. Plant Height. 2012 ANOVA compare p=0.00232 Mix 1 (Cyclamen Mix) and Mix 2 (Cyclamen Mix and 45 Mix Tukey HSD p=0.03).

2013 ANOVA compare p=0.014 Mix 1 and 3 (49 Mix) Tukey HSD p=0.014

In both 2012 and 2013, the plant height differed significantly between the mix means. In 2012 plant height was significantly larger in Mix 1 compared to Mix 2. The means of Mix 1 were less than that of Mix 2. In 2013, plant height was also significantly larger for Mix 1 compared to Mix 3 with the means of Mix 1 less than that of Mix 3.

2. Plant Diameter. 2012 Kruskal Wallis compare p=0.056 Mix 1 and Mix 5 (7 Mix) Mann-Whitney p=0.01.

2013 Kruskal Wallis comparer p=0.005 Mix 1 and Mix 7 (Klasmann peat Substrate 4) Mann-Whitney p=0.039.

In both 2012 and 2013, the plant diameter differed significantly between the Mix means. In 2012 plant diameter was significantly larger in Mix 1 compared to Mix 5. The means of Mix 1 were less than that of Mix 5. In 2013, plant diameter was also significantly larger for Mix 1 compared to Mix 7 with the means of Mix 1 less than that of Mix 7.

3. Fresh Plant Mass. 2012 Kruskal Wallis compare p=0.026 Mix 7 and Mix 6 Mann-Whitney p=0.024.

2013 Kruskal Wallis compare p=0.007 Mix 7 and Mix 4 (45 Mix) Mann-Whitney p=0.01.

In both 2012 and 2013, the fresh plant mass differed significantly between the Mix means. In 2012 fresh plant mass was significantly larger in Mix 7 compared to Mix 6. The means of Mix 7 were less than that of Mix 6. In 2013, fresh plant mass was also significantly larger for Mix 7 compared to Mix 4 with the means of Mix 7 less than that of Mix 4.

4. Number of Leaves. 2012 ANOVA p=0.07. 2013 ANOVA p=0.107.

No significant difference for number of leaves between treatments in both 2012 and 2013 when using an alpha value of 0.05. However, using an alpha value of 0.1 a significant difference is observed. It is therefore further mentioned that the three highest mean values for the Year 2012 (treatment 7, 2, 1) and the Year 2013 (treatment 1, 7, 2) are the same.

5. Leaf Width. 2012 ANOVA compare p=0.00030244 Mix 2 and Mix 3 Tukey HSD p=0.041.

2013 ANOVA compare p=0.011 Mix 6 (Coir) and Mix 3 Tukey HSD p=0.051.

In both 2012 and 2013, the leaf width differed significantly between the Mix means. In

2012 leaf width was significantly larger in Mix 2 compared to Mix 3. The means of Mix 2 were less than that of Mix 3. In 2013, leaf width was also significantly larger for Mix 6 compared to Mix 3 with the means of Mix 6 less than that of Mix 3.

6. Folaige Fresh Weight. 2012 Kruskal Wallis compare p=0.032 Mix 1 and Mix 2 Mann-Whitney p=0.126.

2013 Kruskal Wallis compare p=0.118 Mix 1 and Mix 2.

In both 2012 and 2013, the foliage fresh weight differed significantly between the mix means. In 2012 foliage fresh weight was significantly larger in Mix 1 compared to Mix 2. The means of Mix 1 were less than that of Mix 2. In 2013, foliage fresh weight was also significantly larger for Mix 1 compared to Mix 2 with the means of Mix 1 less than that of Mix 2.

7. Number of Flowers. 2012 Kruskal Wallis compare p=0.293.

2013 Kruskal Wallis compare p=0.651.

No Significant difference for number of flowers between treatments in both 2012 and 2013.

The results of the comparison of mean number of flowers, indicated Mix 1 performed best and the largest mean number of flowers being recorded with Mix 1.

8. Diameter of Tuber. 2012 ANOVA compare p=0.005 Mix 1 significantly smaller than Mix 2 and Mix 5.

2013 ANOVA compare p=0.015 Mix 2 and Mix 5 Tukey HSD p= 0.059.

In both 2012 and 2013, the diameter of tuber differed significantly between the mix means. In 2012 diameter of tuber was significantly smaller in Mix 1 compared to Mix 2 and Mix 5. The means of Mix 1 were larger than that of Mix 2 and Mix 5. In 2013, diameter of tuber was also significantly larger for Mix 2 compared to Mix 5 with the means of Mix 2 less than that of Mix 5.

9. Root Fresh Weight. 2012 Kruskal Wallis compare p=0.005 Mix 1 and Mix 7 Mann-Whitney p=0.05.

2013 Kruskal Wallis compare p=0 Mix 7 and Mix 6 Mann-Whitney p=0.018.

In both 2012 and 2013, the root fresh weight differed significantly between the Mix means. In 2012 root fresh weight was significantly larger in Mix 1 compared to Mix 7. The means of Mix 1 were less than that of Mix 7. In 2013, root fresh weight was also significantly larger for Mix 7 compared to Mix 6 with the means of Mix 7 less than that of Mix 6.

CONCLUSION

The results for the comparison of the growth media on cyclamen growth in a controlled environment indicate that Mix 1 (Cyclamen Mix) and Mix 7 (Klasmann peat Substrate 4) are the best performing growth media. Based on the analysis of the results of the comparison of the combined Season 1 (2012) and Season 2 (2013) obtained during the study, it was found that the most suitable growth media for container cyclamens for South African circumstances would include peat or a mixture of peat. Therefore commercial growers using growth media with peat and peat mixtures, would not only have a better quality product for market but would have the minimum number of flowers, deemed necessary for market ready, present and therefore ready for market sooner than when using growth media without peat. The study was therefore able to determine suitable growth media for container cyclamens in a controlled greenhouse structure. The study also highlighted the benefits to the commercial grower such as faster production cycle and earlier market ready container cyclamen delivery to the market.

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Improving Field Survival of Pine Seedlings and Cuttings: the Sappi Plant Quality Index©

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DEFINING PLANT QUALITY AND ITS MEASURES

Plant quality can be defined as "fitness for purpose" and described as a plant's ability to survive and grow after planting (Mattsson, 1996). Various morphological and physiological plant parameters have been used to measure plant quality in forestry and have been quantitatively linked to increased establishment success (Rose et al., 1990). Many factors can affect plant survival and subsequent growth; these include genetic variability, nursery practice, handling, and transportation of plants as well as silvicultural practices at planting. The potential gains from high quality planting stock in forestry in combination with good silvicultural practices are additive and lead to optimum stocking as well as volume growth (South et al., 2005). The responsibility of nurseries is to ensure that plants with the highest possible chance of survival, that is plants of high quality, are supplied to end users. It is, however, also important to note that producing seedlings and cuttings which meet the desired plant quality specifications do not guarantee that plants will survive, but rather that it guarantees the probability of those plant surviving under normal conditions (Grossnickle, 2012). In much the same way, seed germination estimates the best possible germination under ideal conditions but does not provide a guarantee on the final nursery germination success as this may be confounded by many independent nursery factors.

Transplant stresses are most often associated with water stress in forestry (Grossnickle and Folk, 1993). In order for plants to overcome this transplant stress and successfully establish themselves after planting it is essential that the root system meets the transpirational demands of the shoot system. Immediate root growth and colonisation of the soil as well as sufficient soil contact and good root permeability are essential in this process (Burdett, 1990). It is thus necessary that the plants have functional physiological processes that are required for root growth and development (Grossnickle and Folk, 1993). The relationship between the choice of container size and time in the nursery with differing watering and nutrient regimes can have great impact on plant size, nutrient status, degree of root plug consolidation, and overall health and disease susceptibility. The nutrient, watering, and age requirements for optimum physiological condition for the species in production must therefore be established.

Physiological plant quality measures are very useful in determining plant quality but these are often tedious and time consuming with most commercial nurseries ill-equipped to conduct these measures. Much research since the middle parts of the last century and more recently has focused on developing morphological plant quality measures which can be more easily used by nurserymen to measure the quality of their product and infer some guarantee of physiological quality of the plants they supply. Plant quality recommendations for *Pinus patula* seedlings have been made in Sappi Forests, South Africa, since the mid-1990s. Nurseries were not, however, quantifying the quality of the plants being dispatched. Since 2002 Sappi Nurseries has implemented the "Sappi Plant Quality Index" (PQI) in order to: (1) Quantify and record nursery plant quality, (2) Quality control planting material to eliminate sub-standard plants, (3) Provide a guarantee on the survival and growth potential of plants dispatched, and (4) Ensure the delivery of higher value plants. In this system, easily measurable morphological parameters were identified and ideal specification ranges for each parameter tested for all species for their container type and size (Bayley, 1995, 2000, 2002; Jones and Mitchell, 2005; Morris, 1994). Based on long term trial data, scores were allocated to each parameter reflecting its relative importance to survival and growth in field. Before plants are dispatched from a Sappi Forests nursery, 0.02% of the batch is destructively sampled and measured. Plants

are scored on age, height, root collar diameter (highly correlated with root biomass), root plug integrity, leaf colour, presence of ectomycorrhizae, prevalence of white growing tips in roots, signs of disease, and presence of weeds. Critical zero scores are identified and used to flag poor batches which should not be dispatched. A minimum batch score is prescribed and must be achieved before dispatch. By quantifying and scoring such plant quality parameters one is able to predict the initial field survival capacity as well as the growth potential of batches (Grossnickle and Folk, 1993).

PLANT AGE SPECIFICATIONS

Plant age, irrespective of root plug status, can affect field performance as roots become suberized with age and are less able to take up water, particularly after planting when active moisture uptake is essential in ensuring plant survival (Jones and Mitchell, 2007; MacFall et al., 1991; South and Mitchell, 2006). In a containerised system there is a definite ideal age window where plants display the optimum physiology and size for the container size and type. Before this time the plants root plug is not fully colonized which can lead to root damage, loss of plug integrity at planting and ultimately mortality after planting. There is also increased chance that the plants root biomass may not yet be sufficient to rapidly colonise the soil and support the transpirational needs of the shoot biomass once planted out. Plants older than the ideal age window would tend to be highly suberized and also show root defects associated with being root bound, such as deformed root systems and poor root growth. This often leads to poor plant growth, and in trees can lead to basal sweep and wind throw 1 to 2 years after planting.

PLANT SIZE SPECIFICATIONS

Raising the ideal plant size for a specific plug type/volume is very important for both growth and survival potential (Bayley, 1995; Johnson et al., 1996; Ortega et al., 2006; Zwolinski and Bayley, 2001). Seedling height, root collar diameter and sturdiness ratio are important determinants of field performance (Bayley and Kietzka, 1997; Donald, 1992). The heights and root collar diameters (RCD) of plants raised in a containerised nursery system are of vital importance as container size determines the limit of biomass which can be supported. Plants which exceed the size recommendations have a high probability of being root bound, while plants below the recommended size would tend not to have fully colonised the plug. The ratio of height (highly correlated to shoot biomass) to RCD (highly correlated with root biomass) is also an important consideration. When the ratio is high (i.e., shoot biomass: root biomass is greater than prescribed) plants tend to be tall and lanky, hence decreasing stability in the field, which may lead to mechanical damage and mortality. There is also an increased probability that the root biomass may be insufficient to support the shoot biomass under droughty planting conditions. Pine seedlings and cuttings which have a low height : RCD tend to be more sturdy and are less likely to show mechanical damage through wind, and also have a greater likelihood of root biomass being sufficient to support shoot biomass at planting (except if root bound).

ROOT PLUG COLONISATION

The degree to which roots have colonised their root plug is a good indicator of absorptive root surface (Thompson, 1985). Poor root development may be responsible for the plant not meeting the transpirational demands of the shoot system during adverse climatic conditions after planting (Burdett, 1990). Conversely, when root plugs become over colonised (or root bound) pine seedlings and cuttings show a reduction in their ability to produce new roots after planting (South and Mitchell, 2006). This may lead to reduced survival and growth (South and Mitchell, 2006). It is also possible that while early survival and growth may not be effected by being root bound it can still lead to decreased stability in the longer term (Lindström and Rune, 1999). This may lead to trees being blown over at around 1 to 2 years of age. For the reasons listed above seedlings should be planted when they have colonized the root plug but the root plug has not yet become root bound (Bayley, 1995). A root plug is not fully colonised if growing medium falls off the

plug and exposes roots at extraction. Ideally root plugs should be fully colonised, firm but not hard, with white root tips (actively growing roots). A plug could be classed as root bound when the plug is hard with many roots visible on outside of plug, a high proportion of which are relatively thick brown roots, forming a dense mat particularly at the bottom of the plug.

ROOT SPIRALLING/COILING AND J-ROOTING

In some container types, lacking root trainers, roots may grow in a circular fashion. This "root spiralling" or "coiling" can lead to infield root deformations which constrict around the main tap root causing decreased stability, and ultimately wind damage and mortality 1 to 2 years after planting (Zwolinski and Bayley, 2001). It is important to score the frequency of this defect and manage batches accordingly. In order to significantly reduce this phenomenon it is advisable to use containers with pronounced internal ridges which prevent root spiralling by training roots downwards (Mitchell et al., 2012). "J-root" formation is a phenomenon that is sometimes a problem with forestry seedlings (Bayley, 2000). J-roots may be artificially formed when the root plug is bent during planting or when young seedlings are transplanted in the nursery (Bayley, 2000) or naturally through large media particles inhibiting vertical root growth downwards. Primary roots with a bend greater than 90° are generally considered to be J-rooted.

PLANT HEALTH

Leaf Colour

The colour of foliage gives an indication of the nutritional status of the plants and of their photoprotection ability (Close et al., 2005). Needles which are deep green are indicative of levels of nitrogen which are too high as increasing nitrogen supply can reduce drought resistance (Etter, 1969; Pharis and Kramer, 1964). These are sometimes referred to as "soft plants." Needles in the light yellow/green to yellow range usually show that nitrogen levels are too low. Nitrogen in the deficient to low range can also reduce drought resistance (Driessche, 1991) and these are referred to as "weak plants." Light green needles show an intermediate and possibly more ideal level of nitrogen where plants are hardy but with sufficient nutrient reserves to survive transplanting.

Mycorrhizae

Beneficial mycorrhizal fungi, naturally colonising most horticultural and forestry plants, can increase disease resistance and enhance water and nutrient uptake (Cuny, 1995; Davies, 2000; Linderman, 1993). The presence of ectomycorrhizae is usually visible as grey to white fungus on the root plug and/or where the tips of roots are swollen or branched (bifurcate).

Disease

Any signs of disease within a pine batch must result in the batch being held back until the disease issue has been remediated. An example of a common forestry disease is *Fusarium circinatum* which has become one of the largest threats to the pine forestry industry in South Africa (Mitchell et al., 2011; Wingfield et al., 2008). Crous (2005) observed that during 2003 and 2005 in the Mpumalanga province of South Africa an average of 25% of planted pine died because of the disease. Mitchell et al. (2011), using the current establishment costs for pitting, planting, and blanking of these areas, estimated this loss to be R602 per ha for the saw timber industry, and R896 per ha for the pulpwood industry, which he estimated cost the industry, as a whole, 11 million rand per annum. Thus, any signs of disease within a pine batch must result in the batch being held back until the disease issue has been remediated. In the case of *F. circinatum* it is necessary to continually rouge out all symptomatic plants as early as possible to maintain low levels of inoculum in the nursery. This usually requires the rouging of less than 1% of a batch which has a much lower economic impact on the industry than the alternative described

above (Mitchell et al., 2011). *Fusarium circinatum* symptoms initially manifest as a shoot tip wilt, turning blue/grey and ultimately reddish brown. Roots will be dead and root collar will have resinous staining by the time disease symptoms are noticed. Another common disease in pine nurseries is *Botrytis cinerea* which appears first as a grey to blackish mould on the stem and then seedlings show wilting of the shoot tip. Outbreaks of this disease are often associated with suboptimal nursery practice and are more easily remediated, before dispatch, than *F. circinatum* outbreaks.

IMPLEMENTATION OF THE SAPPI PLANT QUALITY INDEX

The Sappi PQI system is implemented as standard operating procedure at all Sappi nurseries, and has been since 2002. Specifications for pine and *Eucalyptus* species, as seedlings and cuttings, have been researched and established. Each batch produced at a Sappi nursery has a PQI score sheet attached to the dispatch note. This is to allow both the nurserymen and foresters to assess the quality of a batch before dispatch and planting. This also serves to flag any potential quality issues, thus avoiding the significant costs of replanting areas initially established with poor quality seedlings and cuttings. The implementation of the PQI system within Sappi Nurseries is audited annually and training is provided to nursery staff responsible for measuring and scoring plant quality on an annual basis as well. The recommendations are revised annually, based on new trial data and industry feedback, to accommodate necessary adjustments or fine tuning for new challenges.

ACKNOWLEDGEMENTS

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Ornamental Plant Selection Using the "Shotgun Technique": a Complex Process Simplified©

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Currently there is very little commercial ornamental crop development in South Africa. There is unfortunately little stimulus or incentive to develop this industry and this in part this is due to the fact that floriculture is not offered at any tertiary institution in the country. Yet, South African plant genera are of the most commercialised in the world. Plant breeding can be a complex and daunting process, so the purpose of this paper is to introduce a simple low-tech method of multi-generational plant selection which can produce very rewarding results.

"Indigenous" often has the unfortunate reputation of being dull and difficult to grow, often because there has been little or no selection on the plant before its release onto the market. As a result, unselected and unbred wild plants will always pale in grandeur against the highly bred petunias, pansies, and practically every other plant you will find in a commercial nursery nowadays. One of the objectives of the horticultural operations at Kirstenbosch Botanical Gardens is to promote indigenous plants by introducing new selections into the industry. Horticulturists at Kirstenbosch have undertaken limited plant breeding projects, like *Plectranthus* 'Plepalila', Simply Beautiful® Mona Lavender plectranthus PP13,858 for example, but generally the gardens don't have the capacity to undertake in-depth plant selection programmes. There are a few commercial nurseries in South Africa that breed on a very limited scale, and there is the odd back-yard breeder, but generally there just isn't the commercial incentive to invest in large scale breeding operations in this country.

There are two important but slightly different processes involved in developing new commercial floricultural products:

1) Plant breeding — (usually interspecific hybridising between two or more different species). When executed properly, breeding can be a very complicated process. Hybrid vigour often initially leads to strong plants with strange and wonderful characters but if not done carefully can lead to inbreeding depression (crossing brothers and sisters) often leading to harmful mutations causing weak and disease-prone plants.
2) Plant selection — (a natural process of selecting the best and eliminating the worst). This is usually a part of the breeding process but can also exist as a stand-alone process in directed intraspecific crossing.

For the record, there are two types of ornamental plant products: seed products and vegetative products. The breeding processes required for each, although there is some overlap, are quite different (Table 1).

Table 1. Comparison of the two types of ornamental plant products.

Seed products	Vegetative products
Uniform germination	Quick and easy to develop
Vigorous growth and larger flowers	Less vigorous than seedlings
Can be stored by grower	Smaller flower size
Easy distribution to growers	Limited shelf life
Virus free (in most cases)	More expensive to produce
Cheaper to produce	More expensive to buy
Cheaper to buy	Expensive to eliminate viruses
Longer and more complicated to develop	
More expensive to develop	

For the purposes of comparison and illustration, the conventional breeding process is elaborated here.

CONVENTIAL BREEDING PROCESS

Seed Products

Seed products are derived from conventional plant breeding processes. The correct process of true plant breeding involves ideally starting with a large and varied gene pool of parent plants (often of different species). Through a process of carefully directed and well-recorded cross pollination, the desired hybrid can be developed.

Then using similar but not identical parents, a breeder will attempt to repeat this whole process numerous times with the aim of breeding a number of identical offspring hybrids, say perhaps 10, (these are called parent lines). These are the equivalent of very distant identical cousins. Then by mass cross pollinating these genetically different but identical-looking parent lines, large quantities of commercial seed, all with identical characteristics, will be produced. This process of only crossing distantly related plants will avoid inbreeding depression; all offspring will be genetically sound and strong. This process, however, can take many years, and requires dedication and patience, which is the reason why it is seldom done outside of large commercial ornamental plant development companies, like Ball Horticultural Co. for example.

Vegetative Products

The process dealt with in this paper will be to do with breeding a vegetative product, i.e., a product that will ultimately be reproduced via conventional means of asexual propagation. Breeding a vegetative product requires far less time than a seed product, and is relatively easy to do. Although not as profitable, the short turnaround time and low investment factor make it the more attractive option.

At Kirstenbosch, we prefer to focus on naturally developing pure wild species rather than hybridising different species. Quite simply there are more than enough beautiful pure species to develop without the of need resorting to hybridization.

THE “SHOTGUN” PROCESS

As was mentioned, there is still a need for some plant selection to make a wild plant more marketable. So, through the following very simple and natural process, by exploiting the natural variation that exists between individual plants, one selects combinations of desirable plant traits to produce ornamental “winners.” The “shotgun process” gets its name from the analogy of somewhat crudely firing a shotgun in order to hit a tiny target; in a similar way the larger the pool of genetic characters one has to choose from in a population of wild plants, the higher the chance one will have of finding the winning plant.

From an ethical point of view, the question that could be asked is whether or not this plant could have naturally occurred in the wild? If the answer is yes, the process gets an ethical tick. This process is essentially entirely natural — nothing artificial. The process is called natural selection, except now the process has been sped up and the traits being selected for are purely for ornamental benefit.

How the Process Works

1. The First Step. Select a plant species or form of that species that naturally already has the potential to be a winner — i.e., it must already have numerous good traits. Genes cannot magically appear, so if they’re not there in the population to start with then they’re probably not going to magically appear during the course of your selection — e.g., if neither of the parent plants contains the genes for blue flowers, the offspring are almost certainly never going to exhibit blue flowers. General rule of thumb: Pretty parents generally make pretty children. Ugly parents, however, very rarely make pretty children!

2. What Traits Would One Typically Look For and Select For? Here is a list in order of priority for herbaceous or woody perennials:
Ease of Propagation. This is essential right off the bat. If you can't propagate it, it will always struggle to take off as a commercial product, no matter how pretty it is.
Flower Size. Bigger flowers are generally better but not always if there are a lot of them, so generally overall flower cover is important. It should pass the 90 mile per hour test — i.e., it should catch your eye if driving past at high speed!
Flowering Period. Longer is better, particularly if flowering at times of the year when other things are not — mid winter is good! Plants that flower for only 2 weeks of the year, as stunning as they may be for their 2 weeks, have minimal appeal for the 50 weeks of the year when they're not in flower!
Good in a Pot and Good in the Ground. This is surprisingly not always the case for both. Some plants do very well in containers but fail dismally when planted in an open bed situation, and others that do very well in the open ground can sometimes make very weak and unshapely pot plants.
Habit. Neat and compact is generally better than long and lanky.
Drought Tolerance. In South Africa which is generally considered an arid country this is very important, particularly with the trend towards waterwise gardening. So, the more the better.
Nice Foliage. This is especially when not in flower.
Good Branching. This is better than sparse and twiggy.
Not Deciduous or Having "Off Periods". A bare twiggy leafless shrub will not sell in a nursery.
3. A Good Seed Bank of Wild Seed Is Essential. This will have the highest variability of traits. Seed originating from unknown horticultural origins is usually genetically very limited, and often has gone through a genetic bottleneck at some point resulting in homogenous or inbred plants. One could manually harvest vegetative cuttings of forms of wild plants too, but cuttings generally have less vigour than seedlings and to collect a thousand genetically different plants is somewhat impractical.
4. A Trial Ground. Preferably not in the Natal midlands or in Contsantia, actually the harsher the conditions the better. If something performs well under unfavourable and highly selective conditions, the better chance it has of doing well in a domestic garden. Examples of conditions to look for in a trial ground are:
- Poor soils.
- Strong winds.
- Extreme temperature variability (preferably freezing on occasion).
- Low moisture, etc.

These are all good conditions for doing selections. Often what grows well in a Kirstenbosch glasshouse is not necessarily going to thrive out on the Cape Flats or in Wellington, or Upington for that matter.
5. Sow and Germinate Your Wild Seed. Just selecting the first 1,000 that germinate out of 10,000 is already a selection for easy-germinating forms (Fig. 1).

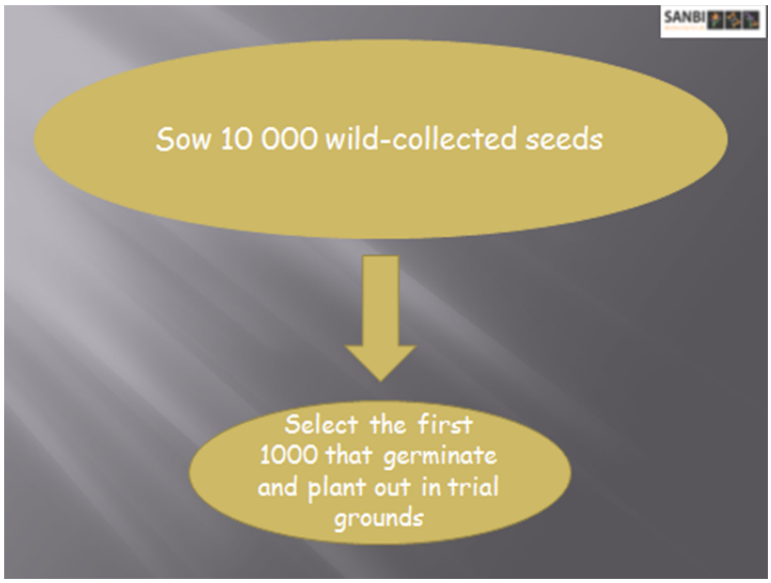

Fig. 1. Ornamental plant breeding — starting the process.

Plant them out in your prepared trial ground, well spaced and in manageable rows (Fig. 2).

Fig. 2. Planting out the first 1,000 selected seedlings.

Use flags of different colours to flag plants with good traits, i.e., first to flower from seed, good flower size, good habit, etc. Drip irrigation is better than overhead watering — it minimizes weed growth and saves having to use herbicides. However, hold back on the irrigation to test for drought tolerance. Those that produce better tap roots will probably survive better.

6. Based on the Flagged Selections of Your Initial 1,000 Plants, Select No More than about 20 of the Very Best Individuals (Fig. 3). It will be tempting to select more but any successful plant breeder will tell you that the secret to success lies in getting rid of the runts! These 20 are all now superior in some way over your remaining plants.

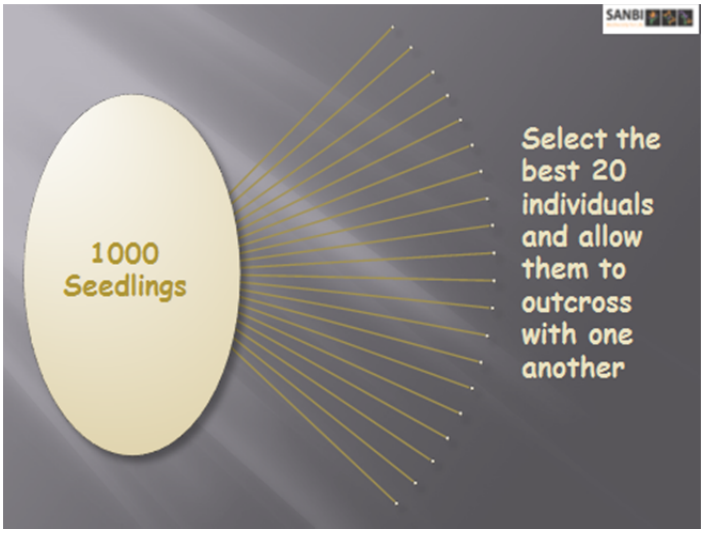

Fig. 3. Making the first selection of the best 20 plants.

7. Now, Bring Your 20 Plants into Close Proximity and Let them Mass Cross Pollinate and Set Seed, Either Naturally or by Hand Pollination. You may need to propagate these plants and grow them out again side by side in order to do this (Fig. 4). The reason we chose a reasonably big group of 20 is that you lessen the risk of inbreeding depression later on. These again will be very distant cousins.

8. Harvest This Now Genetically Improved Seed and Start Your Process All Over again.

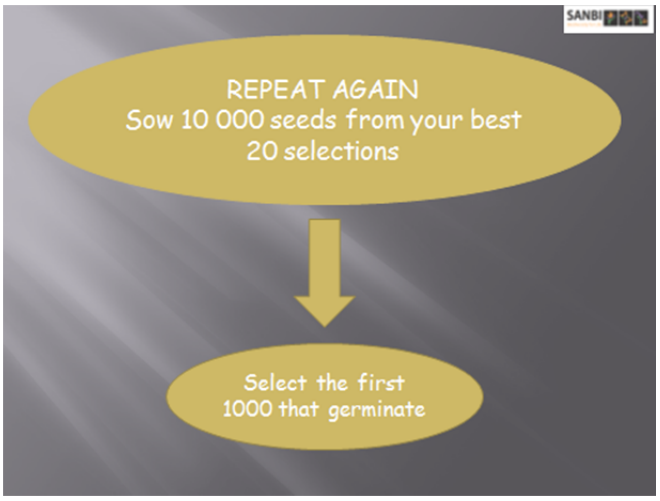

Fig. 4. Repeating the process over again for the second time.

Sow your seed, plant out your first thousand germinating seedlings in your trial ground and through the same selection process flag the next best 20 individuals (now significantly better than your originals). Discard all the unwanted plants and repeat the pollination process amongst this selection of 20 and harvest their seed.

9. Now Repeat the Process All Over again for the Third Time. Sow your seed and plant out the first thousand germinating seedlings; flag them in just the same way as before. These should all look substantially more improved upon than your original crop.

10. Now, Carefully Select Your Very Very Best Individual which Incorporates All the Characters You Are Looking for Good Flower Colour, Good Habit, Good Flowering Period, Good Drought Tolerance, etc (Fig. 5). This plant should be significantly better than what you had to start with, yet at the same time could quite easily have naturally occurred in the wild.

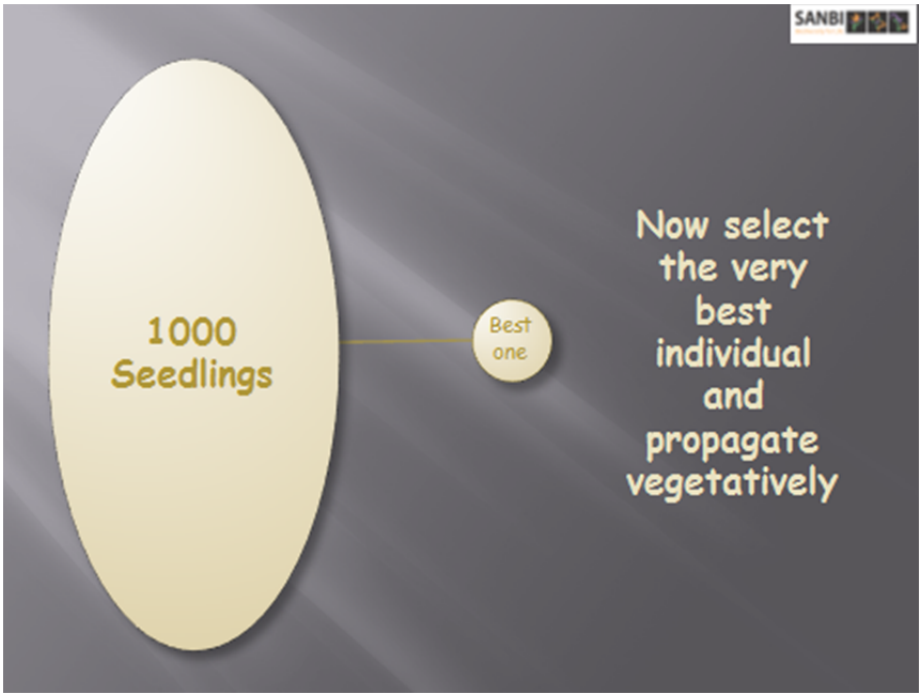

Fig. 5. The end of the process with selection of the best individual.

11. Propagate your plant with sterile implements and produce a number of clean mother stock plants, preferably kept in two or more different geographic locations to prevent viral cross contamination infection.

The following three images show a *Petunia* selection trial in California (Fig. 6) and a *Selago villicaulis* selection trial (Fig. 7) and final very best *Selago villicaulis* selection (Fig. 8) at Kirstenbosch Botanical gardens.

Fig. 6. Comparative trial grounds of *Petunia* selections in California, USA.

Fig. 7. Trials of *Selago villicaulis* at Kirstenbosch Botanical gardens.

Fig. 8. Selected ornamental winner *Selago villicaulis* ‘Purple Turtle’.

South Africa has over 20,000 plant species, about 10% of all the plants on earth, many of which have ornamental value. There is huge potential in this country to develop our indigenous flora locally before it gets plundered by abroad. This simple guide will hopefully stimulate more activity in the local floriculture industry and hopefully will be improved on by future growers and breeders.

The Use of *Meta*-Topolin as an Alternative Cytokinin in the Tissue Culture of *Eucalyptus* Species©

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***Meta*-topolin (*m*T) is a relatively new cytokinin isolated from poplar leaves in 1975 and is closely related to 6-benzyladenine (BA). Research on the use of *m*T in tissue culture has been conducted on several species, including *Hypericum*, citrus rootstock, *Aloe*, banana (*Musa acuminata*), pineapple (*Ananas comosus*), and *Barleria*. 6-Benzyladenine (BA) is the most widely used cytokinin in the regeneration stage of the tissue culture of most plant species, because of its availability and price, but it has a few drawbacks which include causing the hyperhydricity (vitrification) of shoots and it can have a negative effect on rooting. In light of this a series of trials were initiated to determine the effect of *m*T on the regeneration, hyperhydricity, and rooting of *Eucalyptus* species. In the initial trial various concentrations of *m*T (ranging from 1.2 to 14.5 mg·L^{-1}) were tested with the resulting shoot growth compact and stunted. In a follow-up trial, a *m*T concentration of 0.2 mg·L^{-1} was found to produce shoots that were less vitrified and that resulted in better in vitro rooting. Further trials on rooting of other eucalypt species are in progress to determine the benefits of *m*T.**

INTRODUCTION

In the in vitro propagation of plants a high cytokinin:auxin ratio is typically used to induce multiplication or regeneration (Murashige and Skoog, 1962), but the types and concentrations of auxins and cytokinins used vary between species (Niedz and Evens, 2010). The cytokinin most widely used is 6-benzyladenine (BA) or otherwise known as BAP (6-benzylaminopurine) because of its availability, effectiveness and affordability (Bairu et al., 2007). This cytokinin has a few drawbacks such as causing the hyperhydricity (vitrification) of plant shoots and can also have a negative effect on rooting in some species. In research conducted with *meta*-topolin (*m*T) these negative effects have not been evident (Meyer et al., 2009; Bairu et al., 2007). Alternative cytokinins include kinetin, zeatin, or thidiazuron (TDZ) and their use depends on the species propagated. The choice of cytokinin is determined by the cumulative efficiency in inducing an acceptable rate of multiplication, normal shoot and root development as well as ease of acclimatization. *Meta*-topolin is a relatively new cytokinin isolated from poplar leaves in 1975 and is closely related to BA (Strnad et al., 1997; Teklehaymanot et al., 2010). Meyer et al. (2009) found that *m*T is twice as effective as BA in the induction of shoot cuttings. Hyperhydricity usually increases with an increase in cytokinin concentration. When comparing BA with *m*T, no hyperhydricity developed in the shoots and higher multiplication rates were obtained. Plants also rooted spontaneously in the multiplication media (Bairu et al., 2007; Meyer et al., 2009). When *m*T was used in the multiplication of banana, superior multiplication rates were recorded (Bairu et al., 2008; Escalona et al., 2003). Research on the use of *m*T in tissue culture has been conducted on several species, for instance *Hypericum* (Meyer et al., 2009), citrus rootstock (Niedz and Evens, 2010), pineapple (Teklehaymanot et al., 2010), and *Barleria* (Amoo et al., 2011).

