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by Dr Kevin Seaton

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Foreword

Waxflower is a major export cut flower of the Australian cut flower industry. Maximising performance of plants is critical for economic returns to the industry. Failure of plants to perform in the field can be attributed to a number of causes; including disease and poorly, developed root systems. Root binding has been identified as major concern in growing waxflower plants.The way in which the quality of a root system affects plant performance of waxflower varieties is poorly understood and it may be critical in terms of waxflower performance in the field. This research project investigated the factors affecting root binding of waxflower in the nursery and the field. The research focuses on the higher value new hybrid wax varieites, and develops strategies for production and management of planting stock suitable for field planting.

This report provides an understanding of how root binding of waxflower root systems can be minimised, particularly in new varieties. This information will be of benefit to growers of waxflower in Australia, as it provides propagation methods and post propagation planting methods that are directly applicable for use in nurseries and on farms. The outcome of the research will be the provision of quality waxflower plants which are better equipped to utilise water and fertilisers through healthier root systems. Production from these plants will benefit processors and exporters of waxflower, by providing them with better quality product i.e. longer stem length and more profuse flowering displays and higher yields. This research should benefit the whole of the waxflower industry, through longer lasting, higher yielding plants with increased sales of premium stems and increased profitability.

The key findings of this research are that it:

- identifies the major causes of root bound plants in waxflower
- defines the effect of the propagation tube as it affects root growth
- determines nursery practices that result in root bound plants
- determines how management practices post propagation affect root quality
- provides strategies for tube stock management and the production of quality plants

The importance of this report is that it provides a new approach to propagation in the nursery and tube stock management of waxflower on the farm. As well as indicating the importance of correct tube stock management, it emphasises the importance of linking farmers with propagators to get the best tube stock for planting. Growers now have a strategy for ordering and managing tube stock before planting. The report provides the tools for propagating quality waxflower tube stock. It will be a useful for the industry, particularly using new wax flower hybrids, enabling the industry to grow healthy plants which are early to come into production and have a longer productive life. This should benefit the whole export industry as the approaches developed here could also have spin off into other cut wildflower crops.

This project was funded from a grant from RIRDC, WA Department of Agriculture and Food and contributions in cash and in kind from the waxflower industry in WA.

This report, an addition to RIRDC's diverse range of over 1800 research publications, forms part of our Wildflowers & Native Plants R&D program, which aims to improve the profitability, productivity and sustainability of the Australian wildflower and native plant industry.

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Peter O'Brien
Managing Director
Rural Industries Research and Development Corporation

Acknowledgments

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The technical support of Mr J Berston for managing Medina trials, Mr G Morris at South Perth of WADAF is appreciated. The assistance of other technical staff at WADAF employed on the project is also appreciated

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Executive Summary

What is the report about

Use of quality tube stock for waxflower plantations is imperative to maximising plant performance in terms of stem yield, flower quality and plant longevity. Having plants that maintain production over an extended period has economic advantages in flower production. Failure of root systems and loss of plants can have a major effect on production and profitability. Little is known of how the choice of propagation method and design of planting tubes affect the quality of wax flower plants. This report determines the method for managing propagation and tubing up to achieve healthy non compromised root systems in waxflower. This study concentrates mainly on hybrid waxflowers.

Who is the report targeted at?

The report targeted at nurseries and growers of waxflower in the Australian cut flower industry. It provides them with information on the nature and occurrence of root failure in waxflower. Knowledge gained from this project should enable better management of plant production of native Australian flowers, particularly new hybrid waxflowers.

Background

Plant failure has become apparent with increased planting of waxflowers. This can't always be attributed directly to disease incidence and indications are that root system failure of plants are a major cause. This project addresses this problem. It appears that root failure originates during plant propagation. Root spiralling in propagation tubes develop into root knotting and ultimately to plant failure. This needs investigation in particular for waxflower varieties.