Research by Bairu et al. (2007) showed the effect of different cytokinins on the ex vitro growth of *Aloe polyphylla*. The addition of both 2.5 and 5.0 µM *m*T (0.6 and 1.2 mg·L^{-1}, respectively) to full strength Murashige and Skoog medium (MS) gave better growth and root formation than with BA and Zeatin.

MICROPROPAGATION OF EUCALYPTUS SPECIES

Benzylaminopurine is the standard cytokinin used for the propagation of several *Eucalyptus* species. When using a protocol developed by Jones and van Staden (1994) for

Eucalyptus grandis × *E. urophylla* (GU) with BA as the cytokinin, hyperhydricity developed in the shoots (Fig. 1a), which resulted in low survival and rooting (±40%). Since *m*T has been extensively studied at the University of KwaZulu-Natal, attempts were made to test this product to alleviate shoot vitrification. A trial was conducted to determine the effect of *m*T on the regeneration, hyperhydricity, and rooting of GU hybrids. The concentrations of *m*T tested in the initial trial were 1.2, 2.0, 6.0 and 14.5 $mg \cdot L^{-1}$ in full strength Murashige and Skoog (MS) (Murashige and Skoog, 1962) basal medium, supplemented with 20 $g \cdot L^{-1}$ sucrose, 0.01 $mg \cdot L^{-1}$ α-naphthalene acetic acid (NAA), and 8 $g \cdot L^{-1}$ agar, with a pH of 5.8. Plants were kept in a 16-h light and 8-h dark photoperiod under cool white fluorescent lights. The resulting shoot growth was compact and stunted on all concentrations tested. In a follow-up study the concentrations of *m*T were significantly reduced and 0.2 $mg \cdot L^{-1}$ was determined as the optimum concentration for multiplication (Fig. 1b).

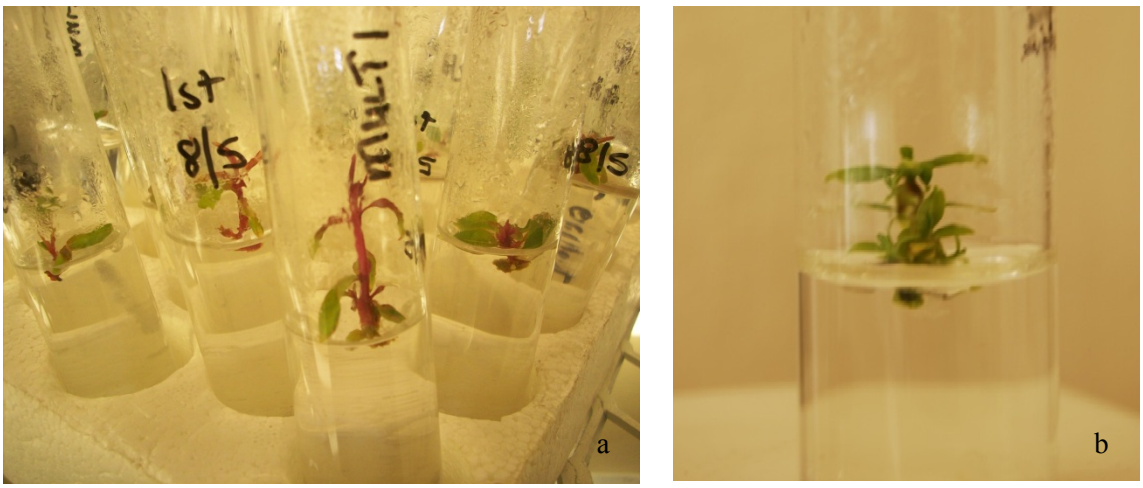

Fig. 1. Multiplication of *Eucalyptus grandis* × *Eucalyptus urophylla* hybrids on (a) MS medium supplemented with 2.0 $mg \cdot L^{-1}$ BA and (b) Murashige and Skoog medium supplemented with 0.2 $mg \cdot L^{-1}$ *meta*-topolin.

The shoots obtained from the second trial were transferred to rooting medium consisting of half strength MS salts, 0.2 $mg \cdot L^{-1}$ IBA (indole-3-butyric acid), 20 $g \cdot L^{-1}$ sucrose, 10 $g \cdot L^{-1}$ activated charcoal and 8 $g \cdot L^{-1}$ agar. A 20% increase in rooting was obtained (±60-80%) with the use of *m*T in the multiplication medium instead of BA (data not shown).

The rooted shoots also acclimatized very well with a 90% survival rate after it was planted in a pine-bark medium, closed with plastic. After the first week, the plastic was gradually removed in a greenhouse with high humidity (±75%) and bottom heating. As the plants acclimatized they were moved to a lower humidity.

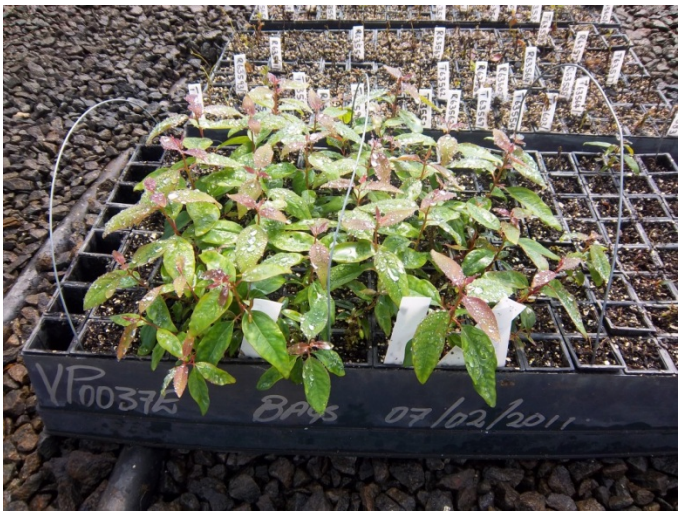

Fig. 2. Well-developed, acclimatized, rooted *Eucalyptus grandis* × *Eucalyptus urophylla* plants after *meta*-topolin was used as the cytokinin source during in vitro multiplication.

The same protocol was also applied to a temperate *Eucalyptus* species, *E. dunnii*, with similar results (Figs. 3). The higher *m*T concentration (1.2 mg·L^{-1}) caused compacted and stunted growth, while well-developed plants were obtained using the lower *m*T concentration of 0.2 mg·L^{-1} *m*T, with no apparent hyperhydricity (Fig. 3a). After 5 weeks in culture shoots grown on 0.2 mg·L^{-1} *m*T were well developed and normal in appearance (Fig. 3b). The rooting trials of with this species are not yet completed.

Fig. 3. Multiplication of a temperate *Eucalyptus* species using (a) 0.2 mg·L^{-1} *meta*-topolin (*m*T) (left) and 1.2 mg·L^{-1} *m*T (right), and (b) 0.2 mg·L^{-1} *m*T.

A major problem with the use of alternative cytokinins is their affordability. The prices and possible suppliers of various cytokinins are given in Table 1.

Table 1. Comparison of cytokinin prices as at April 2013.

Cytokinin	Supplier	Price/g (R)
Benzylaminopurine (BA)	Sigma-Aldrich	330
Kinetin	Sigma-Aldrich	925
Zeatin	Sigma-Aldrich	53,000
Thidiazuron (TDZ)	Sigma-Aldrich	43,300
meta-Topolin	Duchefa (Labretoria)	7,500

The most affordable cytokinin is BA, but for *Eucalyptus* propagation, use of *m*T at 0.2 $mg \cdot L^{-1}$ was more efficient than the use of BA at 2 $mg \cdot L^{-1}$ (Table 2). At this rate *m*T is only approximately double the price of BA and much less than that for zeatin and TDZ. Trials to test the efficacy of kinetin have not been conducted since several researchers have indicated that kinetin cannot be used continually for successful in vitro propagation of *Eucalyptus* species.

SUMMARY
With the production of plants through tissue culture, the quality of the shoots obtained is extremely important as this determines the ability of the shoots to be rooted and acclimatized effectively. Although *m*T is more expensive per gram than BA, the quality of the plants is better and consequently better rooting can be obtained. Further trials on rooting of the temperate *Eucalyptus* species are in process to determine the most effective protocol.

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Plug and Liner Production: Are You a Grower or Manufacturer?©

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Profitable production of young plants (seedling plugs and rooted cuttings) requires consistency, efficiency, and tracking of costs and revenue. Uniform quality across a tray, shipment, and over time is demanded by a market place that is characterized by increasing competition and tight profit margins. The artisanal perspective of horticulture has given way to plant factories, as economies of scale push young plant production towards highly specialized and mechanized operations. However, the requirement to minimize waste in terms of crop losses, or inefficient use of labor, space or materials, applies equally to large and small businesses.

Young plant production involves a series of processes in common with manufacturing in other industries, which include inventory control of inputs (trays, substrate, fertilizer, etc.), assembly (filling trays, sticking cuttings, or sowing seed), material transport (placement in the greenhouse), quality control (patching or fixing trays), order pulling, and shipping. Growing (irrigation, climate management, height control, fertilization, etc.) is the least standardized part of young plant production. However, even with growing processes, well-defined and standardized crop plans are more achievable in propagation than with most other horticulture products, because multiple crops are grown each season with short production times.

This paper discusses three areas of important focus to help young plant growers move from art to manufacturing in their production. These are identifying sources of crop losses, understanding costs, and identifying opportunities to increase efficiency in production processes.

SHRINKAGE

Shrinkage refers to any reason a plant product is started but is not successfully sold. During January to June 2010 (spring season in the USA), a survey was conducted of 11 greenhouse operations producing at least $1 million in sales of young plants. After an initial discussion with each grower on how they tracked shrinkage, crop losses were separated into three broad categories. These included:

Internal Production Losses

The product is grown but is not of saleable quality. This may arise because trays are only partially filled (from patching of incomplete trays or having to purchase a minimum unrooted cutting order size that is not divisible into complete trays), poor germination or rooting, disease or insect damage, chemical damage, or other reasons that crops were not to market specification such as excessive height.

Unsold Product

The product is successfully grown but cannot be sold. This may result from cancelled orders, speculation miscues, or planting excess buffer to account for possible crop losses.

Credits on Shipped Product

The product is sold, but the customer demands a credit. This may occur from shipping damage during shipping, heat, or cold; the customer may find the plant quality unacceptable; or the wrong cultivar may have been shipped.

Figures 1 and 2 show the results of the shrinkage survey. Internal production losses contributed the largest category of losses, followed by unsold product and credits or other unspecified losses (Fig. 1). Losses were higher on young plants compared with finished plants, which occurs because seedlings and cuttings are the most vulnerable crop stage,

susceptible to disease and physiological problems. Surveyed growers also indicated that their finished plant customers were tending to order young plants later in the season, based on how their own sales are progressing and to manage their own risk, which increased speculation losses (unsold product) for their supplier of young plants.

Businesses varied widely in the type and level of shrinkage (Fig. 2). Company "1" sold young plants to another profit center of their own business. Therefore, sales forecasting was more reliable, product was not shipped long distances reducing credits, and the speculation loss was passed from the young plants to finished plant sales. Company "2" grew young plants mainly on contract to another grower, thereby passing along speculation costs to their customer. The high level of production losses at Company "3" indicated a need for improved growing practices. Losses at Company "8" were dominated by the unsold product category, indicating over-speculation and the need to better match production levels to the market.

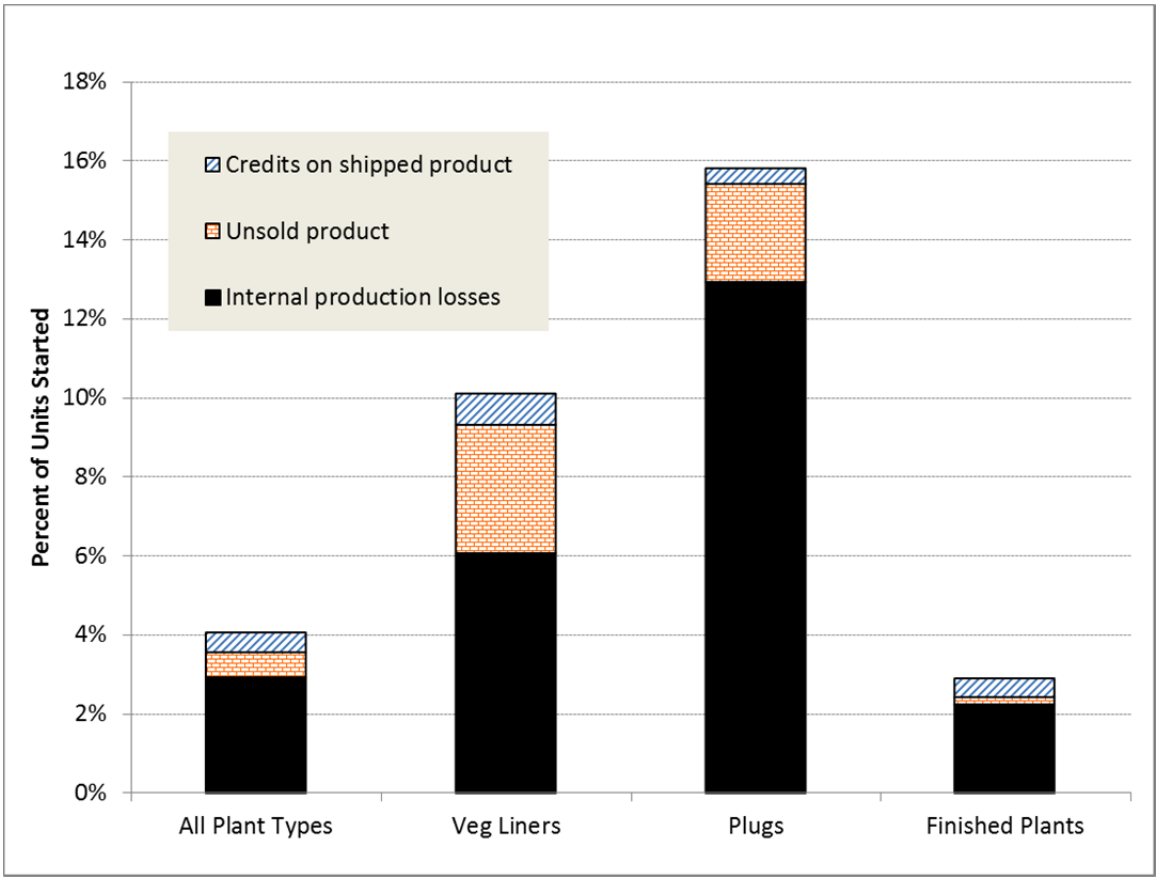

Fig. 1. Results of a survey of 11 young plant growers on the value of several categories of shrinkage in their young plant and finished plant products during 2010.

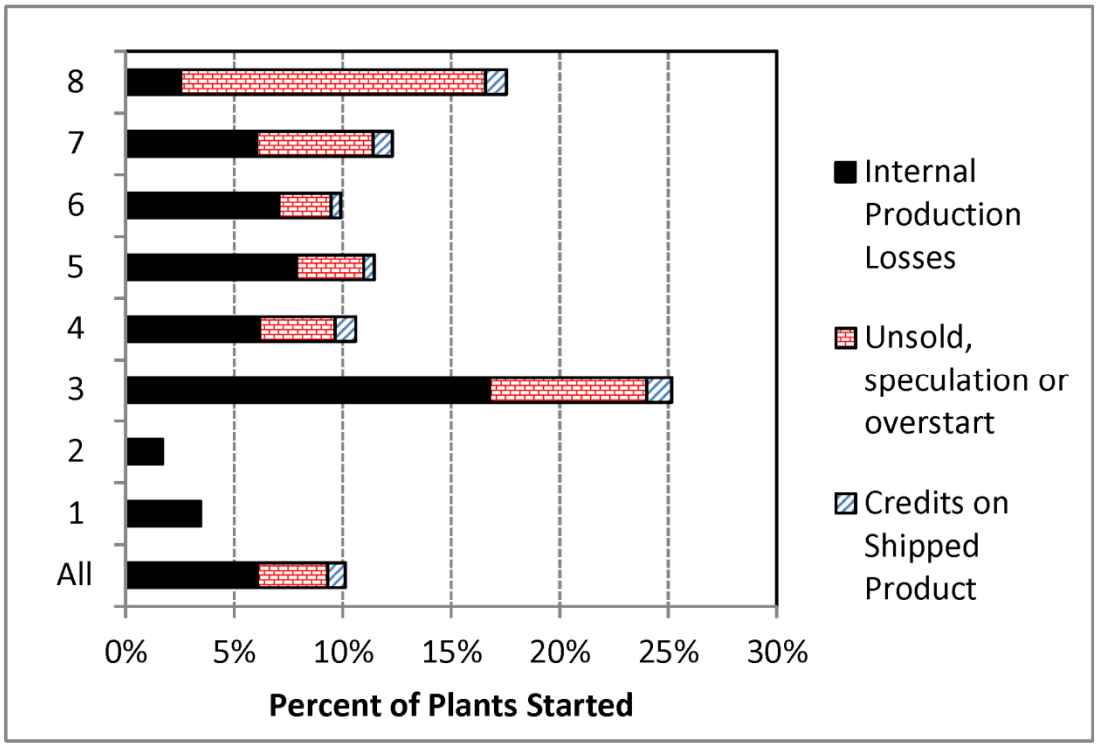

Fig. 2. Individual results for crop losses for eight growers producing rooted cuttings surveyed during 2010.

The observed variation between companies in Figure 2 emphasizes that each business needs to track its own shrinkage in order to provide the management team with a clear focus for areas of improvement. In some successful businesses in the survey group, the grower and sales management staff collectively identified annual target levels of shrinkage and required actions for the coming season.

With the economic recession since 2007, young plant growers have reduced speculation planting, and provided incentives for customers to place orders early in order to reduce risk. Product assortment is also important to reduce speculation losses and production cost per unit, although many growers find it difficult to drop minor value crops to allow production of fewer, more profitable products. As Healy (2012) states, "By aggressively dropping low performing varieties, you create space for new varieties to grow your business."

EFFICIENCY ANALYSIS

On the production side, tightening up monitoring and control of production procedures allows the grower to reduce shrinkage. For example, improved germination or rooting percentage decreases the required buffer of extra plants that must be started to cover future losses. The steps to improve efficiency in any process such as sowing are to monitor the activity using a quantitative measure such as trays sown per hour or germination percentage, identify target levels, investigate root causes when targets are not met, and then take appropriate actions (Healy, 2012). Benchmarks are not widely available or shared across businesses, but can be developed as internal targets within a company over time. Efficiency measurements may include shrinkage percentage, or units processed per worker hour, per machine, per square meter, per square meter week, or direct and total production cost per unit.

Increasing numbers of USA growers are incorporating manufacturing concepts such as lean flow into production processes, particularly the initial stages up to moving plants into

the greenhouse or germination room (stage 0), and shipping. “Lean” considers that resources expended for any goal other than the creation of value for the end customer is wasteful, and thus a target for elimination. “Flow” refers to a smooth progression through stages in the production process. An internet search on lean flow manufacturing is an excellent starting point, followed by hiring of a specialized consultant if major changes are considered (Eddy, 2012).

Although repetitive tasks often undertaken by a supervisor and team of workers, such as fixing trays or pulling orders lends itself to standardization, growing itself will always have a subjective (art) component. For growing tasks, efficiencies can be gained from educating production and growing staff, and documenting crop plans. The most critical aspect of growing is irrigation, and training on a five-point plug-tray moisture scale has been very successful to standardize irrigation practices (Healy, 2008).

COSTING

We developed a series of articles (Fisher et al., 2012a, b, 2013a, b) to help young plant growers calculate production costs and profitability. A first step is to evaluate the annual income statement to differentiate between (1) direct input costs (pot, cutting, label, sleeve, etc.) that increase with every additional unit produced, (2) labor costs (production, shipping, sales, and management), and (3) overhead costs such as marketing, insurance and utilities that are difficult to assign on a per unit basis. In our survey of eight young plant growers in 2006, costs were evenly divided between these three cost categories (direct, labor, and overhead).

In an enterprise budget, such as shown in Table 1, it is easy to calculate direct costs that increase with each additional container produced. It is more challenging to allocate overhead costs, which is usually done on a square meter weeks basis for greenhouse production. An example calculation for overhead cost per square meter week is shown in Table 2, where the annual overhead cost (from the income statement) is divided by the number of square meters used in production throughout the year. Labor costs can be included with overhead costs and allocated on a square meter week basis, particularly for labor categories such as management, facility maintenance, growing, and sales. Alternatively, a more detailed analysis of the production labor required for processes such as filling pots, planting, moving, pinching can be quantified and treated as a direct cost.

There are many ways to develop budgets and allocate overhead, and it is not essential that all growers use the same procedure. However, the key point is that growers must calculate their production costs in order to make informed management decisions. For example, the comparison of two plug sizes in Table 1 shows that although the direct costs are lower when transplanting from a small plug size (392 plugs per tray), the larger 128-count plugs have lower total cost and higher profitability for finished production because of a shorter time after transplant. Because space and time are limiting resources during peak spring production, a trend in young plants in the USA has accordingly been towards production of larger plug sizes, allowing multiple turns of short term crops, and greater net revenue per square meter week.

Table 1. Enterprise budget for an 11-cm-diameter container of Wave® petunia grown from two plug sizes.

Plug size	392-count tray	128-count tray
Plug cost	$0.15	$0.26
Media, pot, tag	$0.10	$0.10
Total direct cost	$0.25	$0.36
Sales price	$1.25	$1.25
Profit/pot	$1.00	$0.89
Spacing between pots (cm)	20	20
Area/pot (m^2)	0.04	0.04
Weeks	6	4
Square meter weeks (smw)	0.24	0.16
Overhead cost per smw	$3.30	$3.30
Overhead cost	$0.79	$0.53
Profit/pot	$0.55	$0.59
Profit/smw	$2.29	$3.69

Table 2. Calculation of overhead costs per square meter week.

Factor	Calculated amount
Salaried staff…	$3,300,000
Fuel, electrical, water…	
Depreciation, interest, insurance...	
Greenhouse bench space (m^2)	20,000
Weeks per year in production	50
Total square meter weeks	1,000,000 (=20,000 * 50)
Overhead cost $/square meter week	$3.30 (=$3,300,000/1,000,000)

CONCLUSION

This paper described several areas of potential improvement in tracking losses, increasing efficiency and uniformity, and tracking costs. When evaluating adopting new management procedures, although it is not possible for everything to be done at once, something can be done at once. Growers are encouraged to choose at least one action that helps move the production philosophy from growing to manufacturing.

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Attention to Detail Is a "Not Negotiable" for the Production of *Pseudopanax* Hybrids from Cuttings©

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BACKGROUND

Pseudopanax taxa are extremely popular woody native plants and commonly used in New Zealand amenity plantings. The main appeal of these taxa is their very varied, often unusual, leaf shapes (Figs. 1). Commonly they have varying shades of green leaves but some hybrids have purple/brown leaves (Fig. 2). One cultivar, *Pseudopanax lessonii* 'Gold Splash', has variegated green and yellow leaves giving a mottled effect.

Fig. 1. A. A juvenile *Pseudopanax ferox* plant on the left with the right plant showing adult leaves on the top. B. A closer view of the adult on the top of the plant.

Fig. 2. This dark coloured plant is probably a *Pseudopanax lessonii* × *P.* (Adiantifolius Group) 'Adiantifolius' hybrid.

A range of *Pseudopanax* hybrids was introduced by Duncan & Davies, New Plymouth. Widely used and among this range are:

- *P.* (Adiantifolius Group) 'Adiantifolius' (*P. lessonii* × *P. crassifolius*)
- *P.* (Adiantifolius Group) 'Cyril Watson' (*P. lessonii* × *P. crassifolius*)
- *P. lessonii* (syn. *discolor*) 'Rangatira'
- *P.* 'Purpureus' (*P. lessonii* × *P. discolor*)
- *P. lessonii* 'Gold Splash'

Pseudopanax lessonii 'Gold Splash' (Fig. 3) originated from a cut back stump in the garden of Trevor Davies sometime around 1969. It was finally released for sale in 1978. It is interesting to note the time frame of 9 years in development here, as only with extremely careful management of stock plants and very selective cutting collection was this commercial release made possible.

Over the following years at times it has been noticeable that the true forms of these cultivars have been compromised by poor wood selection, with either weak quality cutting material or poor selection of form.

Fig. 3. *Pseudopanax lessonii* 'Gold Splash'.

"NOT NEGOTIABLE" PLANTS

Many native New Zealand cultivars fall into a group of plants I call "Not Negotiables."

These are plants that provide only a very small window of opportunity for cutting collection. Extra care with timing and wood selection is imperative for cutting success. All have only one or sometimes two growth patterns naturally per year. Recognising and reading these patterns is essential for successful cutting collection. Only strong, healthy, true-to-type cuttings should be selected.

Other native woody plants included in this "Not Negotiable" group with the same rigid requirements are *Sophora*, *Pittosporum*, *Metrosideros*, and *Podocarpus*.

CUTTING PRODUCTION

Requires the following skills:

- Observation
- Attention to detail
- Planning
- Knowing the "little things that add up"

Reference books tell us that to produce *Pseudopanax* from cuttings you require "soft to firm semi-hardwood cutting, March-April, hormone."

Let's peel back this information and apply the required attention to detail with:

- Stock plant management
- Timing of cuttings
- Wood selection
- Setting and aftercare

Stock Plant Management
What we finally require are tip cuttings which are:
- Terminated
- Semi-hardwood
- Strong and healthy
- True to type

Timing of Cuttings
Pseudopanax taxa have a natural growth pattern twice a year in the north of New Zealand.
- Spring – giving cutting wood Oct./Nov.
- Dec/Jan giving cutting wood Apr./May

Being woody plants it is easier to maintain good strong stock plants if you can feed and trim working with these natural growth patterns.
1. Stock Plant Age. Maintaining strong young stock is also essential. Good rooting percentages can be maintained until the stock plant is approximately 5-6 years old when percentages fall away.
2. Trimming. *Pseudopanax* have a ring of buds at the base of the last growth made. Trim leaving these buds in place. Trim just above the node or you may experience dieback in your plants (Fig. 4). The resultant growth from this will give you multiple breaks i.e. cuttings (Fig. 5). If you trim back to one stem bud you may get only one cutting (Fig. 6).

Fig. 4. A single break from cutting at a single bud.

Fig. 5. Cutting selected wood.

Fig. 6. Trimming to just above a ring of buds results in multiple breaks.

Wood Selection — the Cutting
We require:
- Semi-hardwood
- Terminated tip growth
- Nodal
- Light wounding

Setting and Aftercare
This is where the "little things add up."
- Well drained mix.
- Cuttings must be firm in the mix, not easy to firm if cells are being used as the cuttings are quite large in diameter.
- Space cuttings to give air movement.
- Hormone approximately 0.3% IBA.
- Water in well to settle the cuttings.
- Bottom heat 22°C.
- Mist — don't saturate the mix.

POINTS TO REMEMBER
To achieve a quality *Pseudopanax* plant you must be able to select a strong, true-to-type, terminated, semi-hardwood, tip cutting. This cutting will give you the basis to produce a quality, bushy plant. Managing and often renewing your stock plants to produce quality material is imperative.

Remember, to grow roots on a cutting is one thing, to produce and sell a quality plant is quite another, and this can only be achieved with:
- Attention to detail in managing your stock plants.
- Selecting only healthy, true-to-type cutting material.

Commercially Usage of Geothermal Energy for Growing *Gerbera* in Rotorua©

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For more than 10 years Connie and Harald Esendam from PlentyFlora have been making use of geothermal fluid to heat their 2,688 m² glasshouse used to produce *Gerbera* for the New Zealand cut-flower market. PlentyFlora's glasshouse is located on the Central Plateau, where the winter conditions can be very harsh, with an average of 20 to 30 frost days with -8°C (17.6°F) as the lowest measured temperature. *Gerbera* is a subtropical plant originating from South Africa, and requiring a minimum temperature of 14°C (57°F).

Supplementary heating for the PlentyFlora's greenhouse is provided by geothermal energy from two shallow (approximately 300 m depth) geothermal bores. The original bore produces about 70 m³ per 24 h of 100°C (212°F) liquid, while the second bore produces 30 m³ per 24 h of 65°C (149°F) liquid. The two bores are working as two individual heating systems. After passing the energy through a heat-exchange system the fluid is injected back into the shallow geothermal reservoir to complete the re-cycling. PlentyFlora has just completed an upgrade to improve the output of the original bore with the installation of a compressor, which is used to inject air in the bore, enabling an increase in the volume of geothermal liquid produced and so increasing the pipe temperature, inside the glasshouse, from 38°C (100°F) to up to 60°C (140°F). The existing diesel peak-heating system on a fan coil unit, which is forcing hot air on the plants, will now be used as a back-up system only. The new systems will save up to $15,000 in severe winters and will have less of an environmental impact.

Each year PlentyFlora produces, from 14,000 plants, around 600,000 *Gerbera* cut-flowers of both the standard diameter size (10-13 cm) as well as the mini-size (7-9 cm). Seventy different cultivars are grown, representing four categories of Standards with black and light centres and Minis with dark and light centres. The plants are hanging in custom designed, self-made tables at convenient heights in accordance with the latest cut-flower growing technology from The Netherlands. The climate control and the nutrient control systems are fully computerised so the flowers receive the appropriate water and fertiliser, depending on requirements. The gerbera daisy flowers are harvested by being pulled out rather than cut. They are sleeved straight after picking, boxed and sent directly to 60 florists, two wholesale companies, and two auction houses in the North Island.

Breeding *Clivia*©

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BACKGROUND

The first things needed in the fundamentals of plant breeding, in my opinion, is to have a passion for what you are doing and an enjoyment of working with the particular plant group you have chosen. Secondly, know your topic. Have some knowledge of the where, how, and why the plants you have chosen grow where and the way they do. Once you have a background to your topic you will need some mature stocks that are flowering. This is the time to go hard and try anything, have an idea of what you think you want to achieve but try all combinations and see what results occur from a little experimenting. The final product may be amazing or a complete failure, but whatever happens at least you will have given it a go.

CLIVIA SPECIES

The genus *Clivia* is a relatively small group in the plant kingdom, consisting of six species from Southern Africa. Most grow in the east of Southern Africa from Port Elizabeth up to Mozambique. Only one species and the last to be discovered, *C. mirabilis*, is from the north western part of South Africa near Namaqualand.

Clivia nobilis

First registered in 1828, it is a coastal species and can be found in semi shade of coastal scrub and forest in dunes of acid loamy soils from sea level to 600 m.

Clivia gardenia

First registered in 1856, this species is found in deep coastal and inland forest in shale or sandstone soils from sea level to 1200 m above sea level (a.s.l.).

Clivia miniata

First registered 1864, it is the most commonly grown and most varied. It can be found in a range of forest types and is the only species found in four of the other species zones from sea level to just above 1500 m a.s.l.

Clivia caulescens

First registered in 1943, it can be found in forests in the sun and shade and quite distinct from most because of its large rhizome and epiphyte habit.

Clivia mirabilis

First registered in 2002, it can be found in high sandstone mountain areas of Nieuwoudtville and Vanrhynsdoorp 850-900 m a.s.l. in shade or sun growing like xerophytic aloes.

Clivia robusta

Although this species was not the last found it was the last registered in 2004. This species was thought to be just a very large form of *C. gardenia* but does grow in quite different conditions, found in grassland and remnant forest normally restricted to swampy terrain from sea level up to 500 m a.s.l.

Fig. 1. This image shows a flower cluster from *Clivia miniata*.

BREEDING *CLIVIA*
Now that we have a little history, where the plants grow, and the types of habitat and soil, we can get into the breeding. Breeding of *Clivia* is like any other type of breeding, it requires male and female parts, in this case the pollen or male part from the anther and a receptive stigma female part. Once we are ready with all the necessary material pollination can begin. The following types of crosses that can be performed over time are:

Self Cross
This is when pollen is used from the same plant as it is to pollinate, the result will be like its parent if it is not already a hybrid.

Intraspecific Cross
This is a cross between the same species but different father/pollen parent and mother/seed parent, the resulting progeny may vary depending on colour of flower, leaf, or plant size etc.

Interspecific Cross
This is a cross between different species and can result in a multitude of different outcomes depending on what has been used.

Backcross
This is a cross from a seedling back on one or other parent, this will normally result in many of the seedlings looking like the parent that has been used.

F_1 Hybrid Cross
This is the first cross between two plants of the same or different species normally producing a very similar sibling seedling.

F_2 Hybrid Cross

This is the next cross on from the F_1 hybrid and can produce some amazing progeny, normally very mixed up.

The following are group names given to artificial interspecific hybrids:

Group Name	**Parentage**
Clivia Caulgard Group	*C. gardenii* × *C. caulescens*
Clivia Cyrtanthiflora Group	*C. nobilis* × *C. miniata*
Clivia Minicyrt Group	*C. Cyrtanthiflora* Group × *C. miniata*
Clivia Minigard Group	*C. gardenii* × *C. miniata*
Clivia Minilescent Group	*C. miniata* × *C. caulescens*
Clivia Minirabilescent Group	*C. mirabilis* × *C. miniata*
Clivia Nobilescent Group	*C. nobilis* × *C. caulescens*
Clivia Noble Guard Group	*C. gardenii* × *C. nobilis*
Clivia Noblemir Group	*C. mirabilis* × *C. nobilis*
Clivia Robmini Group	*C. robusta* × *C. miniata*

With so few species you would think very little can be achieved in hybridizing the various groups but this is not so, as I have found out the results are as varied as the combinations. The fact that all the species have at least two flower colour variants and *C. miniata* with at least five colour breaks means you already have more than twice as many hybrids that can be achieved. Then there are leaf forms and shapes and this is a whole different game that the Asian breeders have been doing since the late 1800s.

Clivia selections with short or variegated leaves are very much the desired result with many named groups/strains arising such as Daruma, Monks, Akebono, and Light of Buddha just to name a few. More for an indoor market, these are also very prized and presented as gifts. In Europe the Belgians have been breeding for the pot culture and probably produce more *Clivia* than any other country. These are grown to flower in 3 years from seed and have a very tulip-shaped flower.

The Africans, Americans, New Zealanders, and Australians have bred more for the garden and gone for a wide colour range in a range of flower types. Colours such as orange, scarlet, apricot, peach, pinks, yellows, whites, greens, bi-colours, green throats, and picotees, and shapes from the formal *C. miniata* type and pendulous or drooping flower types.

The breeding work I have been doing in more recent years is to see if I can breed a range of plants suitable for cooler and more sunlight conditions, and with a good colour range and medium leaves more suited to the smaller garden. Most hybrids can take anywhere from 4 to 5 years before a flower is seen, so I look forward to every new flowering. The reason for using the various species in our breeding programme is to extend flowering over the year as many of the hybrids will flower out of the normal flowering times of the species.

Interpreting Plant Architectural Design©

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INTRODUCTION

Using examples of both herbaceous and woody perennial plant species, this presentation profiles research focused on plant architecture currently being undertaken at Plant & Food Research. At this time, the primary focus of these investigations is branching. In terms of most crops of interest, but especially those grown for ornamental purposes, the extent of branching directly relates to our ability to deliver plants of high quality, by their visual "fullness" (Funnell, 2011).