Aim/Objectives

To develop strategies to enable the waxflower industry to optimise tube stock quality, especially for new hybrid varieties. This includes providing strategies to wildflower nurseries on best practice for producing tube stock and waxflower growers on handling tube stock once received at the farm.

Methods used

Detailed glasshouse trials have determined the causes of root curling, taking into consideration of the geometry of the propagation. Evaluation trials on various tube stock were planted in the field for determining the effects on plant survival and stem production. Observation plots were established on farms, which provided a focus for growers in the surrounding district. Nurseries and farmers have been made aware of the causes of root knotting and the their solutions through workshops and field days.

Results and key findings

The project has demonstrated the occurrence and cause of root failure. Changes of propagation methods and the coordination of timing of orders between nurseries and farmers are critical to success. Best practice methods of propagation and planting of plants with non compromised root systems are detailed in this report. The main points can be summarised as:

1. Use propagation tubes that incorporate flat surfaces, root trainer fins and air pruning.
2. Introduce propagation methods to ensure plants spend a minimum time in tubes.
3. Ensure plants are grown in free draining mixes of sufficient water holding capacity.
4. Coordinate nursery production and plantation orders to minimise time in tubes
5. Ensure early preparation for early planting of new plants in the field

Implications for relative stakeholders (waxflower industry)

In summary waxflower systems can easily be compromised by poor nursery and field management practices. This will have major effects on the survival, production and quality of plants. Large cost savings in terms of avoiding replanting, loss of production and efficient use of fertiliser and water can gained by having plants with healthy root systems.

1. Introduction

The waxflower industry is a significant proportion of the Australian export flower industry (over $4.2 million of exports in 2005). Recent inspections of wax plantations by Department of Agriculture and Food WA staff showed that root spiralling was associated with plant death. The condition of a waxflower root system has a significant impact on its survival and production. Planting of plants with spiralled roots leads to the root system becoming knotted resulting in loss of production and plant death. This can occur within 1 to 3 years of planting. Improving pot design and pre planting protocols can have a positive effect on reducing spiralling and overcoming these field problems of poor root growth. It is also seen as a major problem that can affect waxflower plantations throughout Australia and is not just unique to WA.

Previously little has been known of the effect of nursery practice on subsequent root development management of Australian native flowers including waxflower and especially new hybrid waxflower. This has been part of the reason for an absence of practical advice given to growers on propagation. Nursery practises used by the waxflower industry appear to vary widely, which may explain the occurrence of root failure being seen in the industry. By providing a research basis for correct propagation of waxflower and therefore, better information on nursery practice than presently available, it is considered that this project will greatly benefit the industry.

Root spiralling (egression, kinking, curling) is usually concentrated in the bottom of pots and has been observed in poly bag seedling production in Mexico (Aldrete et al.2002) and in Douglas fir seedlings in the Irish Republic (Sundstrom and Keane 1999), *Pinus ponderosa* seedlings (Dumroese and Wenny 1997). Pruning off curled roots from the bottom of spiralled roots systems has been used to negate the effects of spiralling (Owston and Seidel 1978) but does not appear to be successful for many wildflowers (Seaton pers comm.).

Root spiralling has also been observed in tube stock of wildflowers but has not been well documented. The problem has been highlighted in an article in Flowerswest magazine (Jack 2002) where cell propagation trays gave markedly better downward root growth than the "normal" round propagation tubes. It appears that one of the problems of the round tube system, is that if plants are left too long in tubes after root strike, spiralling occurs. Experience shows that once spiralling has occurred there is little that can be done to prevent this from resulting in root deformation in mature plants. Root knotting of mature plants in the field has been observed in waxflowers (Manning et al. 1996, Seaton 2003) and has been attributed to planting of root bound plants. The quality of the tube stock has a large influence on the occurrence of root knotting (Seaton 2003). As a result root bound plants gradually lose vigour and are often blown over in strong winds (Manning et al. 1996). Root bound plants die prematurely and must be replaced (Manning et al. 1996) adding cost and loss of production to the grower. Estimates of the extent of loss from planting root bound plants, range from 20 to 100% in a four year life span of waxflower planting (Seaton pers. comm.) and indications are that the problem is more widespread than previously thought. There have been reports of plants dying in the field after a few years, which when tested for disease were found to have diseases present such as collar rot (*Rhizoctonia* spp. and *Cylindrocladium* spp.) (Reid 2004). However these were considered a secondary pathogen, gaining access due to stressed or damaged plants which had knotted root system (Seaton pers. comm.).