Before exploring our recent experiences, it's worth considering a little background information about branching in plants. We accept that plant growth regulators, which naturally occur in plants, effectively control the amount of branching that occurs (Shimizu-Sato et al., 2009). Auxins, one of the key groups of plant growth regulators involved, are produced within the apical buds and developing leaves of plants. Once produced, these auxins are transported downwards within the plant. At the same time, however, cytokinins are often produced by the plant in its roots, and are transported upwards. If we try to keep it simple, the net result of this production and transport of both auxins and cytokinins is that whether or not a bud grows out to become a branch is the net result of the antagonistic effects of auxins and cytokinins (Shimizu-Sato et al., 2009). More specifically, if the amount of cytokinin increases and/or auxin decreases, the net result should be that more branching occurs. While this simple scenario involving auxins and cytokinins is useful to explain branching, recently a family of plant growth regulators called "strigolactones" have been identified as being involved with branching (Gomez-Roldan et al., 2008). Hence our knowledge of how plant growth regulators control branching in plants has become that much more complex. The scientific community's knowledge about how strigolactones are produced and how they work is increasing very rapidly, but on a practical scale, strigolactones are best viewed as inhibiting branching.

HERBACEOUS PERENNIAL

Begonia boliviensis Hybrids

Plant & Food Research has been hybridizing *Begonia boliviensis* for use as a bedding plant and potted patio plant. International sales of cultivars developed to date continue to increase (e.g., 'Nzcone', marketed as Bonfire™), but there is a continued effort to increase and diversify the commercial range of cultivars available. To achieve this diversity, in addition to the breeding programme focusing on obvious attributes such as flower and foliage colour, architectural form has increasingly become a focus.

As evident during the process of making pre-selections of hybrids from the 2012-2013 growing season, a repeating theme of architectural form became evident. Those plants selected for their architectural form could be related to their adherence to the "Golden Mean" wherein the relative proportions of height, width, and depth approached the ratio of 1 to 1.618 (Sachs et al., 1976). While an important contributor to achieving these proportions was the overall plant height, as influenced by node number and internode length, the frequency of branching was also found to be a key determinant.

Those hybrids making it through the pre-selection process typically had a high frequency of branches arising from existing stems. This trait of high branch frequency being evident from early plant establishment provides us with a clear indication of an inherited trait for which to select, not only to provide plants of aesthetic proportions at point of sale, but also for sustained floral display.

WOODY PERENNIALS

While a key determinant of the architectural form of any woody perennial is the ability of buds to break into growth following completion of winter dormancy, this has not been the focus of our recent research. In contrast, we have focused on the development of branches during the current season of growth, i.e., sylleptic branching. By understanding what mechanisms control whether new branches arise from a leaf axil, we anticipate that we will be better placed to develop techniques for growers to use to control architectural form.

Acer palmatum

During the current 2012-2013 growing season, we have identified cultivars of *A. palmatum* with three different categories of sylleptic branching: free-branching, non-branching, and delayed branching. In addition, we have determined that a representative cultivar of the free-branching category contained comparatively lower concentrations of the branch-inhibiting hormone strigolactone, while the non-branching cultivar contained higher concentrations. This finding therefore supports the notion that strigolactones inhibit branching, and sets the scene for future research to determine techniques that can offer growers some degree of branching control. While hybridization and selection of *A. palmatum* is not part of Plant & Food Research's current activities, the possibility exists that the presence of strigolactones in young seedlings could be used for early selection of hybrids with either free-branched or non-branching traits.

Malus domestica

The establishment of a branching framework in the first season of growth from grafting is an important factor dictating the quality of apple stock. During this first season of growth, two or sometimes three cycles of branching may be evident, where a cycle comprises a period when branches develop, followed by a period where no branches develop from leaf axils. As with the cultivars of *A. palmatum* discussed above, determining what mechanism controls whether a bud in a leaf axil emerges as a branch, is the focus of our current research.

Using plants of 'Royal Gala' that contrasted in strigolactone content, during the 2012-2013 growing season we have been able to confirm that those plants with reduced strigolactone produced a greater number of branches. While these results appear to be in agreement with those for *A. palmatum* discussed above, the fact that the cycles of branching and non-branching still occurred indicates strigolactones do not have sole control over whether a bud develops into a branch. Again however, as part of a breeding programme for apples, the amount of strigolactone present in seedlings may be able to be used as a useful marker for the desired degree of branching.

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Lessons Learnt from the USA Nursery Industry©

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In May of 2012, I was fortunate enough to be able to travel through California looking at the wholesale nursery industry and how it might relate to the industry in New Zealand. My trip was funded in part by a scholarship from the International Plant Propagators' Society — New Zealand Region, and a grant from The Royal New Zealand Institute of Horticulture's Education Trust. I spent close to a month visiting a wide range of growers and retailers in California from San Diego to San Francisco.

Straight away one of the most obvious and common themes from all of the growers I visited was that the industry was generally in a depressed state with lower demand, due to the ongoing recession. This was visible everywhere I went to varying degrees, with growing sites partially bare and abandoned growing sites dotted around the countryside. One of the flow-on effects of a market in an oversupplied state is huge price point competition between companies; with some growers I visited wholesaling a no.1 potted shrub for as low as $2.30, and one of the big box chains selling three, no. 1, potted perennials for $9.99. These prices are so low that they would be completely unsustainable in New Zealand (even though many costs are also lower in the USA), and in fact many growers I spoke to felt they were also unsustainable in the USA. Many were focused not so much on producing profits as they were on surviving and maintaining market share for the time when the industry picks up again. There was concern amongst some producers about the level of market share that the big box stores had obtained and the influence they were able to exert on the industry, as there is from certain sectors within New Zealand, this is of course exacerbated the current oversupply situation. However, everything was not all doom and gloom, with some growers noting an upward trend in recent times, and many were optimistic the worst was behind them. The factors that the more optimistic nurseries had in common were diversity of product lines, access to branded or proprietary product, and the ability to differentiate their product from their competition through price, branding, quality, or other such factors.

Another challenge at an already difficult time was the threat from, and restriction due to introduced invasive pests, and in particular the Asian citrus psyllid (*Diaphorina citri*) and Huanglongbing virus (HLB), and the light brown apple moth (*Epiphyas postvittana*). The complications and costs for those growers located inside the quarantine areas meant that their ability to compete in the market was further affected, at a time when they are least able to absorb those costs. It highlights the importance of biosecurity to the industry, particularly to island nations such as New Zealand, and also serves to further promote the importance of diversity to growers. If your sole income is through the production and sale of citrus plants and you are within a quarantine area, your ability to generate income is severely affected, with few alternatives to fall back on. One way around the problem is to remove your production from the strictest quarantine area, which is what Four Winds Growers has done in developing a new site near Watsonville, California. Aaron Dillon was still in the process of transforming the site when I visited, but they had already installed the insect proof greenhouses with positive pressure entrances to house all of their multiplication and mother stock, in order to comply with new state and federal regulations. All of Four Winds citrus will now be produced from this one site.

One of the key areas I hoped to gain a better understanding of was the use of automation, and the point at which it becomes economically viable to install. One of the problems with many automated systems is that a diverse range of product and smaller production runs decreases the cost effectiveness of the technology. Given that this diversity can be one of the keys to maintaining a healthy company through hard economic times, the use of automation can become a catch 22 situation. Most nurseries I visited were using automation in some small ways, but all expressed an interest and desire to

increase the automation of their nurseries in the near future. The lower labour costs in California compared to those in New Zealand means that automation would be more economically viable in comparatively smaller nurseries in New Zealand than it would be in California, and potentially offer greater cost savings relative to total nursery costs. By far the most automated system I saw was that being used in Floricultura's Salinas orchid production facility. The whole development had been very carefully thought out, and had largely been designed around the pot they had decided to grow in. The 3.7 hectare greenhouse development — touted as one of the most technologically advanced in North America — is built to have an incredibly stable and controlled environment to produce a consistent product, and to take the guesswork out of the timing. The whole greenhouse is controlled from a computer station, and at any point a particular table can be selected and automatically shuffled until it can be picked up by crane and deposited onto a rolling table, that will then place it into a central area where any work can be carried out, all without anyone lifting a finger. The labour savings and other benefits are obvious, as is the expense and capital required to install such a development. Realistically I think automation of this magnitude is a long way from happening in New Zealand, if in fact it ever is. The size of our internal market means that this level of investment would take a very long time to generate positive returns. Even within the USA. I can only see this sort of automation being widely used by predominantly plug and liner growers, or the very large container nurseries in the near future.

ACKNOWLEDGMENTS
I would like to acknowledge the help of the International Plant Propagators' Society New Zealand Region, and The Royal New Zealand Institute of Horticulture's Education Trust for funding that enabled the trip to happen. Thanks also go to Gordon Harada from J.R. Simplot and Cameron Smith from Everiss who kindly spent much time showing me around various nurseries, as well as all of the owners and managers of the nurseries I visited, whose hospitality and openness made the trip so valuable to me.

Pseudomonas syringae pv. *actinidiae*-Virulent Impacts on the New Zealand Kiwifruit Industry©

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Pseudomonas syringae pv. *actinidiae*-Virulent (Psa-V) was first detected in Te Puke in the Bay of Plenty in November 2010. Since then, the disease has spread to most New Zealand kiwifruit-growing regions, affecting 2,256 orchards [Kiwifruit Vine Health (KVH) statistics as of Sept. 2013]. This equates to around 75% of kiwifruit-growing hectares.

Pseudomonas syringae pv. *actinidiae*-Virulent is a gram negative flagellated bacterium (Fig. 1) that can spread through weather, namely wind and rain, and through the movement of infected plants, rootstocks, plant material, contaminated orchard machinery, tools, equipment, and people. It causes disease to kiwifruit vines only, and poses no risk to human or animal health. Some kiwifruit cultivars, such as Hort16A, are more vulnerable to Psa-V than others. However all cultivars are susceptible to the disease. Therefore, best-practice management must be applied to all cultivars, in all regions, to help achieve successful growth in a Psa-V environment.

The Psa-V infection pathway is via natural plant openings such as stomata, lenticels (Fig. 2), broken trichomes, and petiole scars. It can also infect plants through man-made wounds such as pruning, grafting and girdling; and natural plant damage such as wind, frost, and insect damage. Once the disease progresses into the plant vascular system (xylem and phloem) and becomes systemic, there is no cure for Psa-V.

Fig. 1. Magnified *Pseudomonas syringae* pv. *actinidiae*-Virulent.

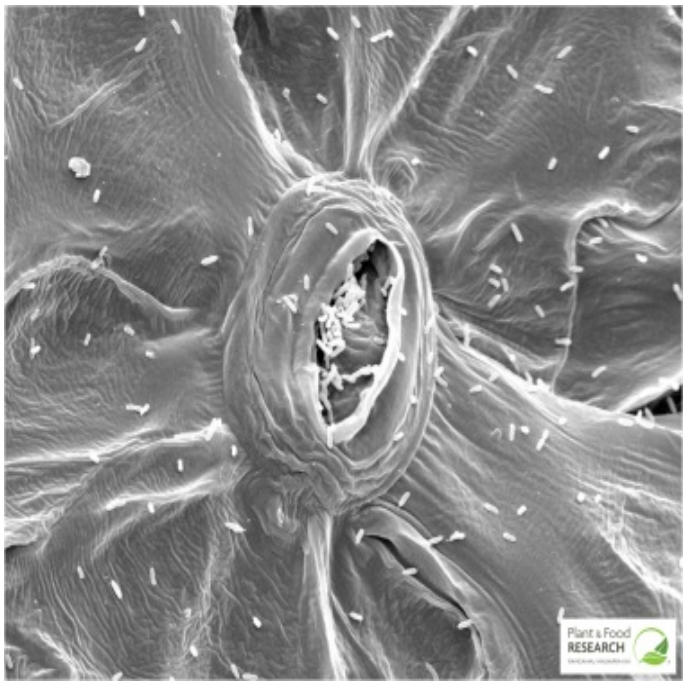

Fig. 2. Magnified stoma and bacteria.

Primary Psa-V symptoms include angular-shaped leaf spots that are often, but not always, surrounded by a halo (Fig. 3). Brown discoloration of flower buds and cane die-back indicate secondary disease symptoms and the advanced stages of infection, produce red and white exudates (Fig. 4) associated with cankers.

Fig. 3. *Pseudomonas syringae* pv. *actinidiae*-Virulent leaf spotting on *Actinidia deliciosa*.

Fig. 4. White exudate is essentially pure *Pseudomonas syringae* pv. *actinidiae*-Virulent inoculum.

GLOBAL EXPERIENCE

Pseudomonas syringae pv. *actinidiae*-Virulent was first identified in Italy in 1992. It is now widespread in the main growing regions of Piedmonte, Veneto, Emilia Romagna, and Lazio. Frost-prone areas have been impacted more severely.

In France, Psa-V was first reported in 2010. Within 2 years around 18% of industry was affected across most regions and multiple cultivars. A different, less-virulent strain of Psa has been recorded since 1989 in Japan. In South Korea, Psa was first confirmed in 1992 where it went on to severely damage the industry. Eight orchards in the Maule region in the South of Chile tested positive to Psa-V. This includes an area of 159 ha of multiple cultivars. Spain, Portugal, and Greece have also reported cases.

Anecdotal evidence is that Psa-V has been present in China for some time.

NEW ZEALAND EXPERIENCE

When Psa-V arrived in New Zealand, it hit rapidly and severely (Figs. 5). It particularly devastated the original Zespri®Gold kiwifruit cultivar, 'Hort16A'. Shortly after the first reported case in Te Puke, KVH was established to lead the industry response to Psa-V on behalf of the New Zealand kiwifruit industry. The industry needed to understand the disease and its impacts on various commercial cultivars, and how to successfully grow kiwifruit in a Psa-V environment.

Fig. 5. Orchards cut out due to Psa-V infection.

A case study carried out by KVH on Te Puke 'Hort16A' orchards (Hardy, 2012) illustrated the impact on orchard productivity for this most vulnerable cultivar. The study followed 57 orchards identified with Psa-V by 2011 harvest (May/June). Only 6 of the 57 orchards made it to the following harvest. Of the 147 ha represented in the case study, almost 127 ha were cut out (Fig. 6). Of the 20.2 ha that were not cut out, the average production was reduced to 31%. Trays harvested from the 57 orchards fell from approximately two million (2010) to 1,600,000 (2011) to 127,000 trays in harvest 2012 (Fig. 7).

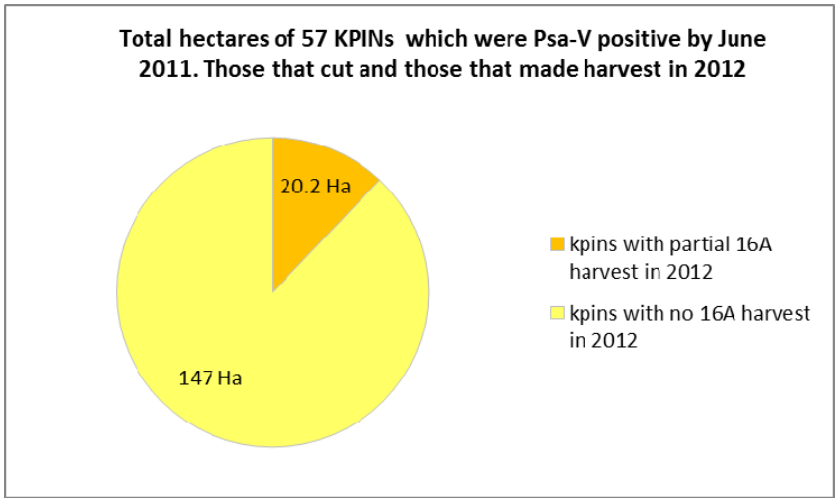

Fig. 6. The impact of Psa-V on the 2012 harvest for the 57 KPINs (Kiwifruit Property Identification Numbers) followed in KVH's 2012 case study.

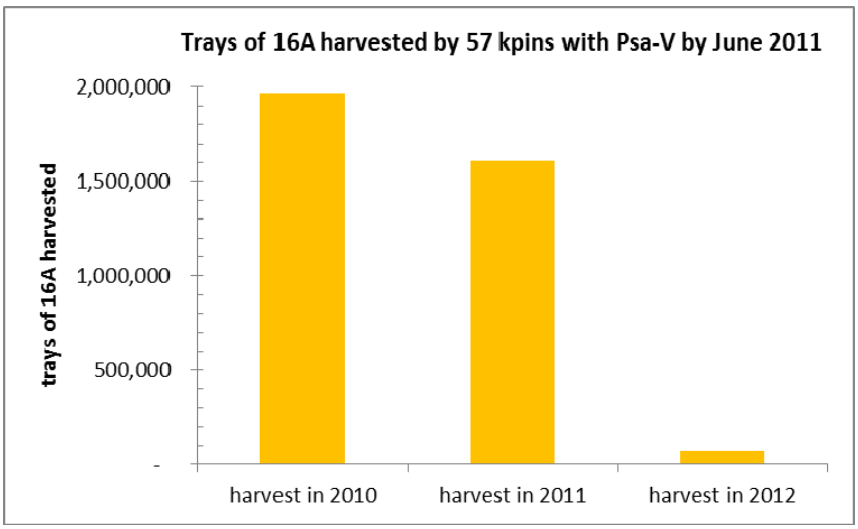

Fig. 7. Orchard productivity fell in 2 years from about two million trays to 127,000 trays for the 57 properties in KVH's case study. Note the numbers shown represent these properties only, not national harvest figures.

The economic impact of Psa-V is huge. Lincoln University Agribusiness and Economics Research unit released an impact report in May 2012, conservatively estimating an industry cost of $310 million through immediate disease impact and $410 million due to response costs. The disease cost in terms of lost development was estimated between $740 and $885 million. Job loss represented a further tier of economic concern.

Eighteen months after Psa-V was first found in New Zealand, the widespread release of 'Gold3', Zespri®SunGold occurred. 'Gold3', a kiwifruit cultivar commercialised in 2010 by ZESPRI, was found to be less susceptible to Psa-V and was identified as the "recovery pathway" for the industry.

At this time, 40% of the country's kiwifruit orchards were recorded as Psa-V positive. Infection levels ranged from low levels of leaf-spot to entire orchards removed due to the disease.

INDUSTRY STEPS TOWARDS RECOVERY

A significant step in the recovery pathway process was taken in 2011/2012 when 1,860 ha of 'Hort16A' were grafted across to 'Gold3'. This represented almost 15% of New Zealand's kiwifruit growing area converting to this new cultivar.

Infected orchards that were originally cut out due to Psa-V, and re-grafted in July/August 2011, had shown an average grafting success of 85% across the group. Individual orchard success rates ranged from 65 to 100%. High levels of site infection, stump dieback, and poor grafting were thought to have reduced success from historical 90-95% graft success rates.

The Zespri Smartkiwi trial set up in summer of 2011 to provide more information about the ability to complete summer grafts on a site exposed to Psa-V inoculum averaged a 96% graft success rate. Some Psa-V symptoms were observed on the new grafts.

In 2012, Zespri Orchard Productivity Centre (OPC) undertook a number of grafting trials and a winter graft-take monitoring survey in Te Puke to establish the success of this industry grafting operation. The monitoring survey showed graft-take tended to be higher (on average 10% higher) on stumps with no obvious Psa-V symptoms.

Lower graft-take was observed on orchards that were cut the season prior to grafting. This suggested stump health may become compromised when left for long periods between cut-out and grafting.

Traditional cleft and kerf grafts outperformed a different "staghorn" graft technique (Figs. 8 and 9). The staghorn technique had been adopted in a bid to reduce cost and time. This method proposed a single junction between scion and rootstock cambium would be sufficient to provide graft takes. However, in practice, blocks using this method required re-graft. This re-emphasised the importance of correct scion placement with alignment of cambium. Scion cambium placed inside the stump cambium lead to graft failure.

Fig. 8. Unsuccessful staghorn graft method.

Fig. 9. Successful kerf graft.

A trial was also carried out to see if Psa-V could spread between kiwifruit vines through the contamination of products used for protecting wounds post-grafting. Transfer was observed, therefore the recommendation was to use a protectant containing a bactericide.

Graft success was also affected by Spring 2012 frosts. Sites where stumps were cut 0.5 m from the ground, to ensure removal of susceptible 'Hort16A' interstock, were most affected.

No significant differences in the rate of graft establishment were observed when different levels of nitrogen were applied on sites with mature stumps.

Young 'Bruno' rootstock expressing white Psa-V exudate was grafted following the removal of infected Hort16A plants was completed. Graft-take was significantly lower

than the industry average, with a 55% success rate. However, suckers grew from a number of these rootstocks and provided a second summer grafting opportunity.

GOING FORWARD

Zespri's breeding programme, through Plant and Food Research, has the challenge of developing a long-term solution for the New Zealand kiwifruit industry. Commercially viable cultivars, with a marked improvement in Psa-V tolerance, are unlikely to be available until 2018. However, cultivars with some improvement may be available by 2016.

To manage Psa-V effectively, the industry must work collectively at an orchard, regional, and national level. To achieve this, KVH developed the National Psa-V Pest Management Plan (NPMP). The NPMP was approved by the Ministry for Primary Industries, and came into effect in May 2013.

Key objectives of the NPMP are to keep Psa-V out of regions where it has not yet been detected, and help lower inoculum levels in Psa-V infected areas (Fig. 10). Under the NPMP, protocols have been formally established to restrict the movement of all high-risk items and help reduce the spread of Psa-V. High-risk items include budwood, nursery stock, plant material, and orchard machinery and equipment. Growers, postharvest, and all those industries associated with the kiwifruit industry will continue to work together to provide the best chance of industry success going forward. Information about best-practice orchard management is available in the KVH Seasonal Management Guide on the KVH website <www.kvh.org.nz/seasonal advice>.

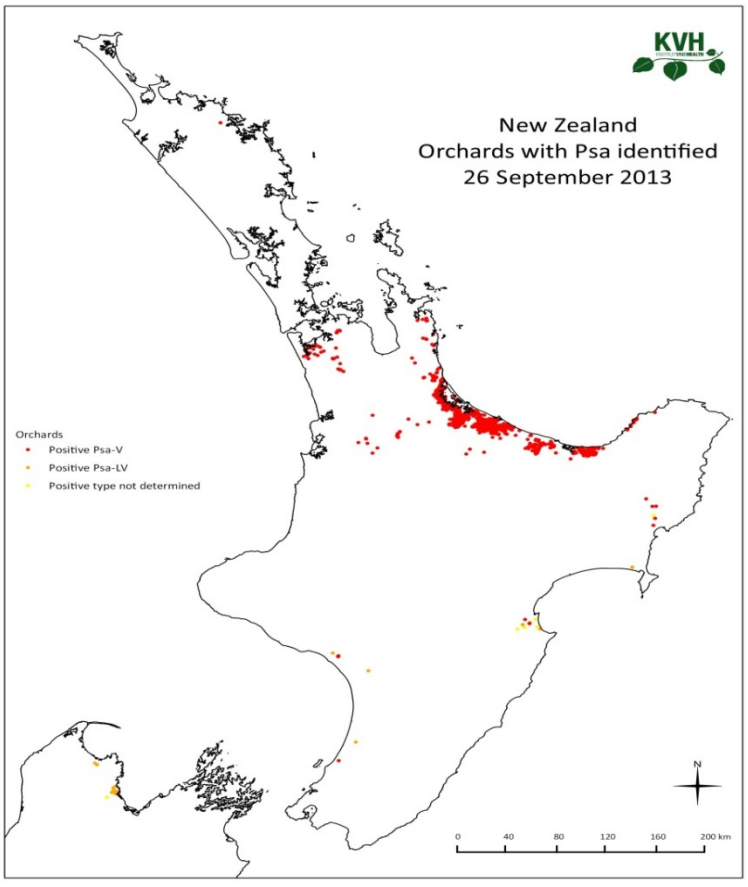

Fig. 10. Current New Zealand Psa-V status.

ACKNOWLEDGEMENTS.
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Conventional Propagation of *Cordyline australis*©

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The New Zealand cabbage tree, *Cordyline australis*, rates internationally as one of our most famous indigenous plants. Its popularity is based not only on its distinctive habit, shape and deliciously fragrant flowers but also the relatively recent advancement of coloured foliage forms. The purple foliaged 'Purple Tower' was famously crossed with one of the first striped leaved forms 'Albertii' at Duncan & Davies in the early 1980s. The resulting Pandora's box of colours and variegations this cross produced was an eye opener in terms of what foliage possibilities existed in the genetics of the humble cabbage tree. Since this time, through either seed variation or sports from tissue cultured plants, a plethora of different forms have emerged here and overseas. There was a time when a nursery visit to a fellow grower always seemed to include a quick peek round the back at the owner's latest *Cordyline* find. I, too, was one of those vigilant nurserymen on the look out for new forms, and I found one. I called it 'Whero', which is Te reo (Maori) for red (Fig. 1).

Fig. 1. Plant of *Cordyline australis* 'Whero'.

‘Whero’ was in my view pretty spectacular and it was my duty to make it available to the world, hopefully clipping the ticket in the process. In fact it is possible that I had delusions of wealth and fame in the early days based on the fact that I had a sure fired winner. Age and experience has confirmed that there is no such certainty in the “new plants” world. Attempts by various plant tissue culture laboratories to initiate ‘Whero’ were not totally successful. The best I got, after quite a period, was ‘Whero’ in culture but with only about half of the cultures staying true to type. The other half turned out a plain, but not unpleasant, brown. This made the young plants twice as expensive as other new cultivars and so the plug was pulled on tissue culture production after the first thousand or so plants were deflasked. The brown ones, renamed ‘Chocolate Brownie’, were sold/given away and the true ‘Whero’ were potted up and left to their own devices at the back of the nursery. Some years later, when the plants were well established, I looked at them again with a view of trying to increase their number by more conventional forms of propagation. The results of my attempts follow.

INITIATING CUTTINGS

Those who have cut down mature cabbage trees are very aware of their capacity to produce shoots from the stem. These shoots would not normally develop unless forced by the removal of the growing point. Being monocotyledons, and essentially the tallest growing members of the Liliaceae, their growth is a bit different from most other tree or shrubby species. I hoped that the many shoots I could generate would make good cuttings and I could use these to make new plants. Firstly, I wanted to see what the best time to force these shoots was. Past experiences suggested the spring-summer period. So I cut half of my mature plants off in November and the other half in December. The cutting process removed all the foliage, leaving me with a naked trunk about 1 m tall. The foliage and stem I removed were like “giant” cuttings at least 2 cm in diameter and about 30 cm long. I removed most of the leaves of these “giant” cuttings and set them in a free draining medium of coarse pumice.

After 4 weeks of the hard cutting back process new shoots started to show, after 7 weeks these new shoots were 10-12 cm long.

Fig. 2. Shoot development on cut-back plants.

More and better quality shoots resulted from the November cut back. Those plants cut back in December produced fewer shoots but did force some shoots to emerge from below medium level from the base of the parent plant. I concluded that the earlier the cutting back in the season probably the better.

THE CUTTINGS

So we had two types of cuttings, taken at two times, these being the "giant" cuttings taken in November and a second lot in December and the "generated shoots" taken 7 weeks after the hard trimming (Fig. 2), these dates being late December and late January. All cuttings were treated in pretty much the same way, with most of the foliage removed and the balance trimmed to half their original length (Fig. 3). They were then dipped in Seradix no. 2 (0.3% indole-3-butyric acid in the form of a dust) and set in coarse pumice and placed on heat and were watered/misted manually.

Fig. 3. Cuttings ready to be stuck in propagation medium.

The results were very contrasting. In the simplest of terms the "giant" cuttings rooted well, the "generated" cuttings didn't. To be more specific the earlier set "giant" cuttings rooted almost 100% and grew on quickly into good plants. The later set "giant" cuttings rooted about 70% and also went on to make good plants albeit a little slower. The earliest set "generated" shoots gave about 20% rooting, the later set ones produced almost no roots at all. The rate of growth of plants from these smaller "generated" cuttings was, as expected, very much slower than their larger sized counterparts.

CONCLUSIONS

Firstly, we were easily able to generate shoots on large parent plants by severe heading back. The earlier date of this treatment produced better quality shoots.

Secondly, cuttings made from the “giant” headed back portion of the plant made good solid cuttings that rooted well. The earlier set of these “giant” cuttings being better than later set ones.

Thirdly, smaller cuttings made from the generated shoots, rooted poorly although the earlier ones were better than later ones.

In general for this clone of *C. australis*, bigger cuttings performed very much better than smaller ones and earlier set cuttings were better than later set ones.

DISCUSSION

I know from other people’s experiences that some cultivars will root reasonably well from small “generated” shoots. For those forms, this method of propagation may well be a useful technique. We have clearly demonstrated those shoots can very easily be generated from mature plants. As size of the cutting seemed to be an important issue, I would recommend that earlier heading back, say in the beginning of October, may be a better time to generate these types of cuttings. For ‘Whero’ I will, in future, try and head back earlier to generate larger cuttings to see if this will improve their rooting percentage. However, for the moment, unless I can see considerable improvement in this method I won’t be rushing in to full scale production.

Pingao (*Ficinia spiralis*) History and Propagation©

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INTRODUCTION

Pingao (*Ficinia spiralis*), sometimes called the golden sand sedge, is an endemic native sand-binding plant (Fig. 1). It grows naturally on the most active of coastal foredunes and is not found anywhere else in the world.

Fig. 1. Pingao (*Ficinia spiralis*) grows naturally on the most active of coastal foredunes.

Before European colonisation, pingao was widespread through the North and South Islands of New Zealand (Cockayne, 1911). It was used by Maori to decorate their wharenui (meeting houses), in the tukutuku paneling and in weaving kete (kits), and whariki (mats). However the introduction of farm animals and the spread of goats and rabbits decimated the colonies of pingao. The spread of maram grass (*Ammophila arenaria*) and lupins (*Lupinus* sp.) and other European grasses choked out pingao. More recently dune buggies and trail bikes have mutilated the sand hills.

By 1975 the status of pingao was described as vulnerable and this was reinforced in the 1981 publication of the Red Data Book (Essler, 1975; Williams and Given, 1981).

At the same time, the 1970s to 1980s, there was a renaissance in things Maori. It began with Te Kohanga Reo (the language nests) for preschoolers and there was also a focus on marae and refurbishing wharenui. With this came a greater interest in weaving using

harakeke (*Phormium* spp.), ti kouka (*Cordyline* spp.), kiekie (*Freycinetia* spp.) and pingao (*F. spiralis*). It became vitally important to research the propagation of pingao.

LOW GERMINATION RATES

At this time growing pingao from seed had the reputation of being difficult with very low germination rates (Bicknell and Butcher, 1986; Courtney, 1983).

Since pingao flowers in September in the Auckland area, seed heads were collected between mid-November to mid-December in 1983 at Whatipu (the north head of the Manukau harbour). After drying for 2 weeks the seed was sown and it germinated within the month at an estimated rate of 80% (Fig. 2). Seed collected in February in other areas was found to be largely infertile (Bicknell and Butcher, 1986).

Fig. 2. Germinated pingao (*Ficinia spiralis*) seedlings growing in a greenhouse.

Viability tests using tetrazolium on seed picked in April showed a potential for germination of 87% (Courteney, 1983). It seemed possible that a dormancy mechanism was laid down in the seed in the last stages of maturation. This problem can be negated by the early collection of seed heads.

Growing pingao by seed, after repeated trials in following years, proved to be the most

successful method of propagation. Taking cuttings or whole transplants, while successful in some instances, involved cutting down plants from an already scarce resource. All of this was reported at the IPPS New Zealand conference in 1985 (Oliphant, 1986).

SPREADING THE WORD

The problem at this stage was how to disseminate the knowledge that the hitherto negative reputation of growing pingao from seed had now become a definite positive.

The word was spread through conferences; the Maori and Pacific Island Weavers and the IPPS in 1985 and the New Zealand Maori Artists and Writers in 1986. Seedlings were grown, transported around the East Cape and donated to schools and interested individuals for 3 consecutive years. A television documentary was made under the Koha series which showed how to grow pingao from seed. The big breakthrough came in a letter to *The Listener* in 1986 which bemoaned the fate of pingao and the difficulty of its cultivation. In an immediate reply, notes on the propagation of pingao from seed were offered to anyone who requested them. There were over 50 individuals who wrote as well as people representing Regional Councils in Auckland, Wellington, and Hamilton; the Department of Conservation, Lands and Survey; Native Forest Action Council; Friends of the Shoreline; The Wildlife Service; Kokiri; high schools, Polytechnic Institutions; and the DSIR Botany Division from Christchurch and Havelock North.

The indigenous section of the New Zealand Forestry Research Institute (NZFRI) began rehabilitation trials with pingao at Waikawau Bay, Coromandel Peninsula, and Nuhiti Beach north of Gisborne. It was found that the application of a slow release fertiliser at planting gave a substantial boost to plant growth and is now recommended practice. On the other hand the use of hydrogel (Crystal Rain) did not improve growth or survival of planted seedlings during the following season (Bergin and Herbert, 1997). The NZFRI also evaluated provenance differences in pingao for growth and weaving characteristics and with the assistance of the Department of Conservation seed was collected and seedlings grown from 34 locations throughout New Zealand.

Research began on spinifex (*Spinifex sericeus*) (known also by the Maori name kawhangatara) propagation and re-establishment in the dunes as a companion sand-binding plant with pingao (Bergin, 1999). By 1990 there were thousands of pingao seedlings being grown in Polytechnic, Department of Conservation, and private nurseries, and planted out on the foredunes. A booklet “Pingao: The Golden Sand Sedge” was compiled with the participation of many individuals and published by Nga Puna Waihanga.

In 1991 Cambie and Cooper published their book “New Zealand's Economic Native Plants” in which they quoted “ Botany Division DSIR and the Department of Conservation had succeeded in developing techniques for growing pingao from cuttings and from seed: it will now be possible to set up pingao gardens to supply weavers with all the fibre they want and to increase wild pingao with nursery-grown plants” (Cambie and Cooper, 1991). These claims were inaccurate. The truth was that hundreds of people had been involved in sharing knowledge and in actively growing pingao from seed and planting out in the dunes from the early 1980s. This work had been documented and it predated the DSIR publication.

From the beginnings as the Coastal Dune Vegetation Network in the mid-1990s, the Dune Restoration Trust of New Zealand was formed in 2007. This is a non-profit charitable trust whose aim is to support and encourage the development of cost-effective practical methods for coastal communities and managing agencies to restore natural dune form and function focusing on the use of native plants.

Throughout New Zealand there are now 118 active beach care groups who have help from the Dune Restoration Trust, local councils, the Department of Conservation, and some local businesses. Given that 90% of the population of New Zealand live within 50 km of the coastline, beaches are an important part of their lives. Directing people with the use of boardwalk beach access through fenced dune areas has made a big difference to the survival of plants and to the general awareness of protected areas. All regional councils

throughout New Zealand have encouraged and funded beachcare groups from their dune restoration programmes.

At Kawhia in the early 1990s there was a total of 2,500 pingao seedlings planted on the coast over 3 consecutive years. Subsequent storms washed away part of the foredunes, the west coast being more vulnerable than the east to the prevailing winter winds. Rabbits have not been eradicated and cause damage. Vehicles can access the beach at low tide.

But 20 years later a Kawhia Beachcare Group has begun planting pingao and spinifex on the foredune again and remnants of the earlier pingao plantings were found.

The east coast of the Coromandel Peninsula is also under the Waikato Regional Council's control. At Pauanui beach the foredune had eroded away. Machinery was brought in to reform the area and it was planted in spinifex and pingao. This work was done between 2004 and 2006 (Fig. 3).

Fig. 3. Planting pingao on a foredune.

CONCLUSION

In conclusion, pingao the beautiful and useful golden sand sedge, a once vulnerable species, has in the space of 30 years become a much more appreciated and plentiful plant. This is due in part to the perseverance of plant propagators but mostly to the enthusiasm of all those volunteers who actively care for the seashore and its flora.

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Options for Successful Establishment of Native Species©

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INTRODUCTION

The two options that come to mind are:

Option 1

You allow poor planning, management deficiencies, and poor execution to ruin your results, or

Option 2

You do everything well and on time. The seasons don't wait.

SIX ASPECTS TO SUCCESSFUL ESTABLISHMENT

In common with exotic species there are six aspects to the successful establishment of natives.

Planning and Site Preparation

Plan in advance. Site preparation involving fencing, weed spraying, and animal control may have to start 2 years in advance. Machinery may be required. Order planting stock in advance so that species you want are available and of the quality that you require and nurseries have time to grow them.

Nursery Production

1. Open Ground Production. For large scale native afforestation, open ground (bare root) production is an option. Methods for the cost-effective large scale raising of native species were developed at the Forest Research Institute in the 1950s and early 1960s and we grew many thousands in the following years to provide planting stock for native forest rehabilitation.

In order to produce 1-year-old planting stock the preferred option is to sow in plug trays in the winter and to transfer resultant plug seedlings into preformed and pre-dibbled beds in the spring. From then on the trees are "grown off the tractor seat". The copper treatment (see below) as an option in container grown plants is equally an option for plug grown seedlings transferred into open beds.

2. Container Growing. The horticultural approach of predominantly single plant culture is the prevailing method of raising native plant stock in New Zealand. Some nurseries have installed cavity tray filling and precision sowing lines in recent years. These do away with pricking out, a labour intensive procedure, often resulting in tap root distortion. Cavity trays produce plug grown plants which are then transferred into larger containers.

To improve the quality of container grown root systems, treatment with cupric hydroxide (CuH_2O_2) on the inside of containers is an option. This treatment, apart from stopping the development of curling and tangled roots, also has a fungicidal effect, which is useful for species subject to root rot problems. In addition the treatment allows easy de-plugging without root damage.

The following is a copper paint recipe for spraying container walls. Mix together 1 L white water-based ceiling paint with 1 L water, then add 240 g Kocide® 2000DF, containing 350 $g \cdot kg^{-1}$ cupric hydroxide as a water dispersible granule.

De-bagging. The quality of root systems in planter bags is not readily assessed. Root deformities are hidden and not easily rectified at time of planting. For that reason I have chosen the option of de-bagging, root disentangling, root trimming, water dipping, and placing of trees in white forestry plastic bags.

Transport. Robust container grown trees are bulky and heavy. Shifting such plants is costly in terms of both labour and transport from the nursery to the planting site itself. The advantage of de-bagging is that root system quality can be checked and remedied prior to planting and that trees in white plastic bags are less bulky and lighter to handle. Another aspect of de-bagging is that it provides the option of establishing a mixed species plantation.

3. Storage on the Planting Site. If plants have been de-bagged and are thus bare-rooted it is increasingly important to keep them cool and wet and protected from sun, wind, and frost. Laying bare-root plants out ahead is not an option.

4. Planting. Plant bare-rooted or de-bagged trees from autumn to spring in the cooler and wetter parts of the year. Cultivate the planting spot, plant deeply and firm plants in well. Do not stuff the roots in the hole. Water in if necessary — the use of the local fire brigade is an option! They enjoy the practise!

5. After Care. Weed control is essential, especially in years 1 and 2. Monitor weeds in year 3. Animal control is important. Broadleaf species are particularly vulnerable and the use of animal repellents is a good option.

This last winter we planted 2,000 trees and shrubs. I do not plan for failures and even this year in the drought they are growing vigorously. Anything less than 98% success is not an option. If we had 40 dead trees (2% of 2,000) we would want to know what went wrong.

October 2012 IPPS Japan – New Zealand Exchange©

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My trip to Japan began by car from Taupo to Auckland, a flight to Narita airport and then a very quick transfer to a domestic flight from Narita to Osaka. I was met there by Akimi and Naoki, who had both travelled some distance to collect me. I then spent two nights at Shin Osaka with Akimi, doing a bit of sightseeing around Kyoto and Osaka.

A highlight of those 2 days was seeing the Golden Temple just as the sun was setting. Absolutely beautiful. We also visited the Kyoto Botanical Gardens.

We then caught the Shinkansen to Toyohashi and I spent another two nights there. Akimi showed me around her business, Verde, and we also visited some other members of the IPPS and a large garden centre.

On Day 5, after some more sightseeing and visiting members, Akimi drove me to the home of the Uchida family in Suzuka. I stayed with them and worked in the nursery for the next 4 days. I mainly worked with the strawberry crops but also helped to pack some figs and take them to the farmers market. They had suffered some damage in the nursery from a recent typhoon. Uchida san also took me for a drive around the local area to look at nurseries. There were many small family run businesses growing everything from large grade bonsai style landscape trees to vegetable crops. It seemed that the market for the large Japanese style garden trees was dwindling as modern families did not have the time to maintain traditional style gardens. Another observation was the lack of lawns in suburban areas, it seems food crops take priority over everything, and every possible area of soil is utilised for various food or green tea crops.

I enjoyed my stay with the Uchida family very much, they were wonderfully warm hosts, and Miuki is a great cook!! I think I gained a few pounds during my stay with them.

On Day 9 we travelled to Nagoya to meet with Ackimi, who again had travelled a long distance to collect me. Ackimi and I then travelled on the Shinkansen to Narita were I was to meet up with the international tour group. On the journey we passed through a large citrus and green tea growing area.

INTERNATIONAL TOUR AND CONFERENCE

On my exchange I was lucky enough to be included in the international tour party and to meet other members from around the world. I then spent the next 10 days with the international tour visiting nurseries and sightseeing with a whole bus load of like-minded plant enthusiasts from across the globe. What a great way to see a country and learn something every day. I was immersed in a wealth of knowledge spanning many years in the industry. This was a real treat for a comparatively new member.

Highlights of the tour included a visit to the plant factory at Chiba University, a fascinating insight into the future of global food production. We also caught a glimpse of Mount Fuji before the cloud rolled in, a 360° view of Tokyo from 250 m in the air, and there was Keske's great barbeque. Then off to the conference in Hamamatsu where I was again the lucky one. I got to experience a real traditional Japanese tea ceremony and see how green tea was made in the tea factory at the college.

I gave a talk at the conference on New Zealand native plants. I also was able to catch up with other exchange members from Japan who I had met in New Zealand, which was a great experience. I think the exchange programme is a very valuable way to connect members of an international society like the IPPS and to forge lifelong associations and friendships with other members. The conference ended with some karaoke…I hope there is not a YouTube video of me out there!!!

ACKNOWLEDGEMENT
In summary I would like to especially thank Ackimi, Nioki, and the Uchida family for looking after me so well, and both the Japan and New Zealand IPPS for the awesome opportunity. My general impression and observations of Japan are one of immense warmth and hospitality, cleanliness, organisation, and a beautiful culture that is being strongly influenced, good or bad, by Western society. The history and depth of culture is mind boggling to a girl from New Zealand and I was both impressed and awed by it.
Thank you again and long may the exchange programme continue.

The Himalayas – Source of Many of Our Ornamentals©

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Today I'm going to talk about the exotic plants from the Himalayas. Many of you may not know that plants from the south side of the Himalayas are the absolute backbone of English gardens.

HIMALAYAN PLANT DIVERITY

At the core of this amazing plant source is the holy trinity of *Magnolia*, *Camellia*, and *Rhododendron*. How many gardens do you know without any of these key plants? I could make a very long list of other Himalayan plants. The large conifers: *Picea* (spruces), *Larix* (larches), *Abies* (firs), *Pinus* (pines), and *Cedrus* (cedars). There are many palms, bamboos, and many orchids, including *Cymbidium*, from this area. Lots of garden trees and shrubs including roses, *Viburnum*, *Cotoneaster*, *Daphne*, *Michelia* (see *Magnolia*), *Philadelphus*, *Deutzia*, *Pieris*, *Acer*, etc. There is a huge range of beautiful herbaceous alpine plants such as *Primula*. In fact when you are in this zone you could easily imagine you are in a garden. Many of our garden centres would have Himalayan plants for nearly half their stock.

PLANT HUNTING

I have been fortunate to do some plant hunting that is, collecting ornamental plants in the wild. Every country has its native plants just like New Zealand. There is one guiding principle to do this; you need to find an area of similar climate to your own country. So for New Zealand an annual temperature range of -5 to 25°C is good. As your plant source country gets nearer to the equator, you need to go higher and higher into the mountains to get that similar climate zone. So in the Himalayas a similar climate zone exists between about 2500 m and 4000 m above sea level (a.s.l.). In North Vietnam we collected between about 1000 m and 3000 m a.s.l.

I would like to take you on a little further to an understanding of why this diversity occurs here. There are two important principles at work.

High Mountains

The first is the Himalayas themselves, the highest mountains on the planet, with 14 peaks above 8,000 m. They were generated when the Indian Plate split off from the Australian plate about 70 million years ago and drifted rapidly north. As it approached Tibet from the south much of the intervening ocean bed was picked up and carried, so that now the areas above 6000 m on Mt. Everest are all sedimentary rock with ammonites and other marine fossils. Tibetans mine coral from the mountains for jewellery! Everything below this is granite. The end result of this plate collision is that we now have a huge barrier range running east west across the Asian continent.

Diversification

The second principle is plant diversity. Plants can diversify quite quickly given suitable habitats, but the main driver of diversity is time. The longer plants have growing in an area the more they diverge into more species.

HIMALAYAN HAVEN

Put these two together and you have plants on the wet southern side of the Himalayas growing away happily as an Ice Age approaches. The ice runs into the Himalayas from the north and can't get past. The rest of the Northern Hemisphere is wiped clean by the Ice Age and has to start diversifying all over again. The Himalayas become a safe haven for many of the best ornamentals we know. Since the last Ice Age occurred just 10,000

years ago the haven beneath the high mountains has presumably fulfilled this role many times.

LUCKY

Finally I'd like you consider how lucky you are. Modern man has only been around for 100,000 years. Over the past 10,000 years civilisation has occurred and we are no longer nomadic. Trade in food and commercial plants has dominated recent centuries. Only in the last century really have people been able to explore the planet and gather ornamental plants. Gardening for everyone is possible. So in all of history, it is only right now that you could be a nurseryman!

Drugs and Alcohol in the Workplace©

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INTRODUCTION

Thank you for attending the NGIV-IPPS presentation on drugs and alcohol in the workplace. This can be a confusing and controversial issue in any workplace, so we'll look at some of the main areas of workplace law so see what you may need to consider if you have a problem, or are looking to develop a policy before trouble strikes.

Many people will think of accidents, particularly for employees in dangerous roles such as driving or operating heavy machinery, as a potential outcome of being affected by drugs or alcohol. Although Occupational Health and Safety may be the primary concern and motivation, there are other problems, such as taking "sickies" if hangover or affected by drugs and alcohol, other co-workers becoming disgruntled at a known problem "getting away with it," mistakes in paperwork, or your company being seen as unprofessional. There can be claims such as unfair dismissal or discrimination if a policy is badly drafted, or inequitably implemented or not supported in the workplace.

THE OCCUPATIONAL HEALTH AND SAFETY ACT (VICTORIA)

The Occupational Health and Safety Act (Victoria) 2004 places a duty of care on employers to "provide and maintain for employees of the employer a working environment that is safe and without risks to health" (sec 21), as well as not placing others, such as members of the public or suppliers, at risk. A risk assessment, asking what could go wrong, and what's the worst that could happen, can be a good start. Employers are also obliged under this Act to consult with employees. This can assist with making a policy that fits your workplace.

Many companies think of drug testing when they suspect they have a problem with someone. This can be easier said than done. For this to be done legally, you need a policy that outlines when, how, and who you will test. Will you test randomly or after an accident? If you suspect someone is affected? Will you use swab tests? How much will it cost? Will you only test your manual workers? What if someone refuses to take a test? What will you do if you get a positive result?

Answers to these questions can often be found through research and consultation. This may include consultation with an Employee Relations and/or Occupational Health and Safety specialist. Your company may also need to consult with employees and their representatives, such as union delegates. This will assist in developing a policy that will be accepted by your employees, have the support of the union and be defendable if a claim is made against your company.

EQUAL OPPORTUNITY ISSUES

You will also need to consider equal opportunity issues. No type of addiction is recognised as a protected attribute or a disability under legislation; however, if an employee is adversely affected by a prescribed medication for a recognised condition, you could find yourself with a discrimination claim.

This leads to an important question; what do you do if you think an individual is affected by drugs or alcohol? Answer: TALK to them! In a private setting, with an appropriate, trusted person, tell them what you have noticed (red eyes, slurred speech, smell of alcohol) and ask what they think may explain this. There may be more than one explanation for what is being presented.

Stress, fatigue, problems at work and home, prescribed medications, over the counter medicines, shock, can all produce side effects that may lead you to think alcohol or drugs are to blame. Always take into account alternative explanations, especially when you

know you have an employee with a good work history and you are seeing unusual behaviour for them.

Sometimes your biggest obstacle in getting a drug and alcohol policy accepted and implemented by management. Trying to get other bosses, supervisors, and leading hands to understand and support this sort of a policy and understand their obligations can be extremely difficult. Are they just giving it lip service whilst enjoying lunchtime drinks themselves? Neither your employees nor bodies such as the Industrial Relations Commission are going to take your company's commitment to your policy seriously if this is what's happening. Does a well meaning supervisor allow a particular employee with a known problem to just do an easy job when it can be seen they are "worse for wear?" Worksafe probably won't feel the same consideration if they have to attend the scene of a serious accident. Management needs to understand that they should be covered by the same policy as everyone else, and will be looked to as an example. Supervisors need to understand their role goes further than just ensuring production. They have legal obligations under the Occupational Health and Safety Act (Vic) 2004, and play a key role in ensuring the successful implementation of any policy. Supervisors need to be trained in what this policy means and what steps they are expected to take if they suspect a breach, or have a breach reported to them.

EDUCATION

Education is a key part of implementing your policy. Employees are often unaware that their company even has a drug and alcohol policy. If you have one, then people should know if this means they have to be 0.00 BAC (blood alcohol count) at work, or under 0.05 BAC. They should know when and how they can be tested. Education also can mean for some people finding out how long different substances remain in their body. This usually means that an employee cannot be sacked for a first time offence under a policy. It may also mean helping an employee through drug or alcohol programs, or discussing with employees beforehand how long different drugs may remain detectable in their system.

It can be important to remember that the presence of drugs or alcohol may not mean the employee is impaired. THC, the active constituent in marijuana, can show up in a urine test up to two weeks after use. This means it is important to use testing methods, such as swab testing, or breath analysis for alcohol, which are more likely to show results which indicate impairment, to ensure fairness. Also important for fairness, is whether in the eyes of your employees, or other bodies, is that everyone is treated the same. This includes who is tested, and how someone is treated if they have a positive result after being tested.

Hopefully this has helped to provide a basic guide to a very complex issue. If your company is confronted by drugs and alcohol in the workplace, or looking to draft and implement a policy first, this should provide some food for thought. And don't be afraid to consult, discuss and educate.

Enhancing Phytonutrients to Change the Game: Vitalvegetables©

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INTRODUCTION

The food industry is grappling with the impact of globalisation of world markets and the competition which comes from that. The industry is facing a revolution not dissimilar to the industrial revolution experienced by our predecessors over a century ago. The evolution of technologies like biotechnology, real time non-destructive sensing, data processing and communication technology, and the speed of communication have accelerated the pace of change.

The productivity growth in agriculture and horticulture in recent years is due to the ability to converge these technologies into systems that deliver productivity gains for these industries like no other sector of the economy.

Forty years ago the catch cry in agriculture was get big or get out. This is now an outdated paradigm. The new paradigm is to innovate and create points of difference to distinguish your product from the pack. With globalisation it has now become competition for market share, reflected by competition between supply chains which can take business into new, unexplored markets through strategic collaboration and partnerships. The question becomes what does each organisation bring to the partnership to create competitive advantage in the supply chain to offer the consumer value which no one else can?

The reality is that the agriculture and horticulture industries are facing a major restructure with the imperative to find new, more efficient and innovative ways of bringing products to market that are different and satisfy ever changing consumer preferences. It requires an innovative, integrated, complex system response through the complete value and supply chain.

In the 1990s Victoria had a dynamic broccoli export industry to Asia, along with a range of other vegetables. By the mid-1990s it was feeling the pressure from low cost vegetables coming out of China. Austrade market research found the industry would not be able to compete on price alone, even though the products were of better quality. Product innovation and differentiation was needed to create points of difference, as the platform of a new competitive advantage paradigm.

VITALVEGETABLES® PURPOSE

Vitalvegetables was a program to develop knowledge and integrated management systems for enhancing the phytonutrient content of vegetables to make a naturally good product even better, while being good to eat and retaining freshness. At the outset, this was to be done as naturally as possible, so genetically modified organisms were ruled out due to consumer resistance.

Vitalvegtables aimed at understanding the influence of genetic, management, and environmental factors on vegetable composition specifically antioxidants which have evidence of their benefits in disease prevention and wellbeing. This was the impetus for Vitalvegetables, a joint venture between researchers in Australia and New Zealand along with two leading international vegetable breeders, the Australia and New Zealand (NZ) industries, with funding from Horticulture Australia Limited, Department of Primary Industries Victoria, and Plant and Food Research NZ.

The purpose was to build a new competitiveness platform for the vegetable industries by creating a new category of nutritionally enhanced, higher value vegetables. The intent was to deliver benefits to consumers and participants in the production and marketing chain.

This approach brought together research and development capability with strategic commercial partners including international vegetable breeders and vegetable production

and marketing companies, aimed to create a sophisticated and innovative research, development, production, commercialisation and marketing platform (CIE, 2008). The result was a strategic yet fragile, tri-party joint venture with a competitive advantage.

Modelling by the Centre for International Economics (CIE, 2008) highlighted the significant growth potential for the horticultural industries through increasing market demand for products by development of: novel products, improved quality, and consistency, improved commercialisation platforms and synergies via collaboration. Chasing productivity improvements alone is a challenge as improvements tend to plateau, however improvements in product demand tend to be open-ended. The modelling suggested that big payoffs come in order of declining returns from, the commercial/marketing platform, novel products, consumer satisfaction and productivity.

The main indicative capability contributions are from, breeding and genetic, taste and perception science, cool chain and quality management, farming and systems productivity (CIE per com).

ENHANCING FOOD COMPOSITION

There are two fundamental ways to enhance or alter the composition and nutritional content of plant or animal based food.

Fortification

Is the process of putting ingredients in or extracting ingredients in a factory, much as we see with high calcium, low fat milk for example and processed foods.

Biofortification

Is the process of manipulating the composition or nutritional content of food during the production process on the farm. This works by optimising the genetic attributes for the desired composition ingredients and understanding how management and environment factors interact to alter food composition. Biofortification is an entirely natural process and has the additional benefits that ingredients which are enhanced by this approach are more bio-available. That is availability to consumers is high because they are in a form found in natural food, and they are more bio-effective than the ingredients in fortified product as a rule. The output of the biofortification approach is “smart foods”.

RELATIONSHIP BETWEEN PROFIT, QUALITY, AND COMPOSITION

Food Profitability ($) = [Product volume sold × Price ($)] – Costs ($)

Food price is influenced by quality and value as perceived by consumer. Traditionally quality has been determined by visual and physical attributes: size, colour, shape, etc. However, as consumers become more sophisticated and discerning they are looking for more from food beyond satisfying their hunger. They are looking for, and demanding, other benefits and experiences which include; acceptable taste, interesting flavour and texture, enhanced nutritional, lifestyle, illness prevention, and health and wellbeing benefits. This brings into focus food composition related attributes; total fat, type of fatty acids (e.g., omega-3 or 6), types of oils plant or animal, carbohydrates, glycaemic index (GI), proteins, amino acids, fibre, minerals, antioxidants, vitamins, etc.

Incidentally, the post farm storage and processing performance of most agriculture products are influenced by the composition at the farm gate. Sheep fed pasture have higher levels of omega-3 and vitamin K than grain feed sheep. The meat from these sheep keeps better. The phytonutrients composition of plants is influenced by conditions during, and the speed of growth, and maturity at harvest.

Food quality is a function of the composition and the factors which influence it, which include the complex interaction between genetic, management, and environment factors. The interaction of these factors also influences yield. The relationship of these factors to profitability is the game.

There is broad recognition that food is a major factor in lifestyle related illness (e.g., diabetes, cardiovascular and heart disease, cancer, etc). Food composition can play a pivotal role in disease prevention along with a healthy active lifestyle. In particular phytonutrients in fruit and vegetables such as antioxidants have been found to play a major role in disease prevention and wellbeing.

DEVELOPMENT

The initial focus was on broccoli as a model crop due to its relationship with disease prevention. This research found that yield and antioxidant level can be inversely related, meaning that as yield increases the desired ingredients become less concentrated.

Vegetable post harvest storage and food preparation methods can have a significant influence on stability, and/or availability of some phytonutrients. For example, one of the main desirable ingredients of *Brassica oleracea* Italica Group (broccoli), glucosinolate, is lost by boiling at 100°C for 3 min or more, or inactivated by microwaving so, cooking below 100°C (e.g., steaming) for less than 3 min is advisable (Jones et al., 2006). On the other hand lycopene an ingredient of tomatoes associated with prevention of prostate cancer is made more available if prepared with olive oil. Plasma lycopene concentration in humans was 40 to 80% higher after ingestion of tomatoes cooked with olive oil, compared with fresh tomatoes (Fielding et al., 2005).

The first Vitalvegetables Booster™ broccoli was launched on the Australian market in August 2009. This launch attracted saturation media coverage across Australia and inquiries from overseas due to the novel nature of the product and program, in addition to being a basic ingredient in a healthy diet.

A number of valuable lessons were gained from this experience which included:

- Packaging must be strongly distinctive and enhance the shelf life of the product.
- Ongoing consumer communication is required in the market.
- Everyone must be committed to long term success; growers, packers, marketers, retailers.
- Distinctive convenient meal ready packaging solutions help satisfy consumer information needs, i.e., deliver x% of recommended daily intake of nutrients.

Market Driven

Before the research began there was need to establish was there a market for products of nutritionally enhanced vegetables.

This market research found across all consumer categories there is a high propensity to purchase “fresh and functional” fruit and vegetable products based on the proposition that sound science and R&D can suitably enhance levels of naturally occurring substances (Richards, 2004).

Propensity to purchase is driven by the following:

- High awareness that fruit and vegetables are essential for health with 89% of the population consuming 7-14 + meals per week containing fruit and vegetables.
- Currently, 30% of the population consume a particular fruit or vegetable for a specific health benefit.
- 61% of people buy functional food of some from.
- 63% of consumers indicated they would consume more fruit and vegetables if these had proven functional benefits.
- 20% of consumers claim they would definitely buy, and 43% said they would probably buy newly produced “functional” fruit and vegetables.
- 84% of consumers would rather consume functional food as fresh fruit and vegetables than in a processed form.

In summary the market research found that consumers wanted nutritionally enhanced (functional food), healthy vegetables but they needed to taste good and be fresh. They wanted to get their better nutrient package in a natural form not via a pill, and it should not taste like medicine.

Lifestyle consumers are willing to pay a price premium for health — but want ”wellness” products which is a place where strong focus and strong brand identity pays off, this is the place for ”Life Marketing” Source: Food & Health Marketing Handbook, Mellentin & Wenntron.

Vitalvegetables Booster™ broccoli was up to 200% higher in glucosinolate than standard broccoli and is also sweeter to taste which created huge interest. It’s was important not to get carried away at the product development stage with the potential of differentiating a product with a new ingredient level, because consumers do not buy products because of their ingredients. Consumers buy products for benefits relevant to them (Julian Mellentin per commun., 2009). Distinctive differentiating packaging serves many purposes by catching consumer’s eyes, communication of benefits, adds convenience and cares for the product.

RESEARCH AND DEVELOPMENT APPROACH

The program has been conducted by a strong team of researchers in Australia and New Zealand in collaboration with vegetable breeding companies and commercial partners in the markets in both countries.

Once target crops were agreed upon the germplasm pool was screened by the researcher to test the varieties for their agronomic performance and their composition level of target phytonutrients. The superior lines had further research carried out to understand how management and environment factors influence yield and composition, in addition to post harvest storage, handling conditions and how food preparation methods influenced the stability of key ingredients and their bioavailability.

This knowledge allowed suitable varieties to be identified and integrated production, storage, handling, preparation and testing protocols to be developed so that a consistent product was delivered to consumer every time. It is like running the Melbourne Cup but knowing who the winner was going to be every time, because the whole system from “seed to plate” could be managed. It is known how the crop/products would respond to different conditions.

The marketing/commercialisation of Vitalvegetables is supported by a suit of trademarks which have been registered across the category of products. This protects the systems intellectual property but also communicates to consumers the benefits based upon knowledge of the product ingredient composition.

The trademarks portfolio is as follows:

- Parent brand: Vitalvegetables®.
- Product category: Vitalsalad®, Vitalslaw® and Vitalmedley®. Depending on the product composition, it could be marketed as any of the following health benefit brands.
- Benefit brands: Vitalimmunity®, Vitalheart®, Vitalbones®, Vitalsight®.

GAME CHANGER

On reflection Vitalvegtables® was an innovative, ambitious joint venture aimed at being a game changer for the vegetable industry by taking vegetables from a commodity, caught in “the everyday lowest price” paradigm to a more highly differentiated, premier/higher value , convenient, ethical, health and wellbeing product.

Change creates uncertainty and challenges conventional thinking and paradigms, so we did come up against resistance and barriers to change as there is a threat to the status quo.

A paradigm which many have found difficult to come to terms with is that Vitalvegetables® as a premium, higher value, differentiated product, was always only ever going to appeal to a segment of the market that were seeking those attributes and were prepared to pay a premium.

It could not achieve mass appeal and across the board high volume sales at a premium price. Commodities need high volume as margins are low.

However by segmenting the market it provided the opportunity to grow total vegetable consumption by offering consumer greater choice and improve profitability for the

industry by changing the game from competing only on price in the everyday lower price commodity paradigm.

CONCLUSIONS

- The future fortune of food will be based upon sound knowledge of the composition/quality/value and interaction of factors which influence the composition and yield.
- Inappropriate food preparation techniques may be robbing us of many of the natural healthy ingredients in fresh food.
- Biofortification has a future in development of "smart foods", increasing the efficiency of fresh food production and processing to support increasing market demand for more specialised foods.
- Biofortification shifts competition away from simply being a volume/yield productivity, cost cutting approach, to include value/quality (composition) in the competitiveness profitably equation.
- Multi party, joint ventures, collaborations and partnerships are the keystone of the new competition paradigm. Each partner needs to be able to answer the questions; what do I need to do, own or bring to this joint venture for it to be successful for all? They do not each need to own or have a finger in every pie. Collaborate to be competitive in the game as a joint venture.
- New paradigm joint ventures must be based upon a robust, win-win-win-win cultures where the risks and rewards are spread equitably and are aligned.

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Myrtle Rust in Australia©

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In April 2010 myrtle rust initially described as *Uredo rangelii*, a member of the eucalyptus/guava rust complex called *Puccinia psidii*, was detected on a myrtaceous host *Agonis flexusosa* 'After Dark' by a cut flower grower on the central NSW coast. For many years *P. psidii* has been a high priority quarantine fungus. Myrtle rust spread rapidly and was detected in south east Queensland in late December 2010 and in Victoria in late December 2011. The incursion into Victoria was human assisted. Myrtle rust has only been detected in nurseries, private gardens and amenity plantings in Victoria but is widely distributed in native forests along the east coast from Batemans Bay in southern NSW to the Daintree in far north Queensland. The host range has expanded rapidly to over 240 species from 34 genera of *Myrtaceae*. Several species are highly susceptible with severe consequences for native fauna.

The fungus was first described on guava in Brazil in 1884 where it rarely caused damage, but by 1912 was seen on *Eucalyptus citriodora.* Epidemics have occurred on *Eucalyptus* planted in Brazil, on allspice in Jamaica (1934), on *Melaleuca quinquenervia* in Florida (1997) and on *Metrosideros polymorpha* in Hawaii (2005). It was reported from Japan in 2009 and China in 2011.

Symptoms vary between hosts and may consist of round lesions up to 1 cm in diameter, purple to brown in colour, which show on both leaf surfaces. The fungus produces bright yellow asexual spores and dark red-brown sexual spores often found together in pustules. Lesions turn dark brown to grey with age. The disease affects only young shoots, flowers, fruits and leaves; causing curling, buckling and distortion of tissues. Heavy infection causes shoot defoliation, repeated infection reduce vigour and can kill plants.

Spores are dispersed by wind, rain-splash, animals and humans. Infection requires conditions of high relative humidity greater than 70%, or a 6-8-h period of leaf wetness, during low light or darkness. The optimum temperature for infection is 15-25°C, but the range may be wider. Lesions appear after 5-7 days and spores are produced up to 14 days or more after infection. Spores probably survive for a week under field conditions. Studies conducted in Brazil on *Eucalyptus* showed infection was favoured by a microclimate found from ground level up to a height of 4 m.

Control of myrtle rust will depend on hygiene, fungicides and plant resistance and breeding. Glasshouse studies in Australia have identified susceptible, tolerant and only a few resistant native plants. Currently (27 Feb. 2014) only two fungicides are registered and a number are currently available for use under permit for disease control.

It is illegal to sell infected plant material into Victoria, New South Wales and Queensland and to on-sell that material. Movement of *Myrtaceae* material into Western Australia and Tasmania is prohibited; movement into South Australia and the Northern Territory requires certification.

Ornamental *Eucalyptus* – Something for Everyone©

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INTRODUCTION

This research was conduct in conjunction with Dr Justin Rigden, Adelaide Research and Innovation, Adelaide, SA, and collaboration with Humphris Nursery (Victoria), Narromine Transplants (New South Wales), and Yuruga Nursery/Clonal Solutions Australia (Far North Queensland).

It is an example of a long term breeding program with lots of collaboration, funding, hard work and passion that is starting to bear fruit.

ORNAMENTAL EUCALYPT BREEDING

The *Eucalyptus* genus contains unique flora with over 700 species throughout Australia (and its closest northern neighbours) and represents one of Australia's greatest floral icons. *Eucalyptus* is the primary tree genus in Australia, and plays a vital role in all Australia's ecosystems providing habitat for native birds, insects and animals. There are a great number of species that are rarely seen in cultivation, with highly ornamental flowers, leaves, buds, and fruit. Harsh climatic extremes such as those experienced in many places in Australia and other parts of the world have prompted a renewed interest in Australian trees and plants, especially for street and urban landscape plantings, due to their resilient nature.

The majority of eucalypt species available in the Australian nursery sector are grown from seed, with a small number of grafted selections from the *Corymbia* subgenus. In order for ornamental eucalypts to become widely available to the Australian gardening public, they need to be improved through selection of superior forms. Clonal propagation can be highly genotype dependant and all selected forms must be clonally propagated to ensure genetic integrity. However, clonal propagation, such as cutting production, grafting and tissue culture, is difficult in most *Eucalyptus* species. As research to date has focused on a limited number of eucalypt species, there exists a large gap in knowledge as to how ornamental species will respond to clonal propagation. The development of a rapid, economic and reliable method of clonal propagation for ornamental eucalypts is essential for their ongoing development towards a viable commercial industry.

The University of Adelaide's Ornamental Eucalypt Development Programme (OEDP) commenced in 1996 with the PhD research by Kate Delaporte. Her thesis studies looked at aspects of development of eucalypts for ornamental horticulture and generated 100s of interspecific hybrids. These hybrids were planted in the Laidlaw Plantation, a 2-ha site at Urrbrae, South Australia, which now contains over 900 putative hybrid eucalypt genotypes, as well as around 350 individuals from 30 different species planted for breeding purposes, and is a significant germplasm resource for the OEDP pipeline of new introductions.

Research and development of ornamental eucalypts continued from 2000, with projects funded by RIRDC (Publication No 04/125, No 08/018 and No 04/120) the Playford Memorial Trust, with additional support from the Laidlaw Family, the Frank and Hilda Perry Trust and the SA State Government.

These RIRDC funded programmes sought to select superior forms for further development, including suitability for cut flower production (vase life assessments), propagation (trials including cutting propagation and grafting) and general production capabilities.

During that time, Humphris Nursery teamed up with the OEDP to undertake investigations into our top 10 selections for suitability for propagation by grafting. This required an examination of potential rootstock species and grafting methods, as the OEDP varieties at that time were from the Symphyomyrtus Bisectaria group of eucalypts, and far

different from the Corymbia types then available. The selection process was long, and difficult, but yielded results in 2012, with the first release of two OEDP selections, 'Nullarbor Lime' and "Nullarbor Rose'. These two cultivars are derived from crosses between dry land species from Western Australia, *E. macrocarpa*, *E. pyriformis*, and *E. youngiana*, and have retained the glaucous wax of the male parent *E. macrocarpa* and the more upright habits of the female parents. The cultivars are grafted onto selected seed grown rootstocks to make them more adaptable to a range of climates and soil types. It has been a slow and expensive process, with 5 years of research and development to find the best rootstock and grafting conditions. Production of plants for sale takes 12 months; plants are sold in a 20-cm pot and at a price comparable to other grafted ornamental eucalypts like the Summer series.

The OEDP received a much-needed boost to funding though the successful awarding of funding through Horticulture Australia Limited in 2010, in collaboration with the University of Adelaide and three Industry Collaborators.

HAL Project NY09023 investigated the reproductive biology of eucalypts and aimed to optimise propagation methods to enable a future eucalypt breeding programme. The partners in this project were Yuruga Nursery (Walkamin, FNQ) to investigate tissue culture, Narromine Transplants (Narromine, NSW) to investigate cutting production, and Humphris Nursery (Mooroolbark, VIC) to investigate grafting.

The OEDP identified a number of gaps in the knowledge base underpinning development of eucalypts for ornamental horticulture. Very little information exists on the relationship between climate and reproductive development, and also very little information on stigma receptivity and pollen viability for any species outside of the forestry industry. NY09023 sought to answer some questions about ornamental eucalypt species and hybrids:

1) How well does pollen of these species survive in storage, and what temperatures are optimum for germination?
2) How many days after anthesis (cap fall and pollen shed) do the stigmas become receptive? Previous research suggests anywhere from 0 to 10 days, but what is it for ornamental species? How does the phenology of a species/hybrid change and how do flower buds develop, and is there an effect of environmental conditions, such as temperature, day length or rainfall, on the timing of flowering?
3) What is the effect of flower size and genetic relatedness on "crossability"? If we cross *E. macrocarpa* with *C. ficifolia*, what are the chances that will produce viable seed? And what about the actual technique, can we use the methods developed by the forestry industry to make pollinations more efficient?
4) Propagation research: grafting, cuttings, and tissue culture all need investigating!

Humphris Nursery took on the propagation by grafting challenge, progressing their existing knowledge on methods to increase the efficiencies in production of rootstocks and grafted plants. Rootstock variability was identified as a problem area, and still remains one. Hopefully we can look at producing clonal rootstocks one day. Other problem areas identified are pre- and post- graft environmental conditions and scion size and maturity, and the time and expense of producing plants through grafting. An alternative propagation method would be desirable/more economic, but on-own-roots may be problematic?

Narromine Transplants, brave and generous souls, took on propagation by cuttings. Their approach investigated propagation by cuttings derived from mature trees (coppice) and from seedlings. One problem was the logistics of getting fresh cuttage material from Adelaide to Narromine in less than 3 days — the most efficient, although a trifle expensive, was to personally courier the fresh cut material to Narromine, a process which took 24 h, rather than express post or couriers which could take up to 3 days! The other problem, well, was simply eucalypts! They are extremely difficult to propagate by cuttings. The material has to be taken from coppice, and below a certain height on the tree, and at a specific maturity (firmness), number of nodes and intermodal length seems important too. Dan and his team produced some successes, but they were highly genotype

dependant, and not at all consistent or reproducible. Results are very dependant on maturity of tissue and the genotype. For example, one hybrid 22J, produced roots on cuttings taken in Oct. 2010, but failed to produce roots on material harvested in Dec. 2012. The difference was the maturity of the tissue — material harvested in December is just that little bit more mature and "harder" than material taken in October, even when coppicing occurred at the same time. Seed was sent to Narromine for germination and production of mother stock plants in situ, to eliminate the problem of transit time. Again, results were genotype specific, and also affected by season. So, back to the drawing board?