Relevance and Benefits

Loss of plants caused by root spiralling is estimated to be on average 20-30% of Australian wax planting and yield. The project aims to reduce these losses. Plant failure due to root spiralling needs trialling for waxflower and strategies developed to overcome the problem. This will include methods of propagation and propagation tube design suitable for wax flower. Flower industries being labour intensive enterprises are large employers of staff and by planting better quality plants with a higher survival rate will reduce labour needs and cost. Increased survival and yield in the order of 20 to 30% could mean the difference between a farm being viable or not. Farm viability will ensure continued employment in regional areas and lead to greater job security. The research

will directly benefit the export waxflower industry in Australia. Also waxflower plants with an effective root system will be better able to utilise water and nutrients and reduce leaching of nutrient, which will benefit the environment in less wastage through drainage.

Outcomes of proposed research

Adoption by nurseries of best practice tube stock management

- Nursery industry will have a means of determining the most suitable tube stock management program for waxflower
- Improved survival, yield of waxflowers produced for export from Australia
- *Ability of growers to recognise the impact of planting good tube quality tube stock on waxflower production*
- Greater awareness of the importance of planting quality tube stock on waxflower plantations through filed days and publications
- Increased plant survival and quicker establishment, leading to increased profitability
- Higher yields and better quality flowers increasing profitability and enhancing Australia's reputation on international markets
- More efficient use of fertilisers and irrigation water through extensive root systems, thereby helping to prevent nutrient leaching and conserve Australia scarce water resources.

2. Objectives

To develop a method for propagating waxflower plants including new hybrids to eliminate root spiralling and consequent root failure following planting out in the field through;

(i) determine the characteristics of a propagation tube to prevent root spiralling

(ii) changes in nursery practice to better manage tube stock during propagation

(iii) developing protocols for better management of plants pre planting out

(iv) developing protocols for field establishment

(v) developing information products

This project will address industry priorities as determined by the DAFWA/Industry R&D committee

3. Methodology

The experimental approach was to determine the factors affecting the quality of tube stock and its affect on commercial production of hybrid waxflower. This involved surveys of extent of the problem, conducting propagation tube trials and field trials to test the effect on yield:

3.1 *Surveys and defining problem*–consisted on collection of anecdotal evidence of root binding from examining a number of waxflower tube stock and mature plants in field plantations. The aim here was to establish a base line for structuring the design of trials in the project.

3.2 *Nursery tube evaluation* –Tube evaluation trials were conducted to determine effect of pot design on root curling. Waxflower cuttings were propagated in tubes and then following root strike, root systems were assessed. The trials covered a range of pots designs which represented the range of tubes available in the nursery industry. The relationship of tube design was then compared to the type of root system that developed.

3.3 *Field trials –flower farm* – Plants were propagated in various pot types and planted out in a field trial on a wax flower farm. Growth was then recorded over several seasons to determine effect of treatments on plant growth and survival.

3.4 . *Field t trials--Medina Research Station* – Plants were propagated in various pot types and planted out in a field trial at DAFWA Medina research station. Growth and yield was then recorded over several seasons to determine effect of treatments on plant growth and survival. At the end 3 years mature plants were excavated and roots systems were measured.

3.5 *Optimising tube stock management* – Results from both field and glasshouse were analysed to determine best management practice of planting stock. This was then documented for use by the nursery and waxflower industry and reported in this report.

3.6 *Optimising field planting programs* - Results from both field and glasshouse were analysed to determine best management practice of planting stock. This was then documented for use by the nursery and waxflower industry and reported in this report..

3.7 *Extension* –Field days and workshops, were organised on several occasions to present progress on research. At workshops, handbooks were provided and examples of fertiliser calculations worked through. Also on farm support was provided to introduction of new fertiliser programs and use of tensiometers.

Data from trials was analysed using various statistical packages including ANOVA and linear regression analysis using Genstat VII.

4. Results

4.1 Surveys and defining problem

A number of samples of tube stock were made from plants grown in various tubes from premium plastic 64 cells to tree tubes(50 mm x 120 mm deep square tapered tubes) available in nurseries Waxflower varieties studies ranged from non hybrids to (*Chamelucium uncinatum*) to Pearl flowers (*C. uncinatum* x *C. megalopetalum*). These were analysed in terms of plant and root characteristics. It was found that in some cases plant s were quite tall i.e. up to nearly half a metre with an average height of 25 cm (Table 1). The root systems size was assessed in terms of the percentage of the root system filling the tube with volume quite high averaging >75% of tube volume. Root curling (or twisting of lateral roots into a semi circle) was observed in all samples with around 50% of the root system affected. The root top ratio averaged around 31% indicating that there was a constriction of the growth of the root system by the propagating tube. In some cases this got as high as 49%. Pearl flowers were slightly more affected than *C. uncinatum* plants

Table 1. Survey of root systems characteristics of planting stock available for sale

Character	Average	range
Plant height (mm)	245	76 - 447
Root system size (% of tube volume occupied)	>75	25 - 100
Root curling (% of root system affected)	<50	25 - 75
Root/top ratio (dry wt basis) (%)	31	22 - 49
Samples with root curling (% of samples)	57	

Root development problems such as curling, matting and twisting appear to develop early in propagation and continue on for the life of the plants. The crowding and matting of roots at the base of the propagation cells can be clearly seen (Fig 1.). This may have consequence later on the type of root system developed by mature plants.

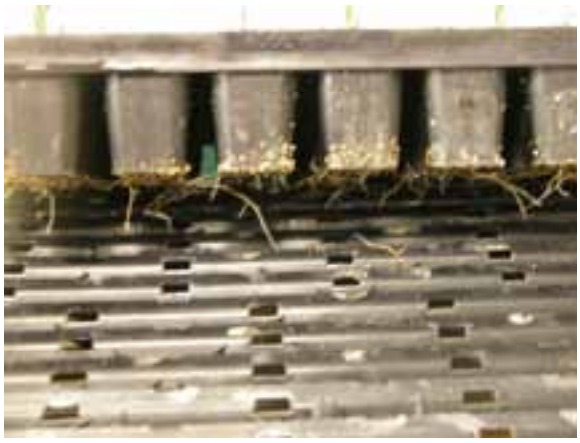

Fig 1. Root matting out the base of propagation cells. (note; these cells have with no aeration slots on side walls)

The occurrence of root deformation and curling occurs as a small deflection of a root off the side wall of a propagation tubes and rapidly develops into a distorted roots system (Fig 2 a, b)