Yuruga Nursery and Clonal Solution investigated propagation via tissue culture, essentially micro cuttings. Using methods developed from the forestry industry, lines were established in culture from seed. This proved highly successful, with good initiation and multiplication from MOST seeds. Rooting and de-flasking proved much more difficult, and establishment even harder! Genotypic differences again reared their ugly heads, and created havoc, as every step is genotype dependant! One thing became clear early on; the *Corymbia* seed lines where much more suited to the standard tissue culture methods used by CSA than the *Symphyomyrtus*: *Bisectaria* lines parent at all stages of the process, including the media and conditions needed for multiplication and rooting, and for deflasking and establishment.

The other problem encountered with tissue culture is selection. If the plants are initiated into culture from seed, how do we select them for their ornamental characteristics? The first selection step is the actual initiation in culture — the line must multiply, root, and survive acclimatisation in sufficient numbers to be economically viable. Then, plants are set out to field trials to wait for flowering. This is most likely to take 5 years from seed, a long time in anyone's language, and for that whole time the lines must be maintained in tissue culture, with regular subculturing to maintain the health of the plantlets. If you are very lucky, you might get a line that flowers early, say, within 2 and a half years from seed. And it might have a flower colour that you are looking for. And it might have a habit that is desirable for home gardens and urban forestry. This is when you would need to start large scale field trials, in pots and in ground, to more thoroughly determine the characters of the new variety, and make sure it is stable.

The OEDP and collaborators are very happy to say that they were lucky that such a line was found, and we are progressing this little wonderplant through the field testing process as we speak.

SO, WHERE TO NOW?

The OEDP and collaborators are continuing to work with grafting and tissue culture propagation of ornamental eucalypt lines. While tissue culture is showing great promise for economical mass production of lines, it still has a long turn-around time until variety selection can take place. And there remains the question of the success of certain species/hybrid combinations on their own roots. Propagation by grafting remains an important tool in the OEDP kitbag, as some varieties may simply not grow on their own roots in all places in Australia. We are now ramping up to the next phase, with comprehensive trialling of a number of promising lines and looking to a bright and successful future. Myrtle rust is a current concern, and screening of taxa for tolerance will be part of our selection process.

The OEDP would like to acknowledge the contributions of many organisations and people, without whose contribution this work would not have made it this far:

- Horticulture Australia Limited, Rural Industries Research and Development Corporation, the Playford Trust, the Frank and Hilda Perry Trust, Don and Margaret Laidlaw and the University of Adelaide.
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Our Passion, Your Future Leaders©

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BACKGROUND

Most nursery owners in today's tough times are concerned about the business today and not about the future. This is completely understandable, we all have bills we have to pay.

I don't know how many nursery owners consider the future, will you still want to be managing the business in 10 years, would you like to enjoy your days fishing or playing a round of golf? Without competent staff to run your business this might be difficult. Ideally you would love to hand down the business to one of your children, what happens if this isn't possible, where does this leave you?

This is where I would suggest looking towards the future of developing your staff to the best of their abilities. I'm sure you're thinking that I don't have staff that are that interested in doing anything else and that's a valid point, however have you actually asked them what they want out of their job.

So you might ask what I should do to…?

If you are looking at developing future leaders within your business, it can be tough and I'm not saying that it will work with everyone, however it can start by finding an area of interest and developing this. Let them see what else is in the industry. You can develop tunnel vision or create an island effect if you see the same thing every day.

Both NGIV and IPPS support youth development in their own way to give the Next Generation an opportunity to succeed.

MY EXPERIENCE

Taken form someone that didn't grow up in the industry.

When I started my career in horticulture, I didn't know where it would take me. I always think of myself being part of the Jamie Durie generation. I would watch Groundforce and BackyardBblitz and think that's something I would like to do. So that's what I did; however, I didn't enjoy landscaping, because I didn't get to work with plants enough. I was lucky enough to have a great start in the industry. David and Andrew Mathews gave me my start at proteaflora, I wasn't to know then how good that start would be. I enjoyed my time at proteaflora, however, that's all I knew. In 2006 I was lucky enough to be involved in the 6-pack at the IPPS Brisbane Conference.

This was one of the best introductions into the industry; it really took me out of my comfort zone. Back then I was quite a shy person and didn't know how to network with people in the industry, let alone striking up a conversation. I had a great opportunity to build confidence in myself and build on my knowledge on the industry. At this point I learnt there was more to the industry than proteas.

Not long after being involved with IPPS and the 6-Pack, NextGen Victoria began. This was a great idea, like minded, simular age group, great speakers. This motivated me to find out more about this industry. Each NextGen function inspired me in a different way and gives me more motivation.

When I won the NextGen award part of the award was to attend each of the Tree & Shrubbies for a 12 month period. During this time I was invited to join the NextGen committee, so it only seemed right to deliver the NextGen report. I remember Steve Day saying to me once that when I started to deliver the NextGen report it was hard to get a word out of me and it was noticeable that I was nervous. How things have changed, this opportunity gave me confidence in public speaking, which in turn game me more

confidence to do my job.

The big turning point in my career was my trip to South Africa as part of the IPPS exchange program. This involved me traveling to South Africa for 3 weeks to work in nurseries and attend the regions IPPS conference. I have never been out of the country; however I saw this as a great opportunity to build on my career.

While in South Africa I was lucky enough to work at Arnelia nursery in Western Cape. This nursery has a partnership with Proteaflora, so I was very familiar with the running of the nursery.

The owner Hans Hettish asked me to observe what they were doing at the nursery and make some recommended changes on my last day. He wanted someone to look at the running of the nursery at the middle management level. I spent time talking with the team leaders and discussing issues and realise that it was something I was comfortable with. When I sat down and spoke with Hans I realise that this is something I wanted to invest more time in.

This is only a brief overview of what I have done in the industry, however I hope it gives you an idea of what the industry could do to motivate, develop, and your staff.

Using Eye Tracking to Understand Consumer Behaviour in Garden Centres©

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BACKGROUND

The Nursery and Garden Industry of Victoria (NGIV) with an international team of horticulture and retail researchers have been using eye tracking technology in stores to evaluate consumer reaction to point of purchase displays and signage. Eye technology captures exactly what the customer looks at and these data can be downloaded and analysed.

For example:

- What first catches the attention of a customer?
- How long does that element hold their attention?
- How many gazes does it attract?
- What area gets the most attention?

This information can be directly related to customer demographics, expressed preference and sales data. The research can provide information to plant producers and garden centres with evidence of what the customer looks at, what factors determine the decision and what they ultimately buy. This research aims to provide the nursery supply chain with unique information on customer behaviour leading to improvements in the shopping experience and enhancing profitable sales.

From a marketing standpoint, observing where people look id not a new concept. Nixon (1924) hid behind a curtain and first observed consumers' eye movements as they viewed magazine advertisements. Today, the gap in relating a purchase to stimuli viewed is closing (Pieters and Warlop, 1999; Russo and Leclerc, 1994) faster than when Triestman and Gregg (1979) first documented. Eye tracking hardware and software allow direct robust measurement of eye movements to assess that link. The majority of eye-tracking literature is related to the act of reading (Rayner, 1998, for example package labels Bix et al., 2009) and more traditional printed materials (Leven, 1991). Recently, eye-tracking studies have expanded to evaluate consumer perceptions and liking of outdoor advertisements (Maughan et al., 2007).

Merchandising displays are ubiquitous in retail settings. Producers and garden centres rely on displays to be silent salespeople, to draw consumers into the store and motivate them to touch, evaluate, and purchase products. Displays have the capacity to increase sales, for example Norfalt (2011) found that disorganised displays, which signal cheaper merchandise, can increase sales by over 900%. Thus, increasing our understanding of how consumers view and react to merchandise displays has both academic and practitioner relevance. The affordability and portability of eye-tracking hardware and software, along with the dearth of information about attention capturing stimuli in merchandise displays, make the time ripe for discovery about visually captivating elements of displays to the benefit of academia and industry.

Several studies have investigated consumer attention to discrete elements of the

environment, such as shelf facings and brands (Chandon et al., 2009) and mall media (Smith-Thomas, 2011). Virtually no holistic investigations of products in the retail setting have been published. Our goal is to provide qualitative and quantitative information to producers and garden centres to help them create more effective displays.

Visual cognitive processing requires the eyes to attend to an object, and attention requires eye movement (Russo, 1978). Eye movement is the fastest movement the human body can make (Holmqvist et al., 2011), consisting of a series of stops (fixations) and moves (saccades). Eye fixations direct attention and attention increases mental processing of the meaning of the object (e.g., word, image, or other stimulus). Characteristics about the person (top down factors) and about the stimulus (bottom up factors) contributes to attention and, thus, both have an impact on meaning derived from the stimulus. More is understood about top-down factors than bottom-up factors (Wedel and Pieters, 2008). The bottom-up factors (mode, objective, and features) or stimuli attributes and their role in capturing attention are only now becoming the subject of investigations due to improved affordability and compactness of eye-tracking hardware (Chandon et al., 2009).

The bulk of the peer-reviewed studies using eye-tracking investigated the process of reading by following eye movements (see Rayner 1998, for a 20 year review this subject). In consumer research, the peer-reviewed studies are sparse (see Wedel and Pieters, 2008, for the most comprehensive consumer research review) and nearly all are investigations of attention capture in print or electronic media. They reported that Leven (1991) demonstrated a preferred scan path (the map of a combination of saccades fixations over a stimulus) to create meaning from advertising images. This is because a person's attention selects a specific are on which the eyes focus and the brain enhances processing of that object. Complex information demands a longer fixation duration to more fully understand, when compared to relatively simple information (Wedel and Pieters, 2000). Kuisma et al. (2010) found that animation in online advertisements drew more of the viewers' attention for vertical advertisements compared to horizontal advertisements. Meisner and Decker (2010) demonstrated that consumers spent more time (eye fixations) viewing product attributes that were more important to them.

Maughan et al. (2007) found a correlation between eye fixations and "liking" of an advertisement. However the relationship between time spent looking and consumer decision making is not yet firmly established. For example, Patalano et al. (2009) documented that consumer indecisiveness was related to time spent viewing information about the purchase as well as time spent looking away from information directly related to that choice task.

Eye tracking has been used to analyse some other marketing stimuli, such as packaging but is still largely related to reading. For example, Teixeira et al. (2010) branded products received more viewer attention compared to unbranded products, regardless of product size. Bix (2009) investigated the prominence of package warnings on OTC medicines and showed they were not readily viewed. Sorensen et al. (2012) showed that product name on a label attracted the most attention, six times greater than any claim on organic production. They further showed that illustrations captured more attention than health claims, even if the illustration had nothing to do with the product. Meissner and Decker (2010) showed that consumers spent more time (eye fixation) on product attributes that were more important to them in a conjoint study. Eye tracking software will be used to develop new food labels for European products (Bonsmann et al., 2010).

Eye tracking research has begun to focus on evaluation of point of purchase marketing Chandon et al. (2009) explored the influence of number and position of shelf facings on consumer attention and evaluation of display shelves. The effectiveness of mall media in capturing attention was investigated by Smith-Thomas (2011). For research on merchandise displays in situ, researchers reported that, "Despite the typically large and hence promising sales effects of special display studies, the area is not particularly well marked out (Chevalier, 1975). For instance, special displays are assumed to be a powerful tool to capture the customers' attention. Yet, this aspect is very little elaborated on in academic studies" (Nordfalt, 2011, p.169). He postulated that learning more about

capturing attention is of "great academic and practical interest" and went on to show with eye-tracking hardware that electronic signs, indeed, did capture more consumer attention. Understanding the impact of point of purchase marketing is critical, as 68% of buying decisions are unplanned (Stahlberg and Maila, 2010). Effective displays and other marketing materials present an opportunity to capture consumer attention and share of wallet.

The emerging body of peer-review eye-tracking literature has more studies related to the act of reading (e.g., advertisement assessment or package labels) than viewing merchandise displays in store. Wedel and Peters (2008, p.143) call for more research on "other static visual marketing stimuli besides print ads". Given the void in the literature for field research on displays and the emergence of affordable, portable eye-tracking hardware and software, there is an ideal opportunity to investigate what captures attention in displays that, as Nordfalt expressed would be of "great academic and practical interest. We seek to expand on previous research by using portable eye-tracking hardware to assess merchandised products in displays with signage. We see this effort as an equally important use of the technology to better measure bottom-up factors that literally catch consumers' attention and improves the shopping experience and results in a greater probability of purchase.

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The Design and Construction of Oman Botanic Garden©

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INTRODUCTION: OMAN BOTANIC GARDEN PROJECT

Oman Botanic Garden (OBG) is currently under construction in the Arabian Peninsula. It is located close to Oman's capital city, Muscat, and will be open to the public in a few years. The garden is a governmental project and part of the Diwan of Royal Court. The aim of the project is to conserve the biodiversity and botanical heritage of Oman for a sustainable world. The project will do this by displaying the entire flora of the country in naturalistic habitat-style plantings and will include extensive exhibitions about plants and how they are used. The 420ha site of the botanic garden was selected for its beauty, dramatic landscape and plant diversity, with 10% of Oman's native flora already naturally present.

Fig. 1. Oman Botanic Garden site.

VISION AND MISSION OF THE PROJECT

Vision

People are inspired to conserve and cherish the biodiversity and botanical heritage of Oman to contribute towards a sustainable future.

Mission

Discover, cultivate, showcase and protect Oman's unique plant diversity and ethnobotany through innovative research, exciting displays and engaging communication.

PROJECT HISTORY

In 2006, Oman Botanic Garden was established by Royal Decree in a rented nursery close to the current site. With few staff they started collecting native plants from the wild. In 2008, the Construction of Oman Botanic garden nursery started on the current site. Fifty-one thousand plants were transferred from rented facilities to new nursery in preparation for the official opening of the nursery by the Minister of the Diwan of Royal Court. From 2009, they started the Construction of the Orientation Centre, Field Studies Centre, Research Centre and Heritage Village (ongoing). In 2010, the team planted the first habitat of the Northern Gravel Desert. Through these years, we still work on collecting the seeds, propagating the plants either by seeds or cuttings, collecting the herbarium specimens and translocation endangered plants destined to be destroyed road construction.

LANDSCAPE AND FLORA OF OMAN

Landscape

Oman covers 309,500 km^2 and encompasses a diverse range of topography, including mountain ranges, arid deserts and fertile plains.

Oman's climate is very diverse with humid coastal areas and a hot and dry desert interior. The seasonal cloud forest of Dhofar, in the south of Oman, is lush during the summer monsoon or Khareef (July-September) and is home to most of the country's endemic flora.

The varied topography and climate of Oman, with the Dhofar range of mountains in the south and Hajar Mountains in the north also contribute to the level of plant diversity.

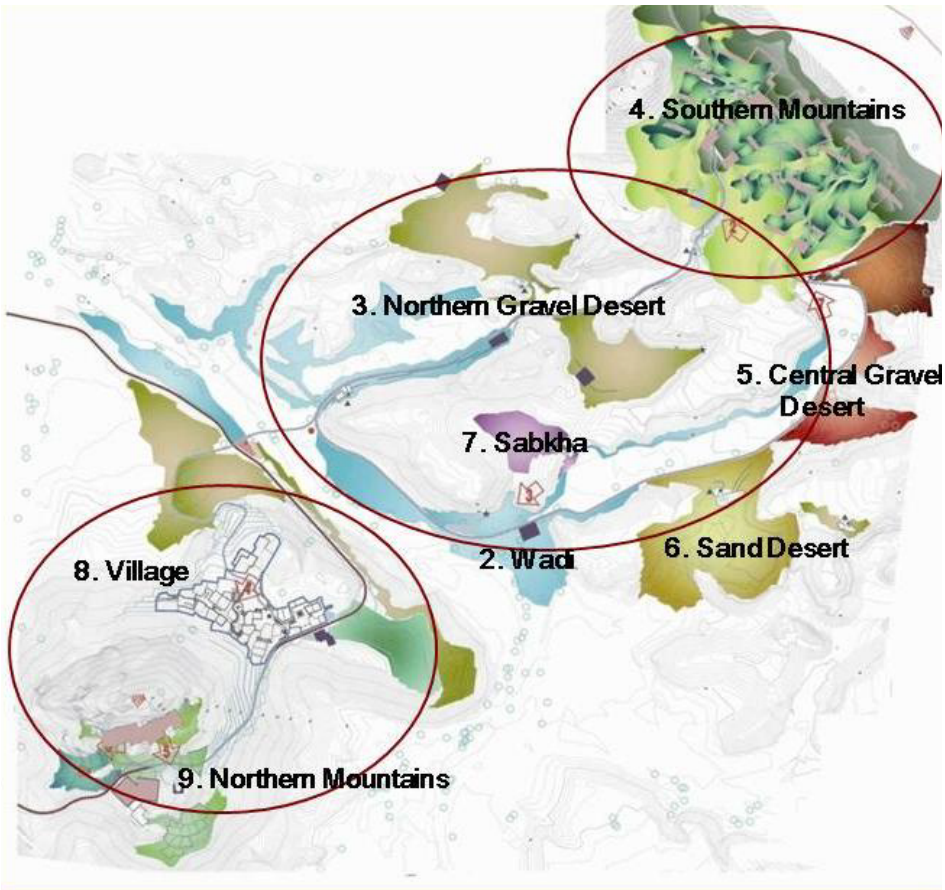

Fig. 2. Oman covers 309,500 km^2 and encompasses a diverse range of topography.

Flora of Oman

Oman is home to 1,200 species of plant, of which 79 are endemic, found nowhere else in the world. About 22% of Oman's plants are range-restricted or face threats such as over-grazing, inappropriate development, off-road driving and climate change.

The Oman Botanic Garden botany team collects plants as seeds and cuttings through its regular field trips; over 250 expeditions have visited all corners of the country since 2006, each one collecting, monitoring and recording invaluable data about Oman's plants and environment. Seeds are brought back to the garden, cleaned and stored in the seed bank until they are germinated by the propagation team in the nursery

From 0 plants in 2006, the number of plants at the nursery has grown to 75,298 plants of 694 species in 2013. This is the largest documented collection of Arabian plants in the world.

The Oman Botanic Garden will form a key part of Oman's response to the Convention on Biological Diversity in particular the Global Strategy for Plant Conservation.

THE PROJECT – WHAT ARE WE DOING?

Master Plan-Key Components

1. Habitats (outdoor): under Construction. Oman's flora will be displayed within a series of naturalistic habitats. The first of these, the Northern gravel desert, was planted in March 2010 with native plants carefully positioned to reflect the natural habitat as closely as possible. Other outdoor habitats will include wadi, sabkha, central fog desert and sand desert (Figs. 3-8).

Fig. 3. Northern gravel desert habitat, planted 2010.

Fig. 4. Sabkha habitat.

Fig. 5. Central desert habitat.

Fig. 6. Wadi habitat.

Fig. 7. Agricultural terraces in Jabal Akdar.

Fig. 8. Dhofar monsoon season.

2. Habitats (Indoor): Northern and Southern Biomes — Construction Not Started. The plants of Dhofar, Jabal Akhdar, and Musandam will be housed in "biomes" to ensure they have the controlled climate conditions they require. In the biomes of Dhofar plants the visitors will experience the Khareef (or monsoon season) at any time of year.

ORIENTATION CENTRE/RESEARCH CENTRE/FIELD STUDIES CENTRE
Currently under construction, this complex includes ticketing and exhibition areas for visitors, with cafes, plant shop and gift shop, laboratories, lecture theatre, offices, library, herbarium, seed bank, classrooms, and accommodation for visiting students and researchers.

Sustainability
Oman Botanic Garden will follow sustainability principles in its design, construction and operation. To protect our unique plants and precious environment, we need to live in a more environmentally-friendly, or sustainable, way so that our lives do not damage the environment that supports us.

We are aiming for international recognition through the LEED (Leadership in Energy and Environmental Design) certification process. This demonstrates that we are using water efficiently, using recycled, locally produced and safe materials, minimising energy use, investing in renewable energy sources and sharing what we learn with our visitors.

Existing Facilities
1. Nursery. The first part of the botanic garden built on site, this state-of-the-art facility includes a shade house (3000 m^2), an outside standing area (3000 m^2), four polytunnels (4000 m^2), seven glasshouses (2600 m^2), a propagation shed, offices and meeting room.
2. Other Facilities on Site. Herbarium, seed bank, and extensive electronic database that keeps track of the plants, where and when they were collected, environmental conditions in the natural environment, how they are grown as well as how much water or fertilizer they need. Each plant has its own complete record — a plant 'passport' which links it the records of its history within the database.

Departments

1. Living Collections. One of the key objectives of the garden is to collect, cultivate, and display Omani plants, the majority of these plants had never been cultivated before, which makes it very challenging. Diversity is of major importance, so collections are mainly from seeds, however cuttings and whole living plants are collected for certain species.

2. Propagation. The propagation team are responsible for the propagation of plants either by seeds or cuttings. Prior to germination seeds either directly sown or socked in water for 24 h and then directly sown into standard seed trays with potting media (fine peat moss cover with vermiculite or fine sand depending on the species). Smaller seeds are broadcast into the trays, but larger seeds are spaced using a sowing template in a tray. The seed trays then labelled (each seed has a unique propagation number in the BG base programme) and kept in the propagation house. The seed trays are watered daily, being soaked in large trays, to enable water to penetrate from the bottom up. If germination occurs, young plantlets are pricked-out after reaching 50-100 mm in height. Once the seedlings have developed strong roots then they are ready to be transferred into larger pots.

Cuttings are prepared and grown in a medium (peat moss and perlite (1:3, v/v). In some cases sieved washed peat moss and wadi sand (1:2, v/v) are used. Cuttings are placed on benches in the propagation house. Mist is applied from the top to keep the cuttings fresh and heated from the bottom, (winter only) in order to enhance rooting.

3. Production. Once seedlings or cuttings are strong enough they are transferred into a polythene tunnel or shade structure. The standard Oman Botanic Garden potting medium, consists of peat moss, vermiculite, and loam soil (3:1:1, by vol.) and slow release fertilizer. All plants are then placed in a cooled, 70% shaded greenhouse, and watered daily. For succulents, desert perennials, and bulbs, different soil mixtures were developed. Succulent mixtures comprise of coarse gravel and vermiculite (1:1, v/v). Desert perennials — standard Oman Botanic Garden mix (1:1, v/v), and for bulbs — Oman Botanic Garden standard mix plus coarse vermiculite and good quality loam soil (1:2:1, by vol.).

Big trees are transferred in air pots until they are planted out on site. Air pots have had a positive impact on growth rates and longer term survival of large trees and shrubs. The perforations in the pots allow for air-pruning so protruding roots are effectively dried out when they come into contact with the outside environment. The air flow also allows the roots to stay cooler, which is vital when there are high summer temperatures (48°C) in the nursery.

Transplanting and rescue of mature trees from degraded or disturbed sites is ongoing. The team works in conjunction with a number of different contractors which include visits to road construction projects, water pipeline sites etc. to identify large trees for rescuing. Large trucks and construction machinery are used to excavate mature specimens that would otherwise have been destroyed. The survival rate is about 75%. Examples of rescued plants include *Olea europaea*, *Dracaena serrulata*, (endangered) *Boswellia sacra* (frankincense), *Commiphora*s, and *Adenium obesum* (desert rose). To date over 1000 mature trees have been rescued.

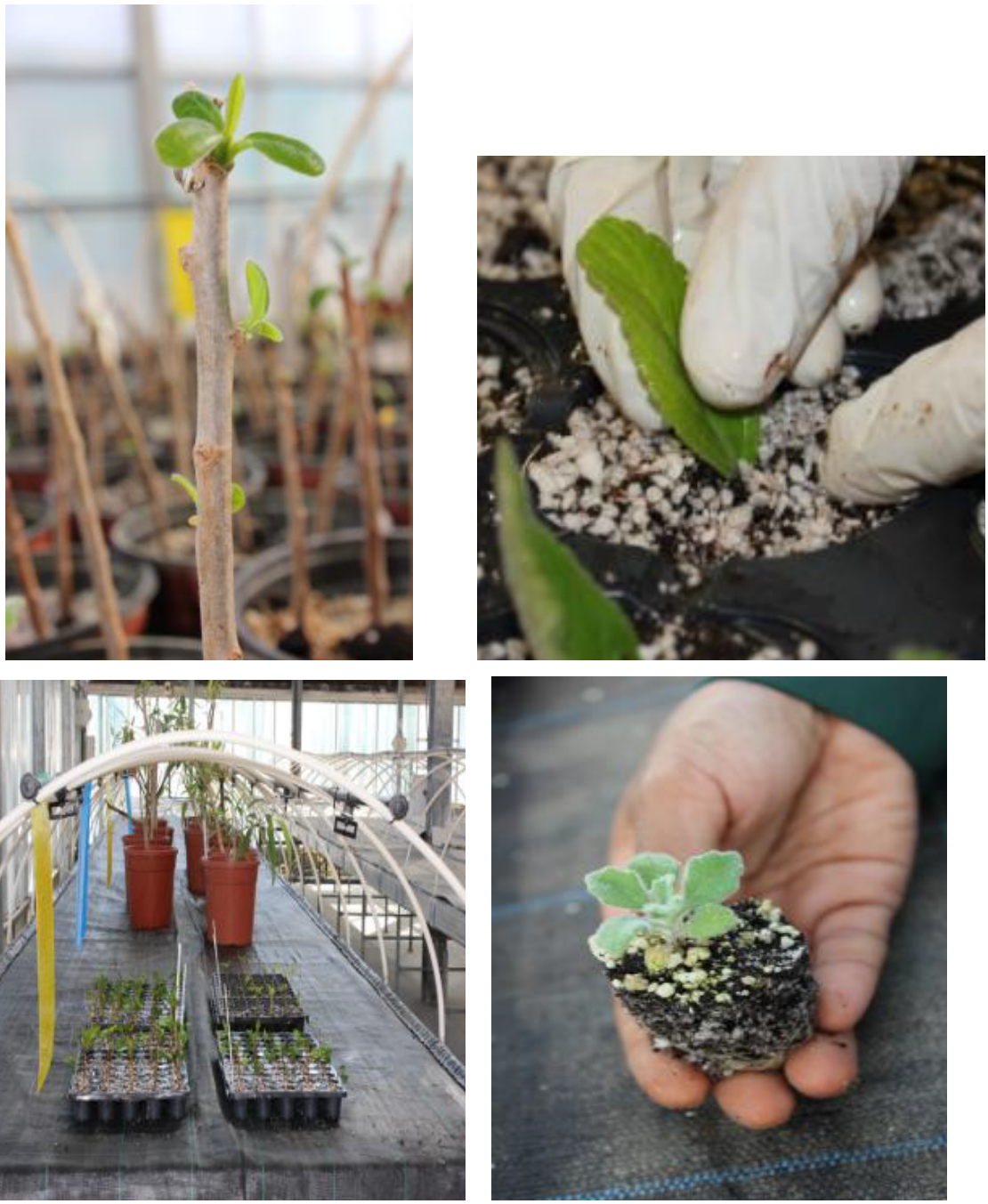

Fig. 9. Propagation at Oman Botanic Garden.

Fig. 10. Air pots.

Fig. 11. Transplanting and rescue of mature trees.

4. Plant Health. Plant health is important in the fight against pests and diseases. Chemical use is minimised and is based on low-toxicity. The use of strong organo-phosphates is not permitted on the site. Instead more environmentally friendly pesticides, like Indian neem cakes (*Azadirachta indica*) and lemon and chilli grass extracts, are used. In the future it is hoped that biological control agents will be used to effectively combat all pests and diseases. Integrated pest management helps reduce pesticide use. Good hygiene is of paramount importance to good plant health. Infestation levels are continuously monitored. Different coloured insect sticky traps help to monitor and trap insect pests.

Fig. 12. coloured insect sticky traps.

Botany and Conservation
This department includes; seed bank, herbarium, ethnobotany, taxonomy, field work, and conservation.

A fundamentally important part of the botany team duties is conducting plant collection trips around Oman. They record information related to the plants, including date of collection, name(s) of collectors, location (GPS), locality, type of material, life form, soil type, associated flora, local use, herbarium specimens. All plant and habitat data are stored on the garden's extensive plant database (BG-Base).

Fig. 13. Botany team duties include conducting plant collection trips and recording information related to the plants.

The current temporary seed bank is responsible for the cleaning and storing of all accessioned seeds. The OBG seed bank currently holds a vitally important ex-situ

collection. The seed bank manages the core of the garden's living collection and is a repository of a vast amount of regional plant genetic diversity.

Fig. 14. Current temporary seed bank.

Plant identification and taxonomy form a vital part of the departments function. New collections are added all the time, in many cases new local, national, or regional records are found.

Ethnobotany team are documenting and digitising Oman's long history and vast experiences with traditional plant uses. The team conduct plant collecting field trips and audio and video interviews with traditional herbalists, crafts people and farmers. All of the information collected is being inputted on to the garden's plant database.

Fig. 15. Ethnobotany team is documenting and digitising Oman's long history.

Oman Botanic Garden's Herbarium is the third largest collection in Oman, housing approximately 2,700 specimens focusing mainly on Oman's native species. From 2006 till now they have nearly 1,500 specimens belonging to 91 family, and 691 plant species. All the specimens are accessioned in a computerized database. The collection is organized alphabetically by family, alphabetically by genus within family and alphabetically by species within genus.

Fig. 16. Oman Botanic Garden staff collecting native plants.

EDUCATION AND COMMUNICATION

To engage with the public, Oman Botanic Garden produces and distributes a regular newsletter, both hardcopy and via email, to several thousand supporters. In addition, a temporary visitor centre is used for pre-booked visiting groups and school parties.

Micropropagation of Sphagnum Moss for Peat Land Regeneration©

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INTRODUCTION

The author has been involved in micropropagation since 1976. He undertook a PhD in the technique at Nottingham University before starting his own laboratory and nursery in partnership with his wife, Barbara and, as an IPPS member for all that time, has shared most of the supposed "secrets" of micropropagation.

Micropropagation is labour intensive and is now largely undertaken in regions with cheap labour such as Eastern Europe, India, and China. However, with very careful management and integration into niche markets, there is still a place for it in the U.K. The basics of micropropagation have not changed much over the last 30 years but there has always been a need to control costs and, in the traditional IPPS manner, low investment innovations have been developed by the author both for the laboratory and nursery at Micropropagation Services. These include home-made sterile air cabinets and alternatives to scientific apparatus wherever possible, and the use of gantry mounted mowers for trimming plug plants to improve bushiness and uniformity. Early adoption of innovations, such as the Evaposensor for mist control in weaning has also proved essential to maintain an edge over the competition.

The business undertakes micropropagation of many different species including woody and herbaceous ornamentals, forest trees, and edible crops. Very careful management of production, order processing, stock and cost control are essential, achieved by the use and development of an in-house database programme which also enables complete traceability from original stock plant to delivery.

Niche markets have been developed and any very large scale production has been passed to laboratories overseas, so competition with producers with access to cheap labour is minimised.

One niche market; the production of native species for vegetation restoration in The Peak District, Derbyshire, has lead to the development of a unique product. Novel propagules produced using in vitro techniques and encapsulated in a gel (BeadaMoss™) provided the opportunity to "re-seed" large areas economically. The business is now propagating Sphagnum moss on a large scale to re-establish it on degraded areas of peat bogs to restore them to the fully-functioning carbon sequestering ecosystems that they should be.

PEATLAND REGENERATION

Re-establishment of sphagnum moss is key to restoring degraded ombrotrophic bogs to functioning ecosystems. In the Peak District and South Pennine bogs of England where sphagnum was almost wiped out after the Industrial Revolution, recovery of peatlands is limited by low numbers of actively growing local Sphagnum populations for regeneration or propagation.

Propagation of Sphagnum

In areas where restoration of sphagnum is desirable there is very little material available as a source, either because it has been degraded or is legally protected by conservation laws. A rapid propagation method was developed and has proved suitable for 12 species tested so far. Large quantities of sphagnum plants can now be routinely produced.

Distribution of Sphagnum Propagules onto the Bog

Sphagnum is very difficult to handle and distribute, when removed from the growing medium surface. It behaves like a wet blanket and it is difficult to separate individual

plantlets. A method has been developed to encapsulate sphagnum plantlets, a few millimetres in size allowing easy separation and planting onto the bog surface (Fig. 1). The beads produced by this system (termed BeadaMoss™) are tolerant of tough in vivo conditions enabling handling with air-seeding machines and distribution from a helicopter, thus making large scale planting viable and achievable (Fig. 2). They can equally be handled and planted by ground based machines on suitable surfaces, such as that on a peat bog which has been cut over to provide peat for horticultural growing media.

Fig. 1. BeadaMoss™: Inside each bead are numerous tiny propagules, each with the potential to grow into a sphagnum plant.

Fig. 2. Helicopter mounted seeder applying BeadaMoss™.

Growth Trials

Sphagnum plantlets in beads (BeadaMoss™) produced recognisable sphagnum growth within 2 to 3 weeks of being placed onto a commercial peat growing medium in a glasshouse at approximately 20°C. Within 8 to 10 weeks these had grown and spread to approximately 10 mm diameter (Fig. 3). The beads have been tested for their ability to grow if buried in substrate, and the sphagnum was found to be able to grow to the surface within 8 to 10 weeks from a depth of 30 mm.

Fig. 3. BeadaMoss™ after 8-10 weeks in glasshouse.

Cold tolerance was also tested. At temperatures down to 0°C there was no deterioration in growth rate or survival. At -5°C 70% of the beads had produced sphagnum growth after 10 weeks, but growth was delayed by 2 to 3 weeks compared with that from beads sown at temperatures above 0°C.

Field Trials on Degraded Bog

A series of permanent 0.5×0.5 m quadrats containing sphagnum beads was set up on two sites in the Southern Pennines (Black Hill restoration site and Holme Moss site with bare peatland), The quadrats were placed at random in three blocks at each site. The plots were first examined in Autumn 2011. All growing pieces of sphagnum were counted and then marked with thin canes for future monitoring. Survival on bare areas has been lower than for restored areas where the surface has been stabilised (Fig. 4).

Fig. 4. A forest of canes marking 62 visible sphagnum plants of the original 90 propagules planted.

Trials on Cut-Over and Harvested Bogs

The best results were produced in areas with a stabilised peat surface (using brash, grass seed, or cotton grass plugs) (Fig. 5).

BeadaMoss™ was applied in spring to plots of bare peat and to peat surfaces stabilised with brash. For the plots where the surface was stabilised using cotton grass (*Eriophorum angustifolium*), cotton grass plugs were planted in spring and beads were applied 4 months later.

Fig. 5. Harvested bog: Early stages of sphagnum growth in cotton grass restored area.

Small sphagnum plants established well on cotton grass stabilised surfaces as the grass acted as an effective "nurse crop" (Fig. 6). Sphagnum grows through coarse chopped brash but finely chopped brash can crust and inhibit sphagnum growth. Without anything to prevent frost heave and surface movement on the bare plots, no sphagnum could establish.

Fig. 6. Established sphagnum from bead.

DISCUSSION

Sphagnum beads (BeadaMoss™) can establish and grow into significant robust patches of moss that can survive harsh winters and even the moderately severe drought in Spring 2010. Given sufficient time a very large percentage of beads can produce sphagnum patches more than 2 years after planting.

Sphagnum establishment from beads on vegetation stabilised surfaces, such as at the Black Hill site, was evident more quickly than on the bare peat (Holme Moss). However, even on bare peat with ground conditions previously thought too severe, sphagnum beads can colonise with a good degree of success, given time.