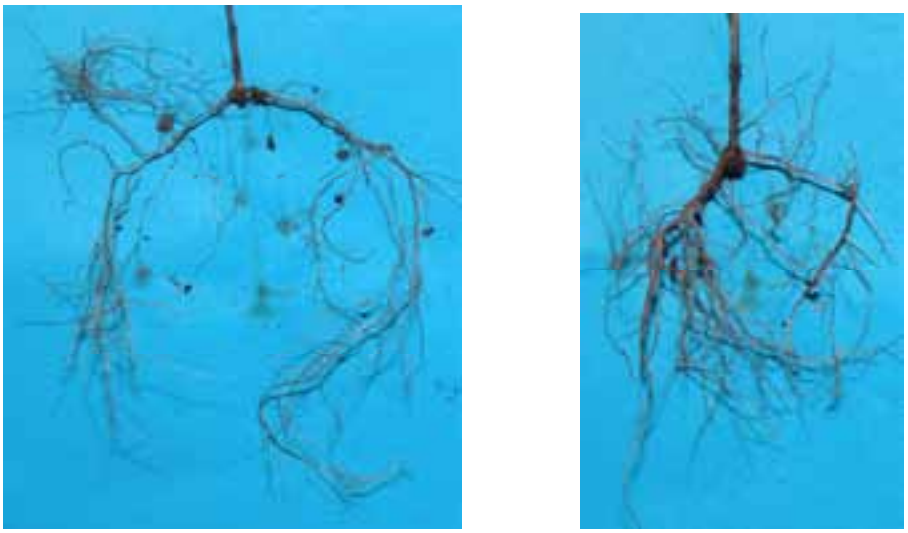

Fig 2. Progression of root knotting (a) early stages (b) and 1 month later

The type of propagation cell or tube appears have a large effect on root development, with square tubes with aeration slots less inclined to produce roots that are matted and curled (Fig 3)

Fig 3. Comparison of roots developed in (a)xsquare (premium 64 tube) and (b) round 50 mm tube. (Photo courtesy of Brian Jack)

What started as a small twist in the root system due to deflection in the nursery tube will eventually become badly knotted root system (Figs 4 and 5). This ultimately leads to an uneven spread of roots out from the plant and the strangulation of the plant and in many instances, where the tops get top heavy the plant stem snaps off at the knot due to wind shearing and eventual loss of the plant. There may be other consequences of a restricted root system preventing sufficient area for water and irrigation uptake during peak growth phase in summer, leading to loss of production.

Fig 4. R**oot knotting of field grown mature waxflower plants (a)** ***C. uncinatum***

Fig 5. Root knotting of field grown mature hybrid My Sweet Sixteen.

Roots that have been left in tubes too long causing the roots to knot long continue to remain tightly bound when planted in the field (Fig 6)

Fig 6. Shape of tube evident 12 months after planting out in the field

Soil type can have a large effect on root growth (Fig 7a). .Roots have concentrated in the to 20 cm of soil due to the higher clay content of the sub soil (20 – 40 cm) layer, with a few main roots penetrating the heavier soil. The clay appears to restrict root development and effectively reduces the volume of soil that is available for extracting water and nutrients by the plant. The result can be either drying in summer or water logging and aeration problems in winter. Under these conditions yellowing of plants at the end of summer is symptomatic (Fig 7b).

Fig 7. Effect of sub soil clay layer on (a) root growth (b) leaf yellowing of Crystal Pearl wax flowers grown on sandy loam soil at Northampton WA.

4.2 Nursery tube evaluation

Types of propagation cells

A wide array of propagation cells are available to the nursery industry for propagation purposes (Table II.1 Appendix II for details). These include open punnets, round and square tubes and cell trays where the cells in an a grid pattern are moulded into the tray. These trays have various features, some with spaces between cells in the trays to allow light penetration and plant growth, slots in walls to allow air pruning to stop outward growth of roots, trainer fins in side of walls to direct roots downwards, open basal ends to allow air pruning and stop roots coiling at the bottom of trays. Trials were conducted to investigate the effectiveness of these cells on root growth and curling.

Experimental

Root growth was affected by the type of tube used. Root curling occurred very early, in the first 4 weeks of propagation and continued to increase with time in pots (Fig 8).

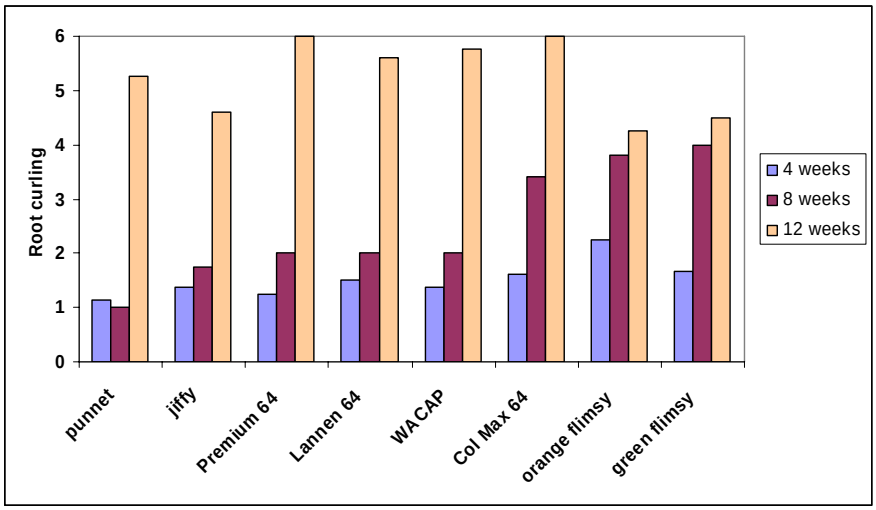

Fig. 8 The effect on root curling o f plants of Denmark Pearl propagated in various nursery cells 4, 8 and 12 weeks from start of propagation. (Root curling scale 1= none , 2 = < 10%, 3 = 10 – 25%, 4 = 50 – 75%, 5 = 75 -95%, 6 ==100%)

The amount of root curling increased with time in tubes, being low after 4 weeks (ie root curling was <10%) then increased sharply after 12 weeks with most root curling had increased to 50 - 75%.(Fig. 8). There was a relationship between the amount of root curling and the type of tube. Punnets and jiffy pots showed very little root curling after 8 weeks, while ColMAx, orange flimsy and green flimsy showed the greatest curling of 25 - 75% (Fig 8). Premium Plastic 64, Lannen 64, and WACAP showed low root curling of <10% after 8 weeks. Punnets (ie holding 20 cuttings) had slight curling after 2 weeks but no curling was recognizable after 8 weeks, however because of the short depth of the punnet (56 mm) and low soil volume per cutting (17 cc) there was a tendency for roots to quickly penetrate the bottom of the punnet and because of the lack of air pruning, with hole only on bottom edge of punnet, for roots to grow at right angles to the stem. So although roots did not curl downward growth was compromised and after 12 weeks showed up as high root curling (Fig 8).

Comparing similar square cells of similar volume at 8 weeks, Premium Plastic 64 (48 cc) had significantly less root curling of <10% compared to Colmax (44 cc) with 50-75%. The main difference between these two cells was the presence or absence of slots in side wall of cells, with slots being present in Premium plastic 64 and not present in ColMax. Also the volume of the cell did not appear to affect the amount of root curling for example both Premium Plastic 64 and Lannen had less than 10% root curling whereas Lannen tubes had 160 % more volume (118 cc) than Premium Plastic 64 cells (Table II, Appendix II).

The appearance of roots in some of propagation tubes is seen in Fig 9.

(a) Punnet

(b) jiffy

(c) Premium plastic 64

(d) ColMAx

Fig 9 Some examples of deformation of roots after propagation for 12 weeks in (a) punnet, (b) jiffy, (c) Premium Plastic 64 and (d) ColMAx.

The amount of curling depended on the amount of root growth (Fig 10). With a higher root mass roots curling increased. This indicates that conditions that favour quick root growth or long roots are more likely to start produced root curl. As a consequence the longer plants are left in tubes during propagation the more chance there is of roots curling. This effect can be seen in Fig 8 where after 12 weeks a high degree of root curling occurs irrespective of the type of tube used. In order to minimise root curling it is imperative that cuttings need to be potted on as soon as roots are visible from baseof the tube to reduce the amount of root growth in tubes.