The survival rate of beads even in fairly severe conditions means that a good sphagnum cover can be achieved over large areas, by seeding with BeadaMoss™. The real possibility of restoring a fully functioning sphagnum bog back to the Derbyshire Peak District and other degraded cut-over bogs is therefore becoming a reality.

Propagation and Reintroduction of Two Rare Plant Species in the South-Eastern United States of America©

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The habitats of *Sarracenia rubra* subsp. *wherryi* (Wherry's pitcher plant) and *Symphyotrichum georgianum* (Georgia aster) have been declining as a result of human population growth, poor land management, invasive exotic species, and fire prevention. Through a partnership with the U.S. Forest Service and the Beattie Foundation measures have been taken to protect these species through a propagation and re-introduction program.

INTRODUCTION

Many plants native to the United States of America have become rare as a result of land development, poor land management, invasive exotic species, and prevention of fire. Fire is necessary for the maintenance of many ecosystems in the South-eastern United States and removing it from such ecosystems results in a dense understory that limits penetration of sunlight to the forest floor (Gilliam and Platt, 1999). Propagation and reintroduction can help to combat the loss of plant populations. This project was divided into two parts, to determine propagation and reintroduction methods appropriate to each species.

GEORGIA ASTER

Symphyotrichum georgianum (Alexander) G. L. Nesom (syn. *Aster georgianus*) is a perennial plant with a native distribution from central Alabama to central North Carolina (Lynch et al., 2013; Anon, 2010). It blooms from October to November with large dark purple ray florets and lavender disk florets. It is native to dry oak and pine ecosystems and tolerates soils from sand to heavy clay (Fig. 1).

Fig. 1. *Symphyotrichum georgianum* flowers.

To date, 127 populations have been recorded, though many of these have not been observed in the past 10 years. Most of the remaining populations are next to roads, railroads and utility right-of-ways where vegetation management mimics natural disturbance (Anon, 2010). The species is classified as having a moderate, imminent threat of extinction.

Seed Propagation

The objective of this part of the project was to determine whether population numbers could be increased through seed propagation.

Seed was collected from a small population in a utility right-of-way located in Talladega National Forest. This population was able to survive because of mowing that mimicked fire by removing woody species that would compete for light.

The seeds were taken to Auburn University to test viability. They were sown into a commercially available germination substrate (Fafard® Super Fine Germination Mix, Sun Gro® Horticulture Agawam, Massachusetts, USA) in February 2010. There appeared to be no problem with germination and stratification was not necessary. The seedlings were potted into 18-cell flats using a pinebark, peat and, perlite (5:3:1, by vol.) substrate containing controlled released fertilizer (Polyon® with micros 17:5:11 (N:P:K), Harrel's LLC, Lakeland, Florida) at 4.5 $kg \cdot m^{-3}$ and dolomitic limestone at 1.8 $kg \cdot m^{-3}$. The plants were grown under natural photoperiod on raised benches in a greenhouse at Paterson Horticulture Greenhouse Complex at Auburn University.

Later in 2010, 30 plants were reintroduced to the parent population. The process was repeated in 2011 and 2012, each year with more seed available from the introduction of more plants to the population. So far, more than 1,300 plants have been reintroduced to Talladega National Forest.

WHERRY'S PITCHER PLANT

Sarracenia rubra Walter subsp. *wherryi* (F.W. Case & R.B. Case) Schnell (syn. *Sarracenia alabamensis* F.W. Case & R.B. Case ssp. *wherryi*) is a carnivorous plant native to bogs in longleaf pine savannas and sandy seeps. It has a historical distribution of southern Mississippi, northwestern Florida, and southern Alabama (Schnell, 2002). In 2000, it was listed as endangered by the International Union for Conservation of Nature and Natural Resources' Red List of Threatened Species (Schnell et al., 2000). This classification means the population has decreased by more than 50% in past 10 years, the species occupies an area less than 500 km^2, has a total population of less than 2500 individuals (with no subpopulation of more than 250 individuals) and populations are expected to decrease by a further 20% within the next two generations.

Reintroduction Trial

The objective of this part of the project was to determine whether growth stage at planting (dormant or actively growing) affected survival rates at reintroduction sites.

Three large clumps were collected in May 2012 from a bog in Conecuh National Forest in southern Alabama. The population was in decline because the land had become heavily shaded as a result of economic conditions delaying a timber harvest. The clumps were taken to Auburn University where soil and leaves were removed from the rhizomes. Rhizome cuttings were taken so that each cutting contained 2 to 4 nodes and cut surfaces were dusted with powdered sulfur to prevent pests and disease. Rhizomes were potted just below the soil surface in 2.5-L containers in a peat and perlite (1:1, v/v) substrate. Plants were grown under natural photoperiod on raised benches in a greenhouse at Paterson Horticulture Greenhouse Complex at Auburn University (Fig. 2).

Fig. 2. *Sarracenia rubra* subsp. *wherryi* growing at Paterson Horticulture Greenhouse Complex at Auburn University.

Ten actively growing plants, from terminal cuttings, were planted in August 2012 at Donald E. Davis Arboretum and 10 more into a managed natural bog in Conecuh National Forest. Twenty more plants from terminal cuttings were placed in a walk-in cooler (4°C) in January 2013, for 6 weeks to induce dormancy. In February, the 20 dormant plants were then planted at the same locations: 10 at Donald E. Davis Arboretum and 10 at Conecuh National Forest. Survival was assessed in September 2013.

All of the dormant and actively growing plants had survived. One plant from the dormant treatment attempted to flower, but the bud was killed in a late season frost. Stage of growth at planting therefore appears to have no effect on the ability of Wherry's pitcher plant to establish after reintroduction. It would be useful to undertake future

research to determine whether induced dormancy can advance flowering of plants grown from rhizome cuttings.

DISCUSSION

Future projects related to this research are planned. Currently there are more than 100 *S. rubra* subsp. *wherryi* plants to be reintroduced into Conecuh National Forest and seed propagation is being explored on other species of *Sarracenia* in Alabama. Seed propagation and reintroduction of *S. georgianum* continues. The success of these projects has led the United States Forest Service to initiate other projects with Auburn University to protect other rare plant species found in National Forests of Alabama.

As consumer interest in native plants continues to increase it brings opportunities for commercial propagators and growers in the southern USA. Native plants have the potential to be an untapped market while carnivorous plants continue to be of high interest to collectors. By having these plants available from environmentally sustainable propagation there is the potential to reduce poaching of native populations.

Native plant propagation, proper land management, and increased research is important to safeguard decreasing populations of rare plants.

ACKNOWLEDGEMENTS

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Propagation in New Zealand for Northern Hemisphere Markets©

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INTRODUCTION

The New Zealand nursery industry has a long history of supplying plants to Europe, particularly to the United Kingdom. Partly this is because of the historical links to "the old country" through the Commonwealth; but New Zealand's climatic and geological conditions mean that plants grown there do well in Europe and North America, despite the long distance from these markets. Native plants for the export trade remain a mainstay of production for many New Zealand nurseries, such as Naturally Native and NZ Liners, and will no doubt continue as long as there are European growers looking for new cultivars, forms, and species to introduce and grow.

This paper describes the author's experiences of supplying plants to Europe and the U.K. from New Zealand.

My first contacts with the products of southern hemisphere nurseries came in the early 1980s when sales and marketing agent Jackie Morris made an annual visit to Wyevale Nurseries, Hereford, marketing plants from France (on behalf of Plandorex) and from New Zealand (on behalf of Topline). At this period, there was a relatively large range of plants on offer from Southern Hemisphere growers, from suppliers such as Duncan & Davies (New Zealand) and Malinsuns (South Africa). Plants new to the U.K. market from such sources included *Photina* × *fraseri* 'Red Robin', actinidia, and phormiums while many other plants indigenous to the Southern Hemisphere were traded in high volumes, initially, to European destinations. Subsequently, European home production of these plants increased and importation was reduced, with only the more difficult-to-grow taxa being imported, such as phormiums.

Initially, stock was exported from New Zealand bare-root with varying degrees of success, depending on the season, taxon, and the technical abilities of purchasing grower. With the development of inert composts and plug production techniques, young plug plants became the normal export product, the bare-root trade for non-woody plants had virtually disappeared by the late 1990s.

During the early 1990s, Peter Williamson, my old boss at Wyevale Nurseries, would often return from visits to New Zealand, full of enthusiasm for production techniques new to us, such as hardwood cutting production of wisterias and hibiscus; and budding of *Acer*, *Cornus*, *Hamamelis*, and *Magnolia* taxa in the open ground. Of course we tried to copy all these techniques to the best of our ability at Hereford, but with little success, putting the failure down to climatic differences, and the unforgiving Hereford clay soils.

When Wyevale Nurseries acquired the nursery business of Desmartis SA in the south west of France, Peter's enthusiasm for copying some of the New Zealand production systems was rekindled, as he felt convinced that the warmer climate the and rich fertile soils of the Dordogne region would allow him to achieve his dream of European "New Zealand" style field produced *Acer* and *Magnolia* crops. Unfortunately the success rate was unremarkable, and certainly not commercial, and the project was abandoned after several years of disappointing results.

GROWING IN NEW ZEALAND FOR EXPORT

During the 1990s I had become involved in nursery stock sales and marketing and in 1994 took over Jackie Morris's portfolio including stock from NZ Liners and a new business called Stepping Stones Nursery which at the time was working to generate a market in *Acer*, *Cornus*, and *Hamamelis* species.

Stepping Stones Nursery is located in the south west corner of North Island, near New Plymouth, where the spectacular volcanic Mount Taranaki dominates the scenery. The nursery is sub-divided into blocks for the *Acer* species, with high hedges to prevent wind

and salt damage to the crop. The soils are deep, well-drained, and volcanic and the mild damp climate lends itself to outdoor *Acer* production. More than a million understocks are produced each year in the 40-ha production area, the stems being cut to the desired size with up to 2 m length rods being produced for the full standard crop.

The production cycle starts during late July to early August with the cutting and preparation of the hardwood understocks, which are then callused in bottom-heated boxes. The callused cuttings are pushed through plastic into a fine tilth and allowed to develop. Irrigation is not usually needed as the climate provides a regular natural watering.

Once the under-stocks are established the propagation process can begin. In the past, budding was the main propagation system, resulting in a single shoot, tree-like plant. Over the years, budding has largely been replaced by grafting to produce a bushier, multi-stem plant, with branching from the base.

Of the 1 million understocks planted, some 850,000 are successfully budded or grafted.

Budding and grafting starts in mid-October, for the larger plants, finishing in December with the "piccolos," the smallest grade produced so far.

The "shut-down" process begins in late May to early June when copper sprays are used to promote leaf abscission, and undercutting in some cases to prepare the plants for lifting.

Dispatch is generally from late June to late July. This short 6-week window for plant exportation from the southern to the northern hemisphere cannot be missed. Invariably, there is a mild New Zealand autumn, but we cannot wait for a natural autumn ripening.

Prior to lifting all plants are sticky labelled to avoid mixing in the lifting, cleaning, and dispatch processes. Plants are bulk-lifted and heeled into holding areas. The plants are then taken for processing and put through the cleaning and dispatch preparation process. Once on the processing chain, the plants are root-dipped in a water-retaining gel and packed carefully to achieve maximum box loading. The plants are packed with damp shredded paper to ensure they arrive at their destination in a damp humid condition. The boxes are shipped to Auckland airport where they are cold-stored at 5-6°C for several days before being palleted and flown to Europe.

All Stepping Stones plants are cleared to U.S.D.A. standards, so are free of soil, and well within E.U. standards. All plants can be traced back to individually identifiable fields and undergo regular growing seasonal inspections, as well as receiving a further health inspection prior to export.

Airfreight is calculated by volume until a certain weight and then the charge is by the kilo, so nurseries aim to use the volume to the maximum. Transport costs are between 10-12% of the overall price charged to the customer despite the long distance involved.

The aim is to have the plants on the client's nursery in less than 5 days following departure of the shipment, but it is often quicker than this.

Once the plants arrive at their destination, they need to be potted immediately because dormancy will already have been broken, with a gradual temperature increase during the journey. Bud-breaking is expected some 2 to 3 weeks after arrival in Europe, with the plants getting on average a half season of growth over 10 weeks.

Production of Cuttings at Alkemade Brothers: Observations on Quality Control and Use of Light Emitting Diode Lights©

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INTRODUCTION

The business was established by Theo Alkemade in 1990 as a cut flower nursery and then began producing rooted cuttings on a small scale as a second crop. A few years later his twin brother Wil joined the company and they started specialising in rooted cuttings. As the company developed it expanded to four locations approximately 5 miles apart, which was not very efficient. An opportunity to relocate the whole company to one location arose in 2011. The new location is 30,000 m^2 and includes 28,000 m^2 of greenhouse. In 2012, approximately 17 million cuttings of more than 1,000 taxa were produced, half of them are sold in the Netherlands the other half is exported, mainly across Europe. This is achieved with a workforce of 12 and there are up to 15 part-time workers during the busiest periods.

Theo and Wil don't want to expand further, so the business will develop by producing better quality cuttings and using the space more efficiently. This can be done by growing the cuttings in a bigger size tray, producing a bigger plant which will give our customers a head start and the chance to produce an extra crop each year.

THE NEW NURSERY

With four locations, one major problem was that the greenhouses were of different sizes which made modernisation nearly impossible. The new nursery gave an opportunity to start from scratch in a single empty greenhouse.

First a water drainage and recycling system was installed in the floor and covered with a layer of crushed lava. The floor heating system was placed on top of that and this was also covered with a layer of lava. After that the lava was covered with anti-rooting sheets. In the old nurseries the trays of cuttings had been stood on sand beds. The lava floor drains the water much faster than a sandy floor. The biggest benefit of this is that there are fewer root problems in the autumn and winter.

A rail system was placed on every bed to carry trolleys for picking orders. The trolleys are taken to the dispatch area with electric transport carts. We also have a a trimming machine that rides over these rails which makes trimming a one-person rather than two-person job and it also gives a significantly better trimmed quality than we were able to achieve with the old set-up because it is now possible to always trim the cuttings on time. Our existing spraying machine was adjusted to enable it to ride over these rails, too resulting in more even spraying.

In the old nurseries there were six rooting areas with a capacity of 800,000 cuttings, in the new nursery two rooting areas were constructed with a capacity of 1.6 million cuttings. With just two areas it is now much easier to monitor how the cuttings are growing and provides the opportunity to react fast if things are not going as planned.

THE PRODUCTION PROCESS

Unrooted cuttings can now be bought-in more efficiently to the new facility which helps to improve quality throughout the production process. The process is based on how long it takes for a rooted cutting to be ready for sale. If it takes 10 weeks and the customer wants the cuttings in Week 25, the cuttings will be stuck in Week 15. This way the customer gets a fresh cutting and it is less work to prepare them ready for delivery, as well as reducing the risk of losses before dispatch.

The business aims to use a minimal quantity of mother stock. By buying the cuttings un-rooted it is possible to plan production more efficiently. Boxes of unrooted cuttings arrive from all over the world to the nursery every day of the week. Cuttings are bought

from a range of different places to reduce the risk of disruption caused by environmental or political problems. Once the boxes arrive at the nursery they are immediately unpacked. The cuttings are also inspected for pests and diseases. If they are unhealthy they are thrown away. After the inspection the cuttings will be watered and placed in a controlled climate cabinet and from here they will be stuck as soon as possible.

Chlorophyll Fluorescence Meters for Quality Control

All inspections are visual. This works in most cases but sometimes early stages of infections are missed. In the near future we plan to use chlorophyll fluorescence to help us inspect cuttings.

Chlorophyll fluorescence measures photosynthetic activity, which is reduced in unhealthy leaves and low activity can be a sign of disease even if there are no visible symptoms.

There are several different ways of doing this. There are cameras that can scan the cuttings so that any infected tissue shows up bright on the image while healthy plants show almost no sign of fluorescence. However these are currently very expensive.

There are more affordable handheld meters already on the market. They are placed against a leaf and display a reading, usually as a percentage. The reading is generated within a few seconds by shining two light emitting diodes (LED) onto the leaf in quick succession. The first LED emits light equivalent to what the leaf perceives as darkness. This means the chlorophyll absorbs approximately 80% of the available light from the LED and the other 20% will be reflected and is measured. The second LED emits light at twice the intensity of daylight. The chlorophyll cannot process this amount of light and the overdose brings photosynthesis to a momentary standstill when most of the light is reflected as fluorescence. The meter provides a reading by comparing these two results. 80% is the maximum in a healthy plant and when the reading drops below 40% then the leaf is in poor condition and if no action is taken it will die. Cuttings with a reading lower than 40% should not be planted.

Chlorophyll fluorescence meters can also be used for other checks, such as the effectiveness of fungicide sprays (take a measurement before spraying and another one an hour after spraying) or to check for damage after using a herbicide. It is also possible to use the meters to time deployment of shade screens — the screen should be closed before the fluorescence reading falls below 40% to avoid damage resulting from too much sunlight.

Sticking the Cuttings

Trays already filled with rooting medium are bought into the sticking area. We buy media in compressed bales – 1 m^3 of compressed bale yields 3 m^3 of medium. Thiacloprid (as Exemptor) is added to the medium, to control sciarid fly larvae, together with a slow acting mini Osmocote fertiliser which releases over five months to give even growth. The fertiliser becomes active after 2 weeks, this gives the cutting time to root and as soon as the first roots are there, the nutrients are available. Perlite is added at 20% to improve aeration and aid drainage. To strengthen the plug a little of clay or glue may be included in the mix – glue helps the plug retain its volume and aeration when the trays are watered.

The trays are watered by hand before sticking to make sure they are all equally moist for even rooting. After watering, holes are made in the plugs with a nail bed and then the cuttings can be stuck.

Rooting Area

High pressure fog keeps humidity at 98% and the cuttings start to root within 2 weeks. Two shade screens are used to help maintain humidity. The high pressure fog produces a very fine mist of water drops less than 1 micron in size. On warm days the high pressure fog is not enough as cuttings with a large leaf area may collapse, so there is also a low pressure fog system which operates when light levels in the greenhouse are above 700 lux. It operates in 10 s bursts and produces 80 micron droplets. This keeps the cuttings

standing on warm days and it also reduces the rooting time to less than 8 days. Because of the amount of water in the environment, the cuttings need to be removed as soon as they can be to prevent botrytis infection.

Weaning and Production

At the first signs of rooting, the cuttings are removed from the rooting area and placed in the greenhouse. Here they will be trimmed a few times (depending on customer requirements) to make side shoots. The cuttings will also be sprayed a few times for pest and disease prevention. After eight weeks the cuttings are ready for sale.

High pressure fog is used to maintain humidity at 65% to prevent leaf scorch on warm days. The pipes run along the middle of each bed with nozzles placed every four metres. The system is set to operate in pulses to provide fog for two minutes and then pause for 20 seconds so that the droplets will evaporate in the air and the cuttings stay dry.

In the summer pulsing is not necessary because if the vents are open it is difficult to maintain humidity. To keep the humidity at around 65% the shade screen is closed to 90% — if it is completely closed the temperature and humidity will rise too much. It may be possible to reduce the amount of venting, too, because if the high pressure fog is working well the temperature should not rise. If this is still not enough to maintain humidity levels then the internal air circulation system is switched off.

High pressure fog used in this way gives a very stable climate in the greenhouse by lowering the temperature by 5 to 8°C. The climate also reduces spider mite risks. A disadvantage is that algae and moss will occur more often and this will attract sciarids. To control algae an extra tank is added to the spraying machine to apply a biocide.

As the high humidity can lead to "soft" growth we use as little nitrogen fertiliser as possible and extra potassium and calcium. However we are also experimenting with the use of LED light to "harden" cuttings before sale.

Light Emitting Diode Light to Harden Cuttings

By using LEDs it is possible to tailor the light spectrum to provide specific growth responses. If a plant is given a lot of far red light it will stretch and the leaves will be thinner. When a lot of red light is given the plant will stay compact and the leaves will be thicker. When blue light is at low levels, or absent, then the leaves will be thinner and bigger. When extra blue is added the plant will make more side shoots and it will produce smaller and thicker leaves. To harden the cuttings a "light recipe" high in blue light will therefore make the leaves thicker, stronger and less vulnerable.

In the production of cuttings combinations of red and blue LEDs could be useful to control growth. And because LED lights produce almost no heat, it is possible to grow cuttings without natural light in controlled climate growth rooms on tiered benches; in this way the whole rooting process can be controlled and less production space is needed compared with growing on a single layer in a greenhouse. The main problem is that all plants have their own ideal light mix which needs to be discovered before commercial production can begin.

In Spring 2013 we undertook a small trial looking at the effects of LED lights on *Erysimum* 'Bowles Mauve'. We placed 10 plants in the greenhouse in standard light conditions; 10 plants in the greenhouse with LEDs to provide extra red light; and 10 plants were placed in a controlled environment with no daylight and LEDs were used to provide a mix of 80% red and 20% blue light.

Differences in growth were noticeable after 1 week. The plants exposed to extra red light in the greenhouse were showing some side shoots coming from the top of the plant while the plants in the controlled environment with red and blue light were developing numerous side shoots most of which were from the bottom of the plant.

After 3 weeks all plants where placed in the greenhouse to see how they would develop. The untreated plants flowered one plant at a time. Five of the plants that received the daylight with extra red treatment flowered together. The plants from the controlled environment treatment (red and blue light) all flowered at the same time and were of a

much better quality than those from the other treatments. Further trials are looking at the minimum light intensities required for these responses.

Connecting with the Gardening Public©

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INTRODUCTION

Kernock Park Plants was established in 1976 by Richard Harnett (then a horticultural advisor), along with his wife Jan. Since then, the nursery has expanded to just over 4.5 ha of polythene and glass on three separate sites. There is a workforce of around 80 during spring and summer, falling to around 50, including permanent staff for the remainder of the year. The nursery produces nearly 1,200 taxa including summer bedding, patio plants, alpines, herbs, hardy and herbaceous perennials, grasses, and shrubs. It is primarily a wholesale business, the main product being plug plants — a range of 9-cm liners having been added recently following the take over of some of the lines previously grown at nearby Hewton Nursery. The nursery has been supplying Proven Winners® brand plants since 1999.

ADVANTAGES OF PARTNERSHIP WITH PROVEN WINNERS

The Proven Winners initiative began in the early 1990s — the original ideas actually came from some European colleagues, but Proven Winners really began in earnest in North America. The original principle was simple, to market new plants, mostly cutting raised product in a completely new way, as "patio plants" for use in baskets and containers, something not really done by the big seed companies of the day. It wasn't until 1998 that Proven Winners was formally established in Europe. There are seven main members from all over Europe supported by a network of rooting and selling partners.

The benefits of this sort of cooperation include economies of scale, pooling ideas and experience and being an attractive prospect to breeders seeking routes to market for their new plants — nearly 100 breeders from all over the world contribute material to Proven Winners trials. Potential new introductions are rigorously tested in several countries around the world for performance for the grower and the end user. The best plants are taken into the Proven Winner assortment and there are now more than 200 Proven Winner plants on the market in Europe. The vast majority of the stock is elite, virus indexed material.

The industry has tried pushing the product through the system, with little ability to influence the choices made by consumers. Branding means the market pulls the product through. It also helps differentiate products and helps growers to connect directly with consumers.

BRANDING AND MARKETING DATA

In North America, Proven Winners has not only grown and sold its plants, but has also been able to grow an extremely strong consumer brand — in fact it is one of the most recognised brands in USA horticulture. With 2.4 million unique visitors to its website recorded in the past 12 months, Proven Winners North America has an incredible information source from customers and potential customers. It had more than 100,000 responses to a questionnaire distributed earlier this year via the internet and was able to collect some very interesting information on the gardening public.

First, 93% of the respondents were women. Our industry is dependent on women buying our products, so is our decision-making too male-dominated?

More than 60% of respondents were aged 45 or over but 70% of them said they were hooked before the age of 21, which may seem surprising. While 86% said that they shopped at garden centres, but of those only 4% always know what they want when they walk into a garden centre. A massive 96% shop buy on impulse which means we have plenty of scope to influence buying decisions.

Market research carried out by Kernock Park, and data from our colleagues in North America and the U.K. Horticulture Trades Association suggested the target audience for the brand in the U.K. should be females under 45, the gardening proud, those with "alfresco aspirations" who would be interested in container gardening and who are looking for a "modern younger image" from a company which could offer inspiration and planting recipes which are easy to achieve, using innovative plants that they can trust to perform.

MARKETING MESSAGES

Attaching marketing messages to a brand is expensive and time consuming, and initially there is very little reward for the supplier. But brands have been found to simplify the decision-making process for consumers by providing a sense of security and consistency. The marketing mix is designed to create a perception in the customers' minds, so that when they visit the garden centre they will see the Proven Winner product and know that it can be trusted to perform in their garden, hence differentiating it from the other products. The message is that each Proven Winners introduction has been carefully selected to ensure it meets specific quality criteria. Plants are trialled and tested in sites all over the world to ensure they are bright and colourful, floriferous, flower all season, easy to grow and care for, and disease and pest resistant.

In order to get these messages across the offer must be made as simple as possible. The plant is offered in a branded pot, the logo and information on the plant is offered on the bespoke label and the whole offering is presented in the garden centre with "living labels" and easy to follow instructions.

The simple message on the point of sale material for the garden centre is "Great Plants and Bright Ideas" and includes simple to follow recipe cards. The concept for container planting is that there are three easy steps: choose (pick three 12-cm plants), prepare (by using the planting planner on the card to arrange the three plants in the container) and care (either visit the website for care instructions or follow the instruction on the plant label).

To simplify this further we have split the plant range into three distinct seasonal offerings so that the consumer knows when they should be purchasing which plant. We have "Spring Fling", "Summer Livin" and "Autumn Magic". Each is a distinct group of products within the overall brand.

USE OF SOCIAL MEDIA

Before the brand could be presented to the industry and the consumer, facts and feedback were gathered using the website and social media, focus groups, a launch weekend to consumers at a selected garden centre, and a trade launch at the Horticulture Trade Association's National Plant Show.

Research by both industry bodies and retail experts has shown that there have been big developments in the relationship between retailers and consumers. With the advent of smart phones and the internet, many consumers have an idea of what they want to buy before they go shopping, though this is still tempered by impulse when they arrive at the garden centre. In order to get that interaction with the consumer it is imperative to establish direct channels via social media and the internet and this has been a key factor in the development of the Proven Winners brand. It gives us as growers chance to influence the consumer's decision before they set out to buy plants. It also enables us to offer support and guidance on the products purchased, building confidence in the fact that the right decision has been made.

We have used all of the common social media formats including Facebook®, Twitter®, You Tube® and Pintrest® and have not forgotten traditional 'hard copy'. In this new electronic age where information is transient there is still a requirement for a tangible piece of material that the consumer can take away with them — so we produce a printed *Ideas Book*. We have found this to be a very useful tool for increasing the consumer

interaction. When they sign up to the website we send them the booklet and we have also run competitions on Twitter where the booklet is given as a prize.

We have invited retailers to add their information to the website as stockist of Proven Winner Plants. So far we have around 40 garden centres and online retailers who have added their details.

FOCUS GROUP FEEDBACK

A focus group was held at a retail nursery, made up of nine ladies aged between 25 and 40. The key objectives were: to look at the price perception of plants; establish, what, if any, is the effect of larger/different colour pots; to understand buying motives; and test run the recipes to be promoted. We also wanted to gather some feedback from the retailer following the event and collect sufficient background information to confidently formulate a final plan for the consumer launch weekend, at Plymouth Garden Centre a month later.

From the focus group we heard these consumers would pay £2-3 for a 9-cm summer bedding plant, £3 for a 9 pack of bedding and £3-4 for a 12-cm bedding plant in a Proven Winners pot. They said pricing offers — such as buy 2 get 1 free — made a difference. Their attitudes to seasonal plants were interesting: some said that as soon as they heard the word "bedding" they wouldn't buy it as they assumed it would die. But they didn't think of crops such as primroses as bedding. Others, notably the younger consumers, liked buying bedding because they knew that if what they tried didn't work out it didn't matter, they could try again next year, and they could change the colour each year and keep coming up with new designs. The key element in the buying decisions of all of the focus group members was that they wanted a good quality plant, to the extent that they would only shop at their trusted garden centre or shop with their parents or another older trusted gardener, as they were not confident enough to make the decision on their own. The most important factor was that the plant looked good: they were planting to make their gardens pretty and exciting, and so they wanted the right plants to make sure this happened, hence the desire for quality.

LAUNCHING THE BRAND

The information from the focus group enabled us to make some tweaks in the marketing in readiness for the launch weekend at Plymouth Garden Centre's Container and Patio Festival held over a mid-May weekend in 2013. We set up a retail area in the garden centre with the living labels, the point of sale material, and the plants for sale, with a view to getting consumer and retailer feedback on how the branded plants would be regarded; what implications are there in terms of space, location, and profitability per square metre; and what maintenance and merchandising requirements would there be on the shop floor.

The display area was staffed for the whole weekend and demonstrations were run regularly during this time. There was also a competition running for consumers to vote for their favourite planting recipe.

Probably the biggest single thing learned over the weekend was that the Proven Winners range is incredibly easy to sell to consumers. The higher price point of £2.99 per pot proved to be no barrier whatsoever to purchasing with the consumers understanding that the larger pot size would ensure more rapid establishment and quicker results. The only objections were either customers who had a large area to cover and were happier buying more, smaller plants and waiting for the results a bit longer, or customers who wanted particular cultivars that were favourites of theirs and weren't in the Proven Winner offering on the day. The recipe sheets combined with the living labels and then the relevant plants merchandised adjacent to these were also definite winners. However we realised that we needed to work on making it more intuitive in order to ensure consumers were able to make purchasing decisions without assistance.

From the retailer's point of view, they were very happy with the sales and they compared favourably with similar products such as pack and 9-cm bedding in both

volume and profitability per square metre. They also saw higher sales of related products such as planting containers and compost.

There is still reticence from growers as to the worthiness of the Proven Winners branding. This is understandable because we have just had two of the most difficult trading years for a long while in the U.K. and very few growers are willing to "take a gamble". At the National Plant Show we presented our findings so far to potential growers and retailers with mixed reaction. Some of the key retailers are very keen on the concept and believe that the market is ready for branded plants. It is now a case of completing the supply chain and getting the concept into more outlets.

PROVEN WINNERS IN OTHER TERRITORIES

The Proven Winners network covers North America, Japan, Spain, Italy, Poland, Germany, Denmark, South Africa, and Australia.

North America is the most advanced, with a marketing budget of $5 million and using the whole gamut of marketing tools including radio, TV, and magazines. A complete marketing package enables retailers to increase their business, including a kit to put on a container festival and specific plant promotion days tied to fund raising appeals. There are also training academies for retailers and Proven Winners branded growing media and fertiliser.

The brand is starting to build in Japan by promoting plants within the Proven Winners range.

Other territories include Spain and Italy where they have already set up an academy for retail staff and have recruited numerous garden centres as Proven Winner stockists.

In Poland, Germany, Denmark, South Africa, and Australia Proven Winner members are starting down the same route as us here in the U.K. and are trying to emulate what has already been achieved by our partners in North America.

The Quest for a Pinker Planet: Breeding, Production and Marketing of Hybrid Dianthus at Whetman Pinks©

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INTRODUCTION

Whetman Pinks is a family-run nursery in south west England which has specialised in breeding and production of hybrid pinks, sometimes known as show pinks. These hybrids between *Dianthus caryophyllus* and *Dianthus plumarius* are a "typically English" garden plant. Whetman has developed these and other hybrid dianthus cultivars as attractive modern garden plants and promoted them in many other countries. In April 2013, Whetman Pinks Ltd was awarded the Queens Award for Enterprise: International Trade, for its achievements in exporting pinks worldwide.

NURSERY HISTORY

Whetman Pinks is located in a sheltered valley near Dawlish on Devon's south coast. The climate is mild and light levels quite good despite the surrounding hills. There has been a horticulture industry in the area since the 1800s. As well as apples for cider (the nursery used to be a cider factory) the nursery used to grow fruit and vegetables, particularly during the two World Wars when flowers were grown in the hedgerows, as all productive land had to support the war effort. Flower growing expanded after World War II and the cut flowers were sent to the London wholesale market at Covent Garden by steam train, including bunches of locally grown Devon violets and pinks.

At that time there were very few cultivars of pinks available, the most popular and well known being 'Doris'. This cultivar, and others bred by Montague Allwood, were inexpensive to grow and popular because of their perfume. The portfolio of cultivars was expanded by the local, highly talented, breeder and nurseryman Cecil Wyatt. In order to produce quality flowers, good propagating material was needed and John Whetman established healthy mother stocks. Other local growers began to want plants and the nursery gradually became more of a propagating business. Cloches and simple early polythene structures were gradually replaced with glasshouses.

The 1980s and 1990s saw a boom in the market of pinks for cut flower production, as flower growing moved outdoors in Lincolnshire and Cornwall. Pinks also became more popular as a perennial garden plant with the increasing range of colours and forms gaining the attention of the gardening public.

DEVELOPMENT OF A BREEDING PROGRAMME

The first Whetman bred cultivars were introduced to the market in the mid 1980s as a promotion with Pride of Place Plants, a marketing initiative backed by nurseries in the Farplants group and Blakedown Nurseries. The pinks collection consisted of the new cultivars 'Devon Cream', 'Devon Glow', and 'Devon Blush'.

Breeding with the existing material available in the trade and our own material yielded further cultivars of garden pinks, extending the colour range available. Dwarf cultivars were used in our breeding and the Star™ series of dwarf dianthus was developed and launched. These were followed by double cultivars of an intermediate height, leading to the Scent First™ collection of pot and patio pinks. These perfumed cultivars fit well into modern smaller gardens and the continuing enthusiasm for container gardening. As well as being a versatile garden plant they can be sold in flower more easily than the more traditional selections while their shorter, more compact, growth means that more layers can be accommodated on a Danish trolley thus reducing delivery costs to retailers. These attributes led to their increasing popularity as impulse purchases.

Realising the importance of new cultivars to the industry and the opportunities worldwide for the *Dianthus* genus with its broad appeal, more resources were put into the

breeding programme. A dedicated glasshouse was built, isolated from the production facilities, where breeding could be carried out and nuclear stock held securely. On John Whetman's retirement our current breeding programme manager, Laetitia Moucheboeuf, took over the further development of breeding activities and our high health facility. The programme has become more structured with the following objectives:

Elegant plant silhouette
Grey-green foliage with narrow leaves
No vernalization requirement
Hardy
Perfumed flowers
Repeat flowering
Attractive new colours or patterns
Distinctly different and stable
Well-proportioned plant
Easy to grow and reliable
Good yield of cuttings for production
Disease resistance
Not producing split calyx

The breeding and selection process (Fig. 1) takes an average of 7 years from first crossing, through several selection and trialling stages, to bulking-up and first commercial sales. The breeding team and directors have regular selection sessions and we seek input from as wide a range of people as possible during the selection process. This includes regular visits from licensees, agents, and customers. All material is grown under conditions of strict hygiene and virus testing is carried out every 6 months for both production material and new selections.

Fig. 1. Breeding, rigorous trialling and healthy stock result in uniform crops and customer satisfaction.

CULTIVAR TRIALS

The form of trials conducted will depend on the category of plant and its expected use. All cultivars will be trialled outdoors in an autumn planted trial. Cultivars which could be useful as cut flowers will also be grown under protection and such factors as flowering date, yield of stems, stem length, and so on are recorded. Scent First™ pot and patio cultivars and dwarf selections are grown in both autumn-planted and spring-planted trials in the appropriate pot sizes to reflect the main potting periods and pot sizes favoured by our customers for these categories of plant. Candidates for the Scent First™ collection are grown in 1.5-L pots and dwarf cultivars in 11-cm pots.

Fig. 2. The plants in this picture are from our Scent First™ collection of Pot and Patio Pinks. This grower in Japan has mastered the growing and scheduling of our varieties so that he is now able to have attractive flowering plants in time for the all- important Mother's Day market.

Reference cultivars are grown alongside the trial cultivars so that comparisons of height and flowering time can be made. This is important because no 2 years are the same in terms of environmental conditions such as light levels and temperatures. At this trial stage we will make sure that we have initiated in vitro material and we will send the candidate cultivars for assessment to partners in other territories, so that we can see how they perform in other climates. They will be tested for cold tolerance and for heat and humidity tolerance in the USA. Trialling will be carried out in Europe with our partners there, and in Japan, South Africa, and Australia as appropriate.

A new cultivar will be trialled first in secure locations, then more public trials as we approach the point where it may be released to the market. This stage of trialling is only undertaken once protection of the cultivar by Plant Breeders Rights or patent is in place. For many years we have been fortunate to have been able to enter many of our cultivars in the Royal Horticultural Society trial grounds at Wisley Gardens, Surrey, and many of our cultivars have been awarded the highly valued and respected RHS Award of Garden Merit. There are no current RHS *Dianthus* trials but it is hoped there will be another way

of testing the garden-worthiness of cultivars before long.

YOUNG PLANT PRODUCTION

Multiplication is by softwood cuttings. Once a prospective cultivar is in our trial system we will have initiated in vitro cultures which we use to establish our nuclear stock. The next stage is to increase this by taking cuttings to produce between 10 to 40 plants also kept in isolation as our elite stock. These elite plants are then used to establish our production stock plants, the quantity of which will depend on the popularity of the cultivar and the expected yield of cuttings per plant. All of the stock plants are replaced annually in a rotating programme, ensuring that we have cuttings available at all times, with production peaks matching demand. In practice it is not quite that simple so we may use our cold stores to help buffer the supply and demand by storing unrooted cuttings for a few weeks. We have to guess at what the fashions are likely to be and speculate, like most growers, as to what will be in demand when we decide what numbers to grow of each cultivar.

We root on heated propagation benches, using boom misting until root initials are seen, this takes from 11 days to 25 days depending on cultivar and time of year. Mist is then stopped and the cutting forced to seek water by producing roots. We are currently using a form of glue-plug which has a very open structure. A high air-filled porosity is important as air in the rooting zone is crucial to healthy root development. A regular 3-cm plug in a 104-cell tray takes 5 weeks to produce in the main growing season, longer during the period October to March. No growth regulators are used and pinching is carried out by hand if necessary. Plants are despatched on Danish trolleys and in layered cartons.

EXPORTING

Exporting Direct from the U.K.

Our exporting activities began when we were fortunate to meet a group of French nurserymen from the marketing cooperative Vivaplante who visited us during a study tour in 1990. *Dianthus* were being grown in France, but not the range of cultivars or the clean material that we were offering. Our relationship grew from there and Vivaplante is still one of our valued French customers.

In order to be successful at exporting you have to have a product which is unique and which cannot be easily obtained in the importing country, or which has a competitive price advantage. In some cases the market has to be built or created through promotion. Choosing the right partners is vital otherwise any success will be short-lived. Knowledge of languages can be a distinct advantage and the serious would-be exporter needs to prepare literature in the target country's language. Attendance at key trade shows is an important step as it enables you to gauge interest in your products, engage with potential customers and demonstrates commitment to your target market. Unfortunately some people only exhibit once or inconsistently. In our experience, in order to get noticed and to be seen as being serious you need to exhibit about three times before potential customers take notice.

Logistics is another essential element. Delivery needs to be fast enough to avoid deterioration of the plants. Our relationship with specialist horticultural carriers Transflora has been important, enabling us to get plants to customers on Danish trolleys often within 24 to 48 h of leaving the nursery. However, it can be a challenge to persuade customers to order for the same delivery period in order to fill a lorry. Transport cost needs to be affordable as a proportion of the plant value. With a current value of approximately £1,000 per trolley of 5,000 plants and a cost of approximately £150 this adds £0.03 per young plant, which is acceptable (the comparable cost for U.K. delivery is approximately £0.01 per plant for a full trolley).

Selling unrooted cuttings is another option but brings different problems. Our location in the south west means is a long way from major airports making it difficult to send air cargo efficiently; and couriers are very expensive and do not insure living plant material,

which means a higher risk for us as the exporter.

Exporting to the Global Market

Again the choice of strategic partners is crucial. We have a model relationship with Planthaven International, which introduced Whetman genetics into North America and which, through its knowledge of the market, enthusiasm for our breeding, and complete integrity has created a valuable market for our much loved pinks in the USA and Canada (Fig. 3). Part of that company's activity is to actively promote our cultivars, including through its own website (planthaven.com), setting up a dedicated <whetmanpinksusa.com> site. It also promotes our plants at trials, open days and trade shows, through mail shots and the all- important personal relationships. The company is now representing us in Europe too, working to extend our network of licensees in a sustainable long term way.

Fig. 3. Author at California spring trials.

Our introductions have been trialled and declared hardy to Zone 5 in the USA. The next challenge is to find ways of growing them in climates which are often described as "brutal" with extremes of heat and humidity.

A selection of our introductions is available in Australia and New Zealand where we are represented by Plant Management Australia. Grown outside, the pinks bud up beautifully in their spring. Gardeners there like strong colours, as in southern Europe and other areas with bright sunny conditions. What does well in Australia generally seems to perform well in South Africa where we have relatively recently established partnerships there. Volumes there are never going to be huge but it is good to be able to spread the enjoyment of pinks and their lovely perfume to as many regions as possible.

The Japanese market is particularly interesting. Japanese customers associate carnations with Mothers' Day where they are often used as a gift and therefore more highly valued. Scheduling a crop to produce a specimen sized plant in flower by early May is quite difficult as the grower has a relatively short winter during which to grow a compact plant. It is too hot to pot up before October and temperatures rise again in March. Nevertheless they have mastered the growing and have achieved good results. Much attention to detail is given, watering often by hand. Growing structures are generally polythene or polycarbonate — presumably due to the frequent earth tremors. Feeding regimes range from sophisticated liquid feeding on one nursery to the use of controlled release tablets on others. Some growers use peat based media but the majority seem to use a volcanic soil-based medium, lightened with perlite. Presentation of the finished product in garden centres is very impressive. The buying public have high expectations. As well as cherry blossom pink, reds, and patterns are popular in Japan.

I am not sure where we go next with our "pinking of the planet." Good plant breeder's rights protection, a national interest in gardening, a suitable climate and reasonable level of disposable income are all needed in a potential new market. The quest continues.

The Development of Responsibly Sourced Growing Media Components and Mixes©

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The U.K. Government White Paper on the Natural Environment of June 2011 set quite specific targets for ending the use of peat in horticulture in England and Wales. The result of an initial consultation on these targets led to the formation of a task force with a remit covering a number of inter-related project areas. The task force responded to the White Paper in October 2012. In February 2013 Richard Benyon, minister at the Department for the Environment, Food and Rural Affairs, acknowledged the work of the task force and encouraged the industry to continue the work programmes it had set.

One of the main projects to emerge from the task force was a 5 year programme of R&D and knowledge transfer jointly funded by the government and the industry to advance the responsible use of all growing media materials so that the industry could either meet peat reduction targets or demonstrate the constraints imposed by the targets.

This paper reviews progress with the programme of development work and summarises the work that remains to be done.

INTRODUCTION

The quest for consistent good quality substrates for the production of container-grown plants is not new. In the 1930s geneticists at the John Institute (then in Merton, south London) required a growing medium which would ensure all their seeds from breeding and genetics research programmes should germinate and all seedlings survive, otherwise the expected Mendelian ratios would be distorted and perhaps uninterpretable (Lawrence and Newell, 1939). The problem William Lawrence had as curator was that the "home-made" substrates then used were not of sufficient quality and seedlings often succumbed to disease — meaning that the true results of breeding and genetics research were confounded (Lawrence, 1980). Lawrence and Newall therefore developed what the industry has ever since recognised as the John Innes range of growing media recipes for container substrates. Their most important feature was that they were developed using a prescribed range of materials and could reasonably be produced at different locations to the same standard. Their major problem was, being loam-based, their fresh density which, while acceptable where plants did not have to be transported did not work well where commercial volumes of plants were to be shipped from nursery to nursery or between nurseries and retailers.

To meet the growing media needs of commercial growers, from the mid-1950s scientists at the Glasshouse Crops Research Institute at Littlehampton in West Sussex developed substrates based on sphagnum peat and peat plus "silver" sand for container-grown plants — primarily the result of their visits to the University of California, Davis, USA home of the U.C. system (Baker, 1957). The development of specific mixes for the UK was documented by Bunt (1976).

As peat-based mixes became widely adopted by commercial growers in the U.K. so the demand increased for consistency in mixes for specific uses. Unfortunately the grading of peats was not to a sufficiently high standard and work at various locations indicated the need to improve the physical properties of mixes. In the U.K., mixes for outdoor container-grown nursery stock demanded a stable, open structure to avoid overwintering losses caused by waterlogging and freezing of the root ball. Various researchers investigated the use of additives, notably the work at the Ministry of Agriculture's Efford Experimental Horticulture Station (EHS) near Lymington, Hampshire (now closed) led by Margaret Scott on the use of bark products as physical amendments to peat/grit mixes. Her research showed that the use of screened and graded pine barks, matured but not composted, gave the most consistent results. The work at Efford EHS was also supported

by the development of the technique for measuring the air-filled porosity of mixes, undertaken by soil scientists at the Agricultural Development and Advisory Service (Bragg and Chambers, 1988). The technique was designed to be quick and easy to use both in the laboratory and on nurseries to allow alteration in mix proportions to be distinguished and related to specific crop production systems.

By the end of the 1980s there was mounting pressure on the U.K. horticulture industry to audit its use of peats and to look for alternative materials to either dilute or replace the peat. Many of the conservation and wildlife non-governmental organisations came together to campaign for the removal of peats from horticultural growing media, and various reports, such as, Peat and Its Alternatives (HDC, 1990) and The Peat Alternative Manual (Friends of the Earth, 1991) were published.

Considerable efforts both in the U.K. and in the rest of Europe were begun by commercial suppliers and growers to develop peat-reduced and peat-free mixes. The primary barriers to the adoption of new mixes usually lay with obtaining consistent quantities of the alternative materials at a commercially acceptable cost.

During the 1990s various materials were trialled and, where appropriate, developed. Bark-based products continued to be developed as did other timber and wood-based additives. The period also saw the importation from Sri Lanka and India of ever increasing amounts of coir (coconut husk waste) and its use both alone and in mixes. There was also government-backed development work on the potential use of composted green waste from domestic and industrially derived sources. The latter development was heavily sponsored by the U.K. Government's Waste and Resources Action Programme, the function of which is to encourage recycling and create demand for recycled products.

By the early 2000s specific peat reduction targets were being set for U.K. horticulture. Other European countries, particularly Germany and the Netherlands, felt they had already achieved a consensus position on the use of peat in growing media and were prepared to see some use of peats in mixes in order to ensure a sustainable future for their industry (Schmilewski, 2012).

THE U.K. POSITION

In 2011 the U.K. Government laid before Parliament a paper on the future requirements for the protection of the natural environment in England and Wales (Anon, 2011). Adopted as policy, it was the first to set specific targets for the future use of peats in horticulture in England and Wales. There were three target dates:

- 2015: From this date no peat is to be used in any public service planting or contract growing works.
- 2020: By this date no peat is to be used in "retail" bags of growing media or soil improvers purchased by amateur gardeners.
- 2030: By this date no peat is to be used by professional commercial horticultural businesses.

Defra (Department for the Environment, Food and Rural Affairs) was tasked with the implementation of the peat reduction targets and setting of the review dates associated with them. Defra set up a Sustainable Growing Media Task Force led by sustainable development consultant Dr. Alan Knight. The task force included representatives from growing media suppliers, growers, retailers, and researchers. Their job was to establish if and how the targets could be achieved on a voluntary basis without the need for further legislation to impose them.

A methodology or "road map" of the route to reduce peat use was agreed and the task force was divided into a number of smaller groups, each tasked with investigating specific areas that the industry could move forwards on over a period of 12 months. The task force chairman reported to Defra in late September 2012 and the minister responsible (Richard Benyon) agreed the road map in February 2013. The main points to emerge from the road map were:

- All growing media should be fit for purpose.
- All growing media and soil improvers should be made from raw materials that are

environmentally and socially responsibly sourced and manufactured.
- Commercial horticulture should use only responsibly sourced and manufactured growing media.
- Retailers should only stock products which meet agreed performance standards.
- All public sector procurement should include a requirement to source plants and products that have been grown in responsibly sourced growing media.
- Consumers should be able to make informed choices in their purchase of growing media and soil improvers.
- An improvement is needed in the quality and consistency of green compost such that it is able to fulfil its potential.
- Waste legislation should be no longer a barrier to the sourcing of high quality waste derived materials.
- A voluntary approach should be adopted to achieve the transition to responsibly sourced growing media use.

The Challenges

It was recognised that these aspirations could only be achieved if a number of actions were implemented:

- There would continue to be a need for a group from all industry sectors to meet and assess if the review dates and targets were being met. Dr. Knight would be asked to continue to chair it.
- There would be a need for a major knowledge transfer and development programme to be undertaken over at least a 5-year period to identify and develop good practice use of materials and mixes by growers over a range of production systems.
- There would be a continuation of the criteria for assessment of all materials so that judgements could be made on their long term suitability of use.
- There would be a move to define basic performance testing of substrate mixes, especially for the amateur market, to ensure that whatever the consumer bought would have a reasonable chance of producing acceptable plant growth, assuming reasonable quality of seed and cutting materials or mature plants placed into the mixes.
- There would be a full economic assessment of materials to ensure that all costs (including environmental costs such as embedded water) were accounted for.
- All sectors of the supply chain had to fully engage with the processes and actions.

CONCLUSIONS

It is arguable that the quest for quality and consistency in growing media is not new but the increasing recognition of the importance of different habitats such as peat bogs and mires has heightened the need for horticulture globally to assess its specific use of "peats." Specifically in the U.K. and particularly in England and Wales, the U.K. Government wishes to see a phase out of the use of "peats" in growing media mixes across landscaping, retail sales of multi-purpose growing media, and in professional horticulture for the production of container-grown plants.

The growing media supply industry has been working closely with professional growers for the last 20 years and has already achieved massive reductions in peat use. The development of alternative materials has significantly helped in poor peat harvest years to ensure growers can obtain substrates which allow them to continue their businesses (HDC, 2012).

The challenge for the industry as a whole is to secure reliable and consistent materials which will replace or substitute to a greater extent the current use of peats. However, the caution which is needed here is that the total volumes of materials used by the U.K. horticultural industry are very small compared to, for example, the big energy producers who are also looking to replace fossil fuels with renewable biological materials. Hence, while materials can be identified which can and are added to existing growing media, other users may be able to command the market for them.

So, very much in the vein of the original work of Lawrence and Newall in the 1930s,

the industry is again challenged with attaining consistent quality substrates for a wide variety of uses which will allow all plant subjects to thrive.

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Raising Consumer Awareness of Your Nursery's Products©

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INTRODUCTION

It takes years of hard work to develop and commercialise new plants but that is just the start — then you have to market them. This paper outlines some of the key ways to get your plants in front of the consumer.

ENTICING CUSTOMERS TO BUY YOUR PLANT

Excite Them

It is crucial when selling any plant — either to the consumer directly, or the retailer in volume, that you pique their interest. Explain how the customer will benefit from owning it. For example, if you are selling a new type of fern (not necessarily the most visually stimulating of plants), explain how there is no better a group of plants than ferns for dealing with those "problem corners."

Inspire Them

Sell the promise of what the plant will provide, and how it can be grown with other plants. Sticking with ferns as our example, show that they are easy, low maintenance plants, that need minimal care. They are virtually immune to attack from slugs and other pests. They deliver a lot while asking for very little in return.

Plant Stories

The potential fern buyer will be amazed by your simple but graphic description of how ferns were around in the time of dinosaurs and astounded that in reproducing they produce billions of tiny spores. Find stories to make the customer exclaim "Wow!"

OBTAINING PRESS COVERAGE

A simple press release is your way in to editorial coverage in newspapers, magazines, and other media. You don't have to employ expensive PR agencies, but it is worth following a few simple rules if you wish to try producing your own press releases:

- Target your recipients carefully to avoid wasted effort, time, and money.
- Keep it short. Ideally, keep it to a single side of paper.
- Give your full name, address, email, website, and complete contact details.
- Pictures are essential. Nearly every form of media will want to see a photo of your plant or product before they decide whether to use the release or not. Most publishers prefer to use digital images. If you are sending out paper releases, submit a good quality print of the product and state that a high resolution digital image is available on request. If you are emailing the press release, always attach the image.
- Remember lead-times. A monthly or quarterly gardening magazine will work months in advance, so if you want consumers to know about your promotion in the first week of February, then you will need to send your releases out in November. Daily or weekly publications work much closer to their publication dates. Most publications will be happy to tell you when their deadlines are.

ACHIEVING THE BEST ADVERTISING

It is not hard to create a good advertisement. It must connect with its audience, be memorable and easily recalled, provide information quickly and succinctly, not confuse the reader or viewer or make them hunt for the pertinent information, and finally call the potential customer to action.

A good print advertisement has four elements: a provocative image; a strong headline; a paragraph or two of tight, well-written copy; your logo (if you have one); and contact information.

THE VALUE OF SHOWS, EXHIBITIONS AND OTHER EVENTS

Here are 10 reasons why you should invest in taking a stand at trade shows or consumer events:

Cost Effectiveness
With a simple sales stand, some technological accessories and selling charm, shows offer simple, inexpensive ways to get your brand on the market.

Target Market
Shows pull in a highly targeted market that is highly interested in your product. In just a few days, thousands of interested clients will see it.

New Audiences
Those attending will have made a positive decision to travel to learn about new brands, new products, and new lifestyle solutions.

Face Time
Events offer more personal time with your customers. Instead of communicating by phone or email, you can really engage with them.

Relationship Building
The personal interaction offered at shows allows you to establish a direct more effective relationship with your customer. This relationship is valuable in the future as you maintain a connection.

Sales Leads
New relationships and deeper connections open channels for new sales leads. You may find a new market that hasn't been tapped into yet.

Small Business Benefits
Smaller businesses sometimes struggle in establishing themselves in a market. Shows and exhibitions allow them to get their name in front of potential customers.

Year-Round Promotions
A one-time meeting at a show could result in year round marketing for you. Handing out brochures and verbally explaining the offer increases customer awareness.

Sampling
A major selling strategy is to give away product. This provides customers with something new to take away and enhances their awareness of you and your products.

Direct Selling
Probably the biggest reason companies take stands at shows is to directly sell their product, avoiding the complications of mail order, web-based or telephone selling, and enhancing interaction with your customers.

TELEVISION COVERAGE

The power of television cannot be underestimated. Any coverage you can achieve for your plant on, for example, programmes such as BBC Gardeners' World or The Beechgrove Garden, or ITV's Love Your Garden with Alan Titchmarsh, are likely to be

fleeting, though they do reach a very wide audience and appearances are known to have stimulated purchases.

A potentially more predictable and effective approach, however, could be to make use of the TV shopping channels. Over the past 20 years, TV shopping networks have exploded onto the retail scene. QVC, Ideal World, and Bid-Up TV, are a boon to entrepreneurs who can achieve extremely high exposure in a short period of time. Not every product suits the format or marketplace, so there are some questions to ask yourself: Does the plant or product demonstrate well? Does it solve an identifiable garden "problem" (or make gardening easier)? Does it have unique features and benefits? Does it appeal to a mass audience? Is it topical or timely? If you can answer yes to at least some of these, then it is worth approaching a shopping channel.

Your first step should be to look at the channel's website. There you will find information on making an appointment with a buyer, to whom you will need to present your product. Just as with selling to a retail buyer, it is important to do your homework beforehand. Become familiar with the channel's programming. Watch the gardening coverage, and note the products and lines so that you can talk with knowledge when making your presentation. And know your own quantities, delivery times, and bottom line. In some cases they will like your product, or plant, but it may not meet their criteria for price (the preferred minimum unit price is usually around £15 so that savings can be passed on to the consumer). But if you are not chosen the first time you try, do persist.

SOCIAL MEDIA

Consumers are using Twitter®, Facebook®, and other networks to communicate with each other. Do you or your company have a Facebook page, and if so do you know if it is driving traffic to plant offerings? Do you know how to integrate social media into your current communications? And is your social media integrated into your website? Integration of Facebook, Twitter, and your website, will save you a lot of time.

The people who like you on Facebook or follow you on Twitter are customers who want a relationship and the most successful commercial users of these media are those who engage with their fans. Many use Facebook to get fans excited about a product or brand, and create a place for customers to interact with each other and the company. Coupons, giveaways, and fan-only deals (making offers that are visible only to your Facebook "likers," for example), when used with some thought and restraint, can be a great reward for your faithful. But it is important not to use social media for "hard selling" as although social media users will buy from brands they trust, trying to give them a hard sell will turn them off fast.

The companies who use social media most effectively are often those who have appointed someone enthusiastic on the staff as "social media champion" responsible for setting it up and running it.

APPENDIX

Some Key Trade Exhibitions

International Trade Fair for Plants (IPM), Essen, January
Garden Centre Association Winter Conference, (different location each year), January
Garden Press Event, London, February
British Plant Fair, Warwickshire, March
The Landscape Show, Olympia, London, March
HTA National Plant Show, Warwickshire, June
Fruit Focus, East Malling, Kent, July
Plantarium, The Netherlands, August
Four Oaks Trade Show, Cheshire, September
GLEE, National Exhibition Centre, Birmingham, September
South West Growers Show, Devon, October
National Fruit Show, Kent, November

HortiFair, Holland, November
GroSouth, West Sussex, November

Some Key Consumer Shows
RHS Plant and Design Show, February
The Edible Garden Show, Warwickshire, March
RHS Show, Cardiff, April
Harrogate Spring Flower Show, April
Malvern Spring Gardening Show, May
RHS Chelsea Flower Show, May
Bloom, Dublin, May
Gardening Scotland, Edinburgh, May/June
BBC Gardeners' World Live, National Exhibition Centre, Birmingham, June
Hampton Court Palace Flower Show, London, July
RHS Show Tatton Park, Cheshire, July
Shrewsbury Flower Show, August
Southport Flower Show, August
Harrogate Autumn Flower Show, September
Malvern Autumn Show, September

Consider linking your attendance at consumer shows with the specialist plant society most closely reflecting the range of plants you sell.

Conifer Grafting at Iseli Nursery: Fundamentals to Creating Great Product©

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INTRODUCTION

The foundation of Iseli Nursery is an unwavering focus on delivering high-quality plant material to many of the best independent garden centers in North America. Grafted conifers are a significant part of our business. I will share the steps and methods we take for grafting during the calendar year as a seasonal outline.

Before we start grafting we work on the production plan. It is rather complex and time consuming to create, but the end result is the blueprint we use to determine how many of which items to graft. Using historical metrics, current demand, and forecasting we hone the list of cultivars to propagate. Our list of production items for 2013 was 266 cultivars from 17 genera. Additionally, we grafted 260 evaluator cultivars last season that are in various stages of development. A select few will become new introductions after years of evaluation.

SEASONAL OUTLINE OF STEPS AND MENTODS FOR GRAFTING

Spring: Potting and Planting

To make great product the plan needs to be executed by the team. We start with the rootstock. An assortment of different rootstock started as seedlings or cuttings are used. The largest quantities of rootstock that we use are spruce and pine and these are purchased and also grown at Iseli as a 1-0 plug or 2-0 bare-root. Potting of seedling stock is done in February-March. The pot sizes we use are #1's and 3-5/8 in. × 6-in. band pots which are larger container sizes than many commercial grafters use. Since we are grafting for our own needs, our goal is to focus on the end product. We make every effort to do whatever is needed to enhance the process as the grafted conifers are stepped up to the planned selling sizes.

Summer: Rootstock Growth and Development

The potted rootstock grows for at least one growing season in the pot in which it will be grafted. This enables a strong root system to support the grafted conifer as it is developing. Ideally, the rootstock will have a smooth straight stemmed "grafting face" of at least 2 in. as low to the root crown as possible void of branching with a caliper approximately 3/8 to 1/2 in. Growing a strong, healthy, uniform rootstock helps the carpentry steps that follow run smoothly and efficiently.

Fall: Rootstock Preparation

Prior to grafting we prune all side branches. This allows maximum light penetration to the new grafts and increases air circulation. Furthermore, it is an easier product to handle. The pruning process is done in an assembly line fashion with the end product graded and sorted by caliper. We assemble these graft-ready rootstocks in a greenhouse maintained above freezing.

Winter: Carpentry

The conifer-grafting period starts in late November and is completed in early March. A side-veneer graft is used. The high-skill carpentry step of grafting is the step most people consider to be "grafting" but it is really only one step in the process. The workload for winter grafting is divided and delegated to various tasks that include scion collection, scion preparation, plant transportation, and grafting.

We have one person in charge of picking; he is also our shipping quality control person.

He has a crew of detail-oriented people available as needed who are plant savvy and have experience grafting and also pulling plants for orders. The connection from start to finish helps the continuity of knowledge. It is kept with the people in the position to make the most positive impact on crop consistency and quality.

We do not maintain a stock block of plants to pick scion wood from. Keeping our production stock in prime condition facilitates the harvesting of a few pieces of quality scion wood per plant. The balance between taking scion wood and preserving or improving the selling status of plants is something that is always considered. Scion selection largely dictates the way in which the plant initially grows for the first few years, and can dramatically alter the size and time frame for a plant to reach marketable size. Good scion wood needs to be from healthy vigorous plants that fully exhibit the known qualities and characteristics of the cultivar being collected. For example, plants that are upright growers need scion wood taken from upright oriented shoots. For prostrate growing cultivars scions need to be horizontally oriented.

After being picked the scion wood needs to be prepared for grafting. Support people do the preparing and transporting of rootstock to and from the greenhouses. The scion wood is cut to a 4-in. length. The needles and buds of the scion need to be removed to simplify handling and to make sure a good secure wrap is performed. Pine needles are plucked and on spruce and other similar conifers we use a knife and scrape the direction the needles lay to remove them. We make sure that the scion stays cool and moist through this process. After scion wood is prepared it is wrapped in a moist paper towel and put it in a small plastic bag, refrigerated and ready for the next step, the carpentry step. We try to pick, prepare, and graft within a few days to minimize variables in the success of our effort.

Prior to grafting the rootstocks are thoroughly watered, because they will not be watered for a month or so after grafting. Our grafting room is set up with efficiency in mind. Potted rootstocks in flats come in on trailers through the middle of the room. The rootstock is fed to each grafter on roller conveyors so that each grafter has a continual supply. There is another set of conveyors that move the finished grafts from the ten grafting workstations back to the trailers.

In the actual grafting process, the carpentry, we look at the rootstock, assess its flaws, find the best “grafting face,” and make a smooth 2-in. cut into the cambium layer. Next, we do the same with the scion, match one side of the cambial material to the rootstock with that of the scion, and, if possible, both sides. We secure the union with a rubber-grafting strip 8 or 12 in. long. We are constantly cognizant of sanitation and use isopropyl alcohol to keep our grafting knives clean. After the trailer is loaded with completed grafted plants they are moved to a grafting greenhouse.

Again, the carpentry is typically thought to be the most important part of the process, but the next steps are equally important. Continual monitoring after the grafts are completed is imperative; looking for things like drafts, fungal problems and varmints. In the greenhouse we drape or tent sections of grafted plants with 12 ft. × 200 ft. × 2 mil poly vapor barrier. We keep the grafts covered with the vapor barrier for approximately 1 month. Pines are the only plants we do not tent. Our goal is to maintain a cool greenhouse. The thermostat is set at 45°F with tenting the relative humidity is kept high while the graft union is knitting. We do not water for at least a month after grafting, we do not seal grafts with wax and watering too soon can flood the new union and inhibit the knitting process.

Spring/Summer: Aftercare

In late May to early June, when the rootstock flushes and begins to overshadow the scion with new foliage, we complete our first cut on the rootstock, approximately half the rootstock is removed. This increases airflow, light penetration and focuses more energy to the scion. Late June into July we make final cuts (remove the remaining rootstock), remove bands, stake, prune, and weed. If the new graft is a miniature or sensitive cultivar a stub of rootstock is left on for a year or more to help sustain the new graft. The grafted

conifers are now ready to be moved from the grafting greenhouses into their summer growing location and are now part of our regular production process.

Conifer grafting in large numbers has been repeated now more than 30 times and with each repeat cycle small changes and details continue to be added to modify and improve the end result. We produce our product through planning, execution, and teamwork. This includes keeping and preserving highly skilled labor that can be relied upon to generate and deliver our conifer needs. The focus on the details of everyone in the chain from sales people to managers to scion collectors to grafters to preparers all contribute to our end product. Each one playing their part to achieve our goal of sending our customers the best product we can create.

QUESTIONS AND ANSWERS

Mike Bone: Do you tent any of the five-needle pines?

Peter Gregg: No.

Mike Bone: Do you find there's more disease when they're covered or do they need more light?

Peter Gregg: We've not tented in my experience and it may be due to concerns over light. Our goal is to keep the relatively humidity high as they go through the grafting process.

Mike Bone: Do you do any hot callus for any of your species?

Peter Gregg: No.

Verl Holden: Just a comment: Hot callus does not work on conifers.

Craig Ford: Can you comment on your use of seedlings and cuttings as *Cryptomeria* rootstock?

Peter Gregg: We don't have a great source of *Cryptomeria* seed.

Joe Braeu: What kind of success rate to you find when the scion is very small?

Peter Gregg: The success rate is approximately 90-95%.

Jim Ellefson: How to handle heat build-up in the winter time on bright sunny days? Do you use shade then?

Peter Gregg: Most of our grafting houses are pretty old, so they already have about 10% shade. We use vapor barriers and if they get too hot we'll open the sides up slightly for ventilation.

Jim Ellefson: How to handle the watering when they're covered?

Peter Gregg: When they're first started they are completely watered in. Since the process is done in the winter when water needs are relatively low they're aren't watered again.

Teaching Plant Propagation Online©

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INTRODUCTION

Responding to the ever-changing opportunities offered by the Internet, the Department of Horticulture at Oregon State University (OSU) decided to offer an online degree in General Horticulture. With assistance from the College of Agriculture and Extended Campus, the first few courses were available in 2009. One of the required courses for this new degree was HORT 311 – Plant Propagation which would be offered Winter Term.

Since 2008, I taught the on-campus course in plant propagation, which includes a lab section where the students experience hands-on grafting, seed germination and seedling growth, cuttings, and layering. When asked to develop the online class in plant propagation my response was "How do I teach plant propagation online? What about the labs?" Frankly, I felt that this type of course could not be taught online and I resisted developing one.

As the number of online, degree seeking students continued to increase, I realized that I must come to terms with developing a plant propagation course. So I let go of what I was doing for the on-campus students and put myself in the position of the online student. My daughter had taken several online high school courses that gave me a little more insight into what was possible. In addition, support from Ecampus and other faculty who had developed online courses helped me to shape a vision.

The key was to let go of what I had done and focus on what I could do, or more correctly, what the students could do. Professional plant propagators reminded me that the most important thing to teach students is the basic science of plant propagation and the general practices used. Any skill a student would acquire would take a lot of time and practice; therefore, it was not a goal for this course.

Instead, seven learning objectives were developed specifically for the online students. These included:

1) Identify the key components of the six major plant propagation systems used worldwide to increase plants for the benefit of mankind.
2) Analyze the physiological and genetic principles underlying the selection and propagation of plants.
3) Summarize the relationships between propagation technique, genetic variation, and the concept of a cultivar.
4) Describe the advantages and disadvantages of the common methods used to propagate plants.
5) Recall how plants grow, their physiological and developmental characteristics and predict how these can be manipulated for successful propagation.
6) Prioritize the complexities of methods used to solve plant propagation issues.
7) Demonstrate an introductory level of evaluating successful methods of both asexual and sexual plant propagation for specific plants.

COURSE CONTENT

Ten weekly topic folders are used to organize the course into major plant propagation topics. This course is not self-paced and a student has frequent deadlines for assignments, exams and discussion participation. The current weekly topics are:

Week 1 – Plant biology and genetics.
Week 2 – Seed development, breeding, and production.
Week 3 – Seed harvesting, dormancy, and germination.
Week 4 – Seedling production systems.
Week 5 – Adventitious roots, stock blocks, and cutting treatments.

Week 6 – Cutting environment and propagation systems.
Week 7 – Graft union formation and successful grafting techniques.
Week 8 – Field budding and layering.
Week 9 – Specialized stems and roots.
Week 10 – Managing plant clones and micropropagation.

Introduction Videos
After reviewing several other online courses. I decided that a 5-minute introduction video would help students get a feel for each weekly topic. It would also provide the student with a visual connection to me. I videotaped myself using a Flip Video UltraHD 120 Camcorder and used iMovie software to edit the video. Each weekly video was shot at a different location (outdoor orchard, inside a mist house, etc.) that was related to the topic. It was a bit of work to do this but I had fun with it. I also discovered that I would not make a very good actor. But on the other hand, my Ecampus consultant had advised me that it was best to be human so that students would relate to me.

Reading Assignments
The required textbook for the course was Plant Propagation: Principles and Practices by Hartmann, Kester, Davies, Jr. and Geneve, 8th Edition. The reading assignments covered most of the book (Chapters 1-18), which contains a vast amount of information. To assist the students in their efforts, I developed a study guide that included terms and concepts they should focus on while reading the chapters.

Narrated Slide Shows
I used narrated slide shows to compliment the reading assignments and to help show students how the science and practice of plant propagation are inter-connected. In total, 19 slide shows were developed using Microsoft PowerPoint and Adobe Presenter software. Each slide show would typically run for 30 to 45 min. Developing these slide shows was one of more challenging components of the entire course. At first, I wanted to make it sound perfect but after 6 h of working on the first one, I gave up and just started talking like I would in the classroom. Again, my Ecampus advisor told me that was a great method to use and that students would feel more at home (or in the classroom) if I coughed and stuttered, now and then.

Video Clips
About 30 video clips are used to demonstrate plant propagation techniques, such as grafting, layering, and seed cleaning. Most of these videos were found on YouTube and a range of amateur to professional propagators produced them. Another set of 10 animated tutorials from Sumanas, Inc. demonstrate general biology concepts, such as genetics, which are essential for students to understand when collecting seeds or understanding plant mutations.

Assignments
I use two categories of assignments for the class. The first category involves writing assignments about the major implications of plant propagation. The second involves a plant propagation activity and writing a report on the results of that activity. Activity assignments for the on-campus students will often focus on lab exercises. Designing assignments specific for online students required a bit more creativity on my part. One of these activities requires the online students to find a plant with seed on it and harvest the seed. They have to clean the seed and review the literature to discover if any seed dormancy exists and what the pre-germination treatment would be. Of course, they must also be able to identify the plant from which they collected the seed. The student documents the process by submitting images of the parent plan and the cleaned seed along with the literature review. The activity assignments are popular with the students. A few times, in order to complete the seed collection assignment, students have had to dig

down a few feet into the snow to find a suitable plant! Other activity assignments involve developing plant propagation profiles for local plants and completing one of the layering techniques on a suitable plant.

Discussion Board

The "Discussion Board" is the place students interact with one another on a regular basis, sort of like texting or Facebook®. They discuss a plant propagation topic related to the material introduced that week and are given an opportunity to express their own thoughts. Once again I was skeptical about this activity but my Ecampus advisor said that I would be surprised at the level of participation. And I was more than surprised; I was amazed at their knowledge and thoughtfulness regarding the topic. It was a channel for each student to feel like they had something to share and the social barriers that exist in a classroom were removed. Often one or more students would share their own experiences or help explain a concept to another student or even provide information on where to obtain propagation supplies and the potential availability of local hands-on workshops. While they are required to make one original post and one response to another student's original post, they often would make several additional posts. One weekly discussion topic "Discuss strategies to conserve plant genetic resources" inspired 86 total posts.

Rarely do I enter the discussion, thus allowing students go without fear that I will comment about their posts. I do follow the discussion to make sure that proper etiquette as outlined in the guidelines is followed and to assign grades. Just as with any in-person conversation, discussion boards have the potential to produce rudeness, disrespectful behavior, and hurtful comments. I have yet to have a problem with this even though we do discuss some controversial topics.

Mid-Term and Final Exams

Two mid-term type exams and the final exam are used to complete the student evaluation of learning process. The other tools that used are the weekly discussions and assignments. Unlike the on-campus students that have to show up at set time for an exam, the online students can select a time over a range of several days. As mentioned earlier, many of these students are employed and the attraction to an online course is the degree of flexibility in time management. Though once they select a time to take the exam they have to compete it in the same amount of time as the on-campus students.

CONCLUSION

In the beginning, I was skeptical and reluctant about developing and teaching an online plant propagation course. It took working part-time for about 6 mo. to complete the course development of all new course materials such as narrated slide shows and introduction videos. It took only about a month after the first course was offered that I realized it was going to be successful. I could see the excitement, energy, and enthusiasm most of the students had for plant propagation through their assignment writings and interaction on the discussion board. Several of the students mentioned how they have been waiting a long time for such a class to be offered online. A few students commented that the course contained too much information and was difficult for them to cover everything, especially those who were employed full-time.

The online plant propagation class is a 4-credit course that is available for degree and non-degree seeking students. Currently, there are 84 students across the country enrolled in the online General Horticulture degree offered by OSU. About half of these students are located east of the Rocky Mountains. Enrollment in the winter term of the online plant propagation class is expected to cap at 30 students. It is interesting to note that in previous terms, many of the online students are actively employed in the nursery and landscape industries, vineyards, conservation agencies, or in agriculture.

To learn more about this and other online degrees offered by Oregon State University, visit the Ecampus website at: <http://ecampus.oregonstate.edu>

QUESTIONS AND ANSWERS

Douglas Justice: How much time do you have to put in online with the students and, secondly, how does student performance on exams compare between the online course and one that's delivered in person?

Richard Regan: It took 6 mo. to develop the course. There's a tremendous amount of upfront work. The course has a schedule like regular courses, that is, students can't show up online any time they want. I spend relatively little time with the students during their weekly online discussion assignment. There may be 80 posts on a particular topic under discussion and I contribute none. I let them go just making sure they all follow the online etiquette rules we've established (e.g., improper language, treating each other with respect, yelling by posting with all capital letters, etc.). On the assessment, which is the exams and written assignments, the online group excels on the written exams in understanding the concepts presented in the course. Online students evidently feel much more secure sharing their views because they are using a computer to express themselves. The students taking the course in person do better answering practical questions on the exams.

Peter Gregg: Do former online students have access to any information related to the class?

Richard Regan: That's a good question. They don't have access to course materials once their online course is finished. They are able to make copies of materials during the time they're enrolled in the course.

Ornamental Plant Breeding at Oregon State University©

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The Ornamental Plant Breeding Program at Oregon State University was established to develop new cultivars, primarily of woody taxa that are adapted to Oregon and beyond. The program is diverse and has active projects in more than a dozen genera. The goals of various projects are as diverse as the taxa and include developing sterile cultivars, improving growth form, or other traits for production and landscape use, novel ornamental traits such as flower color or form, and insect or disease resistance. Examples of projects discussed here include sterile Norway maples (*Acer platanoides*) and rose-of-Sharon (*Hibiscus syriacus*) and mutation breeding in flowering currant (*Ribes sanguineum*) and sweetbox (*Sarcococca confusa*).

INTRODUCTION

I was hired in 2009 with teaching and research responsibilities, specifically to breed new ornamental cultivars for the nursery and landscape industries. The program is broad in scope and includes diverse taxa such as *Acer*, *Berberis*, *Cercidiphyllum*, *Cotoneaster*, *Galtonia*, *Hibiscus*, *Malus*, *Penstemon*, *Philadelphus*, *Prunus*, *Ribes*, *Sarcococca*, *Syringa*, and *Thuja*. Similarly, the goals and techniques used for each project are varied. Main objectives for each project fall into one of four categories: (1) sterility, (2) alternative growth form (e.g., dwarf, fastigiate), (3) improvement of specific ornamental traits (e.g., flower color or form, foliage color), or (4) insect and disease resistance. For brevity, the discussion here will be limited to work being conducted on Norway maples, rose-of-sharon, and two non-targeted mutation breeding projects in fragrant sweetbox and flowering currant.

PLANT BREEDING PROGRAM

Sterility in Norway Maple

Several economically important maple species have been identified as invasive in various regions of the country, particularly New England states. Norway maple (*Acer platanoides*) remains an important species for Oregon growers even though it has been banned in Massachusetts and is officially listed as invasive in Connecticut (USDA-NRCS, 2013). To address this issue we have been working toward developing sterile triploid forms of Norway maple.

In 2011, we treated three genotypes of Norway maple by placing a drop of agar-solidified oryzalin solution on the meristem of seedlings at the cotyledon or first true-leaf stage using a pipette and recovered 113 homogeneous tetraploids. In 2012, we sent 15 selections to J. Frank Schimdt and Sons Nursery to be propagated by budding. In 2013, these selections were tested and 14 of them remained stable tetraploids. Replicates of these selections will be transplanted during Winter 2013-14 to Corvallis for observation and evaluation of fertility when they flower.

Hibiscus syriacus Breeding

The U.S. National Arboretum released four rose-of-Sharon cultivars that were reportedly triploids with reduced fertility including ‘Diana’, ‘Minerva’, ‘Aphrodite’, and ‘Helene’ (Egolf, 1970, 1981, 1986, 1988). These cultivars are still popular in the trade today; however, they have been observed to produce substantial amounts of seed, which is in contrast to their description at the time of release. It is unclear why these cultivars have become fertile. We know that the assumption that rose-of-Sharon is a diploid is incorrect;

its natural ploidy level is tetraploid. This fact has potentially major implications for using ploidy manipulation to develop sterile cultivars.

We have begun a breeding program to investigate reproductive behavior of these and other cultivars, while also working to develop new cultivars. Questions of interest are: (1) what is the ploidy level of available cultivars, (2) what is the relative fertility of available cultivars, and (3) how are ornamental traits such as eye spot, double flowers, and flower color inherited. If we can determine inheritance of these traits we will be able to use targeted breeding to develop sterile forms with specific phenotypes.

We made controlled crosses in 2012 to evaluate fertility. 'Aphrodite', 'Diana', and 'Minerva' did not have reduced fertility, either as a male or female parent, compared to the other cultivars included in this study (Table 1). Of note was the substantially reduced fertility of 'Flogi', Pink Giant® rose-of-Sharon; this corresponded to the fact that it was a hexaploid and was the only cultivar in this study that was not a tetraploid (Table 2). Our observation that reduced fertility is associated with variation in ploidy level indicates that ploidy manipulation remains a viable option for developing sterile rose-of-Sharon cultivars. Nearly 600 seedlings from 2012 crosses were field planted in 2013 and will be evaluated for flower color, eye spot, and double flowers.

Mutation Breeding

Flowering currant (*Ribes sanguinuem*) is native to the Pacific Northwest and is a favorite of proponents of native landscapes. It is attractive in spring when flowering and attracts pollinators. It tolerates poor soils and drought. However, flowering currant tends to be leggy and has a poor form in the landscape. There are varied forms with regard to flower color but our goal is to develop a line of cultivars that are compact and exhibit the range of flower colors available from white to pink to cherry red.

Seed were treated in late-2011 with ethyl methanesulfonate (EMS). This generation (M1) was field-planted in Spring 2013. We have selected several forms that have potential for release including a cut-leaf form that has been distributed to eight Oregon nurseries for trialing. We have begun selecting the most highly branched and compact plants from the M1 and will continue in the M2 generation. With an additional year of field data, I hope to release the cut-leaf form in late 2014 or 2015.

Fragrant sweetbox (*Sarcococca confusa*) is a shrub prized for its ability to thrive in dry shade, an exposure most plants will not tolerate. It has few pest and disease problems and requires little maintenance. Fragrant sweetbox produces white flowers during winter and glossy black fruit later in the year that are persistent. It is more fragrant than *S. hookeriana* and more cold-tolerant than *S. ruscifolia* (Dirr, 2009). Fragrant sweetbox also does not spread by rhizomes; therefore, it will not spread into unwanted areas of the home garden and can be maintained more easily. The major breeding opportunity for fragrant sweetbox is the lack of diversity in this species. We have initiated a mutation breeding program to induce variation. A particular goal is to identify more compact forms that would serve as an intermediate between *S. confusa* and *S. hookeriana* var. *humilis* but would not spread as in the case of the latter.

Seed were treated at the same time using the same method as the flower currant described earlier. All plants were field-planted in Spring 2013 under shade for long-term evaluation. Fruit were collected from a subset of the population and are being grown to evaluate the M2 population. The most compact plants from M1 generation were propagated in 2013 and are being evaluated. A number of selections show great promise as introductions that exhibit compact growth and alternate leaf shape that is much more narrow than the wild type.

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Table 1. Results of crossing study conducted during 2012 to estimate the relative fertility of nine rose-of-sharon (*Hibiscus syriacus*) cultivars.

Cultivar	Flowers pollinated	Seedlings	Seedlings per pollinated flower
As female parent			
Aphrodite	42	423	10.1
Blue Satin	59	318	5.4
Diana	97	155	1.6
Flogi	39	3	0.08
Lucy	34	27	0.8
Minerva	24	44	1.8
Oiseau Bleu	36	66	1.8
Red Heart	74	212	2.9
Woodbridge	70	180	2.6
Mean	52.8	158.7	3.0
As male parent			
Aphrodite	74	55	0.7
Blue Satin	44	443	10.1
Diana	55	186	3.4
Flogi	50	25	0.5
Lucy[z]	-	-	-
Minerva	66	222	3.4
Oiseau Bleu	54	212	3.9
Red Heart	66	154	2.3
Woodbridge	66	131	2.0
Mean	59.4	178.5	2.9

[z]'Lucy' is a double-flowered cultivar that does not produce pollen, therefore could not be assessed as a staminate parent.

Table 2. Mean relative holoploid genome size (2C) estimates ± SEM and inferred ploidy levels of nine cultivars of rose-of-sharon (*Hibiscus syriacus*). Estimates were performed by analyzing DAPI-stained nuclei using flow cytometry using *Solanum lycopersicum* 'Stupicke' (2C=1.96 pg) as an internal standard.

Cultivar	2C	Ploidy level
Aphrodite	4.7±0.04	4*x*
Blue Satin	4.6±0.03	4*x*
Diana	4.7±0.06	4*x*
Flogi	6.8±0.05	6*x*
Lucy	4.6±0.01	4*x*
Minerva	4.6±0.05	4*x*
Oiseau Bleu[z]	4.6±0.04	4*x*
Red Heart	4.7±0.00	4*x*
Woodbridge	4.6±0.06	4*x*

[z]'Oiseau Bleu' is also sold in the trade as 'Blue Bird' and 'Bluebird'.

Investing in Germplasm to Generate Value for the Nursery Industry©

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INTRODUCTION

The economic success of nursery production is intimately connected with the array of plants being grown for sale. This array is a constantly changing mix of species and cultivars. Tastes change, resource availability and costs change, pests and pathogens evolve, and, every day, those involved with breeding and cultivar development deliver new choices bred and selected from a very diverse range of plants to propagators and growers. The ultimate goal for each firm is to develop an inventory of selected plants that gives value and satisfaction to their customers while ensuring profitable production.

If we look carefully at this situation, it's clear that plant biodiversity is the foundation of the new cultivars that feed changing tastes, allow for more efficient resource use, and hold the keys to pest and pathogen resistance. That diversity, which I'll refer to as germplasm, exists in many forms and places, from natural plant communities to public gardens, private collections and genebanks. In this paper, I'd like to present information about how the U.S. National Plant Germplasm System (NPGS) has gone about involving its customers in the process of building valuable, comprehensive germplasm collections for plant genera of interest to IPPS members, along with a few budding success stories.

Those who select and breed new cultivars or who seek out choice, but forgotten ones, can access germplasm in many ways. They can explore the wilds or they can search seedling beds and production fields, private collections, or gardens. Most of that requires special knowledge of the range of cultivars already in the trade (and their strengths and weaknesses), of where and when to look, and of ways to get permission from land, nursery, or garden owners. Of course, some public gardens and arboreta do make their collections available via web-based inventories and procedures that facilitate access for research and cultivar development. The North American Plant Collections Consortium (NAPCC), coordinated by the American Public Gardens Association (APGA), is designed to promote both straightforward access to significant germplasm collections held by its member gardens and high curatorial standards to ensure their long-term conservation (APGA, 2013). But the focus of this paper is on the NPGS, an extensive network of genebanks coordinated by the U.S. Department of Agriculture – Agricultural Research Service (USDA-ARS). The NPGS conserves one of the world's largest national collections of crop germplasm, including many ornamental plants, and it makes that germplasm freely accessible for research and education, with many potential (if sometimes indirect) benefits to IPPS members.

THE U.S. NATIONAL PLANT GERMPLASM SYSTEM & CROP GERMPLASM COMMITTEES

The Combined Proceedings of the IPPS includes a fairly recent paper that describes the NPGS and how its collections can meet members' needs (Widrlechner, 2009). In relation to ornamental plants, the overall network of genebanks noted therein has changed relatively little in the last few years. In addition, guidelines concerning members' access to NPGS germplasm for research and education have also remained stable. However, the NPGS's holdings have continued to expand in attempts to fill important collection gaps, and considerable knowledge has been gained about many of its collections. These advancements have been, in large part, due to two important granting programs, ones that receive significant input from 42 Crop Germplasm Committees (CGCs).

The CGCs were first established in the 1980s to help the NPGS establish standard lists of descriptors used to describe collections (Robbins et al., 2008). These committees are organized by crop, or by groups of related crops. A list of all CGCs and links to their

activities can be found on the Germplasm Resources Information Network (GRIN) website (USDA-ARS, 2012). GRIN is working database of the NPGS. It contains a wealth of publicly accessible information, including plant taxonomy and distribution (with an emphasis on cultivated plants and their wild relatives), original sources of collections, descriptive data, and imagery. It allows customers to request germplasm through its "shopping cart" feature and also serves as an internal NPGS management tool for quality assurance and inventory monitoring. GRIN software has recently been totally reworked for broader applicability across the world's genebanks, and a new version, GRIN-Global, is now being implemented (Postman et al., 2010).

The two CGCs of greatest interest to IPPS members are the Woody Landscape Plant and the Herbaceous Ornamental CGCs. These are large committees that include members from academia, government agencies, public gardens, trade associations, and commercial seed and nursery firms. These two CGCs have very wide-ranging mandates both in terms of crop genera and production environments. Their members are typically chosen to represent a broad range of crop specialties, disciplinary expertise, and geographic locations.

Crop Germplasm Committees members share expertise and consult with NPGS curators and site managers through regular (often annual) physical meetings or via teleconferences and electronic communications. In addition to the development of descriptor lists (their original mandate), CGCs develop crop vulnerability statements and advise NPGS personnel about threats to germplasm, anticipated uses, opportunities for acquisition, and efficient methods for safe conservation (Robbins et al., 2008). The Woody Landscape Plant and Herbaceous Ornamental CGCs are also deeply involved with two key granting programs funded by USDA-ARS that are relatively small, but significant investments in germplasm and, when successful, ultimately generate value for users.

BUILDING COMPREHENSIVE COLLECTIONS

One big challenge in the search for germplasm is that most germplasm holders have relatively few collections of any given species. Without large, comprehensive collections, it is hard to judge the merits of any given plant, because plant performance can be so closely tied to local growing conditions. Even major arboreta often maintain only a handful of accessions of a given species, and those accessions are typically represented by few individuals, sometimes a single plant (which in the case of a clonal cultivar may be all that is needed).

The NPGS and its users have long recognized the need to assemble extensive collections to provide broad genetic and phenotypic representation. For many field crops and for fruits and vegetables, collections numbering into the thousands of accessions were often brought together even before the CGCs were established in the 1980s. But many ornamental genera were not initially well represented within the NPGS. Fortunately, the USDA-ARS's Plant Exchange Office coordinates an annual granting program to support germplasm exploration, and that office looks to the CGCs to work together with curators to identify the most important collection gaps and solicit proposals for explorations that attempt to fill those gaps (Williams, 2005).

Here I will mention three notable examples where the granting program has been successful in building comprehensive collections of ornamental genera. In 1997, funds were granted to Kathy McKeown to coordinate the collection of a broad cross-section of native *Echinacea* populations from across its native range in the United States (Widrlechner and McKeown, 2002). This grant was successful in generating the core of one of the world's premier collections of wild *Echinacea* germplasm, which is widely used by both biomedical and horticultural researchers (McCoy et al., 2005; Birt et al., 2008).

The unintentional introduction of emerald ash borer (*Agrilus planipennis*) into North America in the 1990s has resulted in the tragic loss of millions of ash trees from both forested stands and managed landscapes. Given the importance of *Fraxinus* as a landscape and timber tree and its uses in conservation, the NPGS along with many other

agencies has mounted a national effort to conserve ash seeds before native populations are driven to extinction. These efforts were described in a recent volume of the Combined Proceedings IPPS (Widrlechner, 2012), but to update the role of the exploration grants, I can report that this program has now awarded 11 grants to collect *Fraxinus* (both in the USA and China) since 2007, and that the North Central Regional Plant Introduction Station in Ames, Iowa presently conserves 376 ash accessions.

More recent exploration efforts to build comprehensive collections of herbaceous ornamentals have been undertaken by the Ornamental Plant Germplasm Center (OPGC) in Columbus, Ohio, where the granting program has funded trips to collect seeds and vegetative propagules of *Rudbeckia*, *Coreopsis*, and *Phlox*. Explorations to expand the *Phlox* collection have been particularly successful and are summarized in a recent paper by Zale and Jourdan (2012).

GERMPLASM EVALUATION AND VALUE

By surveying hundreds of germplasm users, Day-Rubenstein et al. (2006) were able to determine that the extent and quality of descriptive information about each available germplasm collection have a significant influence on the perceived value of those collections. Without such information, searching for useful traits can be like seeking the needle in the proverbial haystack. The more that targeted evaluation and characterization data are captured and linked to specific germplasm accessions, the more likely one can efficiently limit searches for the most promising accessions. This is particularly important when navigating large collections of hundreds, if not thousands, of accessions.

About 30 years ago, the USDA-ARS Office of National Programs (ONP) realized that there were major gaps in the evaluation and characterization of horticultural crops. Parallel to the exploration granting program, ONP established a small granting program to support the evaluation and characterization of horticultural crop genera, based on priorities set by the pertinent CGCs. In addition, the CGCs annually solicit and rank proposals to support research that meets their priorities and generates data to populate GRIN. Since 2004, there have been 15 highly ranked proposals forwarded to ONP by the Herbaceous Ornamental and Woody Landscape Plant CGCs that have received funding (P. Bretting, pers. commun.). In closing, I will focus on two genera: *Aronia* and *Phlox*.

In 2007, Mark Brand at the University of Connecticut received a grant to conduct horticultural evaluation and cytological characterization of *Aronia* accessions. At that time, Brand had already been investigating the range of variation within the genus and its potential as an alternative to invasive non-native shrubs in the landscape and as a new fruit crop. He has collaborated closely with the North Central Regional Plant Introduction Station in Ames, Iowa, to assemble comprehensive collections of native *Aronia* populations and a sampling of cultivars. Many of these collections have now been assessed for a range of morphological, phonological, and aesthetic traits and for ploidy level (Brand, 2010; Leonard et al., 2013). Research is also underway to evaluate variation in fruit biochemistry related to potential human-health benefits (Taheri et al., 2013). The data generated by such efforts should be instrumental in selecting the best germplasm accessions for both landscape and neutraceutical applications.

The *Phlox* accessions that are being conserved by the OPGC have been subjected to many evaluations. Two projects supported by ONP's grants are studying the storage life of cut stems of *Phlox* and variation in petal color and pigment composition. In addition, Zale and Jourdan (2012) reported on interspecific hybridization among *Phlox* accessions and ploidy-level determinations. And work is now underway to assess these accessions for powdery-mildew resistance (P. Jourdan, pers. commun.), a pathogen that typically limits the use of *P. paniculata* cultivars (Hawke, 2011).

As these evaluation and characterization data are loaded into the GRIN database where they can be analyzed and used for cultivar selection and development, relatively small investments (most of these grants are for less than $20,000) in NPGS collections have the potential to pay big dividends, ultimately creating new value for those who use these

comprehensive NPGS collections to improve the array of plants available for growers and gardeners alike.

QUESTIONS AND ANSWERS

Tony Sanchez: Is the ONP funding the *Aronia* collection?

Mark Widrlechner: The ONP funded the evaluations. The collections have been funded primarily through the University of Connecticut.

Tony Sanchez: Who does most of the collecting around the country. Is it individuals, people related to the UCs or other universities or someone else?

Mark Widrlechner: Most collecting projects are initiated by curators of the germplasm sites or by university researchers who are interested in working with a particular crop. There hasn't been a great deal of industry involvement directly with the exploration proposals; however, there has been considerable interest from botanical gardens. For example, the Chinese ash collections were all done in conjunction with the Morton Arboretum.

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Review of Root Manipulation in Containers©

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Plants were not designed to grow in containers and, as a result, there are many potential problems growing plants in containers such as the possibility of poor quality root system and drainage aeration issues. This can lead to poor performance of plants at any time in their life even many years later.

In my opinion there are many root-related problems in standard containers that hold back plant performance. Problems like circling roots are some of the worst type of bad roots created in containers (Fig. 1).

Fig. 1. Typical problem of circling roots in a container.

I believe the objective should be to produce as natural a root system as possible with straight, non-circling or even deflected roots in the liner leading to a good long-term root system with lateral support/feeder roots and some straight roots going deeper to create support. The *Eucalyptus* transplant root system in Figure 2 is almost indistinguishable from a natural root system.

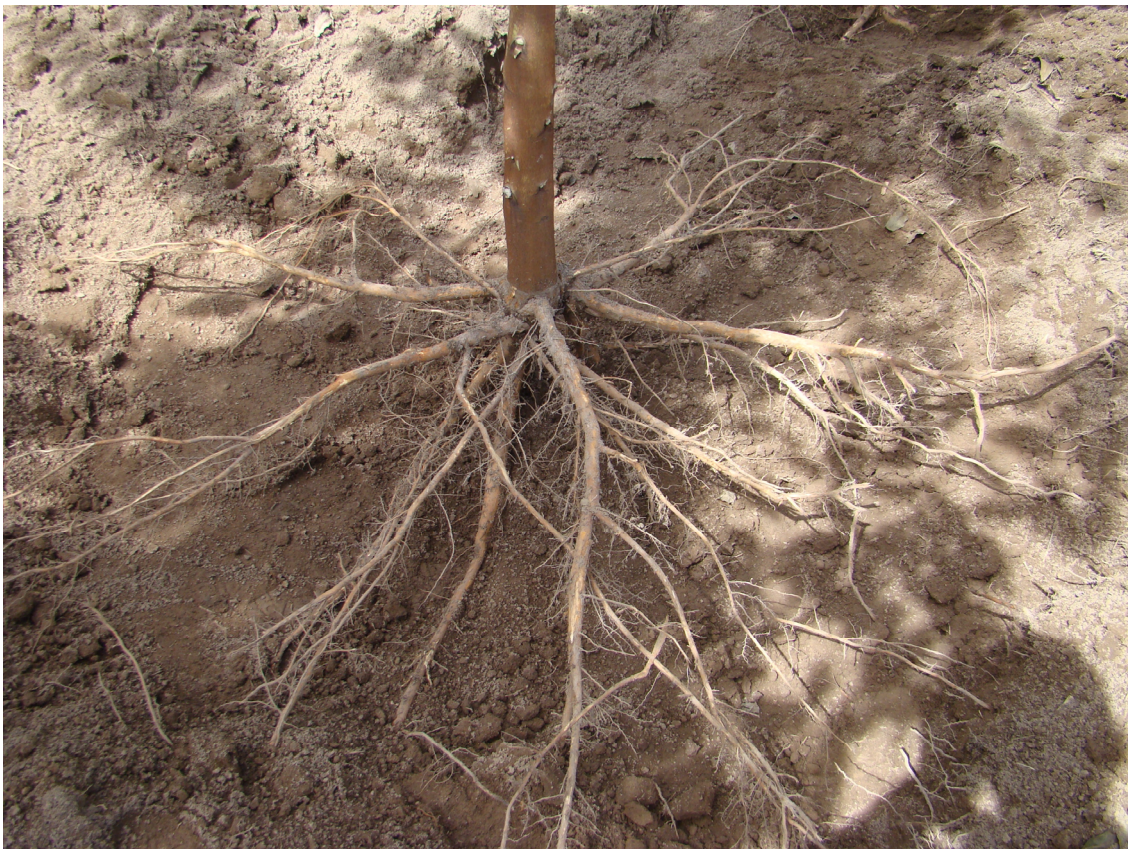

Fig. 2. Fantastic roots are possible with a container plant.

There have been many options to regular containers developed over the years with things such as copper treatment of containers, root trapping material on the inner wall of containers, and air pruning of the root system in containers. It would seem that air pruning is becoming the most popular method of doing this which is logical since there are no chemicals involved and it is a very natural process which allows for the reduction or elimination of bad quality roots, the increase in the total number of roots, and also the possibility of a better micro-climate in the pot.

Air pruning is a much misused term so buyer beware. Check what the offer really is as some people claim air pruning when it's not really happening. Plus, you can get air pruning just at the base of the cell or additionally up the side walls of the cell, the latter is more desirable in the short and long-term.

An example are Ellepots which are often said to air prune roots but this depends totally on what holding tray is used. The thermoformed type tray will create a useful air gap at the side of the Ellepot but not air pruning of the roots. If, however, an Ellepot is placed in a good air pruning tray where contact with the tray is minimal fully exposing roots to the air then air pruning can take place. Figure 3 shows a *Eucalyptus* liner grown in a good tray with air-pruned roots well up the side of the cell, not pretty but effective.

Fig. 3. A well-air-pruned *Eucalyptus* plant in a 35-mm Ellepot.

The question that has baffled me, therefore, is why are root manipulation containers such as air pruning containers probably used today by less than 1% of growers? If an air-pruning container was going to produce a much better root system people would want to use it, but this has not been the case to date for most nurseries.

My theory is that to be used widely within the industry a container needs to be not only able to produce fantastic roots but also be economical and practical. To date, many of the newer containers are expensive and also have not fitted in with normal nursery practices very well (e.g., they are not easy to use). I believe, therefore, that the challenge is for container suppliers to come up with economical and practical containers that produce great root systems.

Typically, air pruning containers are injection molded which means they are a long-life product and more expensive than a thermoformed tray. If, for example, an air-pruning tray is $4 and a thermoformed tray is $1, but only gets used once or twice then the cost per use is about $0.75 per use versus an air-pruning container that should last well over 20 uses and is, therefore, only a maximum of $0.20 per use. Thus, the injection molded container is considerably cheaper per use even if more expensive up front.

If you buy, say, 100,000 containers then even if they last a long time it is still a large up-front investment in cash terms versus a 1-trip cheaper product. However, in recent years this problem has been overcome with finance packages where the product can be leased over, say, a 5-year period. The result is that good trays can now be cheaper per use plus cheaper in cash-flow terms. Hopefully, this can overcome the economic barriers.

If plants are shipped out from the nursery in trays then the ability to be reused may not be practical so other 1-trip air-pruning trays need to be developed. If, however, plants can be pulled and packed or reused internally then the reusable propagation tray can remain on the nursery. One example here may again be with Ellepots that are essentially containers and can be shipped out easily without the tray in which they were grown.

Another angle to the acceptance of the “air-pruning” container is making it practical on the nursery. This means making it easy to use and fit in with current nursery and future nursery practices reducing labor and the amount of handling required. Some of the operations on the nursery that are affected are:

De-stacking
Filling
Stacking
Transplanting

Grading	Transport in the nursery
Benching	Pulling and shipping
Rigidity of tray	Cleaning and sterilizing

Here is a link to a video from a nursery in Uruguay using Ellepots for clonal *Eucalyptus* propagation which is pretty automated: (http://ellepot.dk/ellepot-videos/forestry/stora-enzos-nursery-montes-del-plata-in-uruguay-propagating-eucalyptus-with-the-ellepot-system.html).

The following list contains items that a good air-pruning container should improve on thus reducing unit cost price of plants propagated:

- Percentage take of cuttings (aeration/drainage)
- Uniformity of take
- Speed of take (30% reduction on *Eucalyptus*)
- Shelflife in container
- Tray cost and cash flow (leasing)
- De-stacking in nursery
- Grading and re-filling of trays
- Semi-automatic and automatic transplanting
- Percentage take and speed of establishment in next container size
- Faster top growth in next container
- Faster to fill container with roots
- Uniformity and grade out of plants
- Stability of plants after establishment

Just a small improvement in a few of the above can reduce unit price of plants and thus boost profits and get a plant with a great root system as a bonus.

AIR PRUNING PROCESS

I would now like to describe a little bit more by way of re-cap the air pruning process and some of the benefits it has on the root system. The animation on this link shows how air pruning works: <http://www.youtube.com/watch?v=iW_NkywQtoU&feature=youtu.be>. This air-pruning process multiplies the number of roots in the container resulting in:

- A very large quantity of young vigorous roots in the container.
- A large proportion of the roots are in the upper half of the container rather than the active roots just being at the base of the container.
- The container, by definition, is also very well-drained and aerated which seems to have given a big advantage to the health of the microclimate in the pot.
- Less defective bad roots in the container.
- Figure 3 shows a *Eucalyptus* plant in an Ellepot with air-pruned roots, a bit messy, but a great root system that will establish very well.

The theory, therefore, is that the large quantity of young roots will establish better when transplanted into a larger container or the field. Figure 4 shows a regular container alongside a container with air pruning at the base of the container and thirdly a container with air pruning up the side of the container as well.

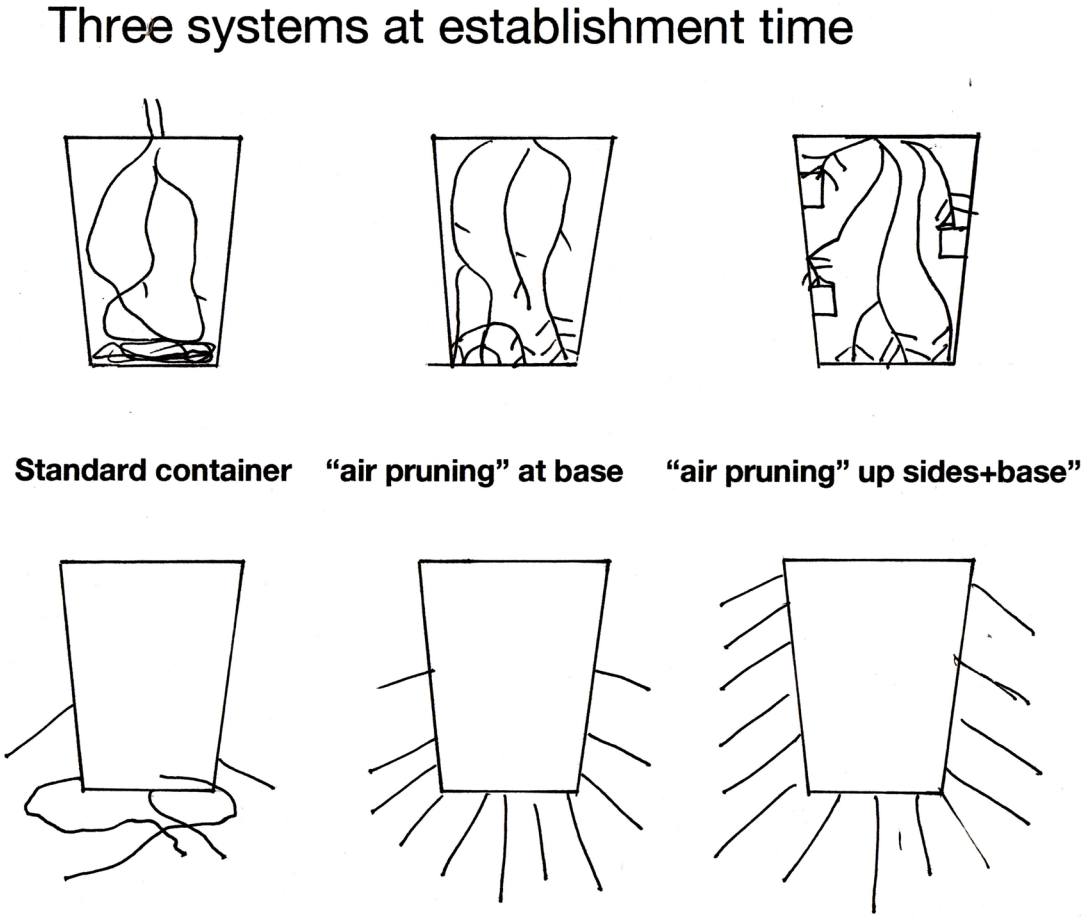

Fig. 4. Roots before and after planting with a regular pot, one with air pruning on the base and one with air pruning also up the sides of the pot.

I'm afraid to say that most of my observations are based on just that, observing what I see going around the nurseries and aiming to try and improve things. As yet there is little true science to this, but I'm pleased to say that there are some projects starting soon that will quantify some of the benefits of manipulated air-pruned root systems and establish some more scientific data.

Air-pruning container options are now available from a number of sources such as Nursery Source, Nursery Supplies, Stuewe, Blackmore, Rootmaker, and Proptek so check what suits you and perhaps do a trial. However, do the trial properly as air-pruning containers tend to require less water more often and trials are often spoiled when not treated properly. Air-pruning containers also need air movement to work and this means the containers are often smaller but this may well still have a larger active soil volume versus big pots with "dead" areas in them.

Check what suits you, do a good trial, convince yourself the system is right and the product is practical and economical then change.

QUESTIONS AND ANSWERS

Damian Sowa: We have to grow all our plants in styroblocks for insulation purposes, do you see any way of getting an air-pruning system in a styrofoam insulated block?

John Cooley: No.

Antonio Sanchez: What's the smallest size available for the air root-pruning (ARP) pot?

John Cooley: It depends on the configuration of the pot. For example, Ellepots get quite small and can be configured as an ARP pot. I would say that right now the smallest ARP pot is about 1½ in. across the top. More and more ARP pots will become available with

time. The limiting factor is that you need to have air flow around the root ball to achieve air pruning which limits the space you have. So, getting smaller gets to be more of a challenge.

Antonio Sanchez: What's the average price in the USA for a 1-gal container?

John Cooley: Different suppliers will have different prices. They'll probably be more expensive than the regular pots so you'll have to balance the cost with the added benefits.

Valerie Sikkema: How do you make the ARP pots work when the plants are sold at a retail nursery?

John Cooley: ARP pots do look a bit unsightly so the challenge is to wrap them with something before they're shipped.

Esteban Herrera: When was the data taken for determining mortality rates?

John Cooley: I'm not familiar with that data. That slide was used to illustrate the point that we have a great deal of data showing the response of plants to the ARP process.

Alan Elliot: Do you think there is a point where you can have too many roots in a container?

John Cooley: I think in terms of the number of roots in a container, you're absolutely correct. We've found that upon transplantation some roots are lost leaving the strongest ones to take over and become the roots that will grow out.