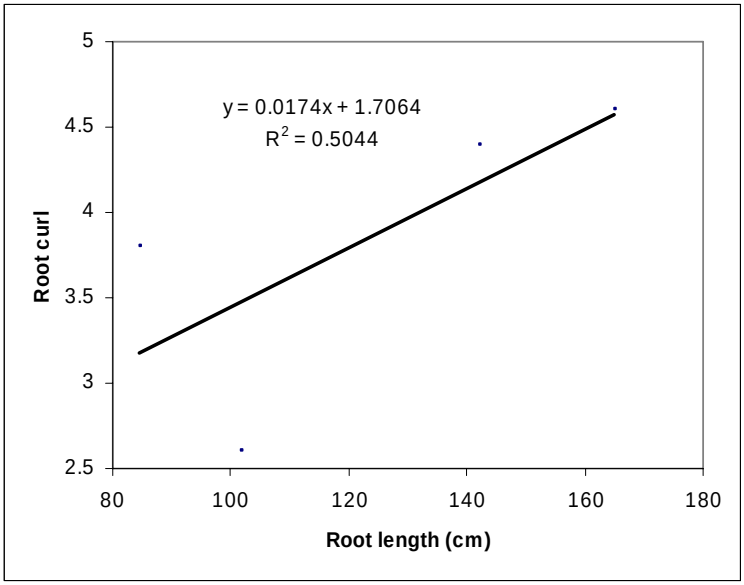

Fig 10. The relationship between amount of root curl and the root length

4.3 Field establishment trials - flower farm

In field trials planted on a waxflower farm, the health of plants was not not affected by the type of tube but was affected by the length of time plants were held in tubes (Fig 11). For plants held for 16 weeks there was initially a loss of health but this corrected itself after 3-4 months, whereas plants held in tubes for 12 months started poorly and continued to deteriorate.

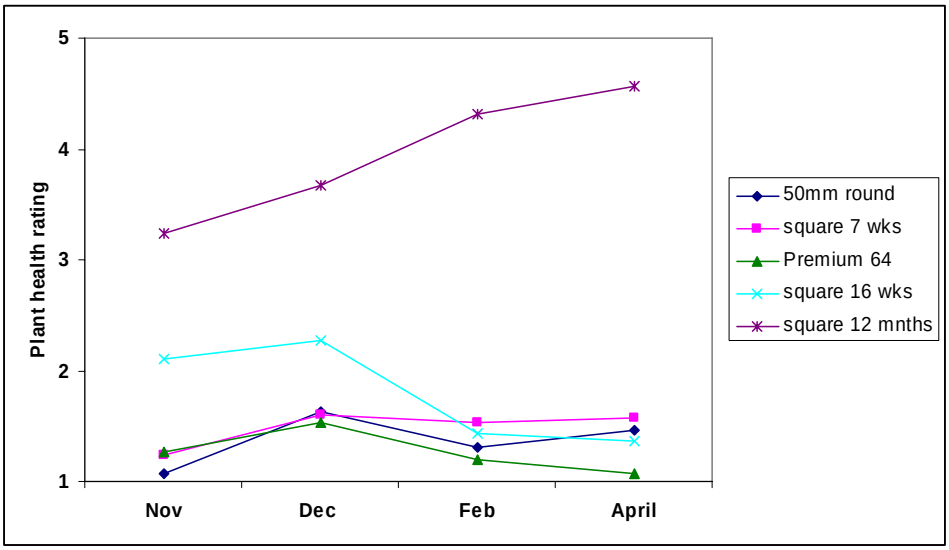

Fig 11. Plant health up to 5 months following planting of Crystal Pearl planted on a flower farm after propagating in different tubes types, including cell trays square tubes and round tubes. All plants were 7 weeks old at planting except in the square tubes plants were 7, 16 weeks and 52 weeks in tubes before planting. (Plant health scores: 1 = all leaves green, 2 = <10% yellowing of leaves, 3 = 25- 50% of leaves yellow or missing , 4 = >50% leaves yellow to red or missing, 5 = plants dead)

Survival of plants in the field was dependent on the age of tube stock. Plants that had been held in tubes for 12 months before planting decreased to 50% of planting numbers within 4 months of planting and all plants had died 12 months after planting (Fig 12). This was compared to 20 to 30% losses in plants that were held in tubes from 7 to 16 weeks.

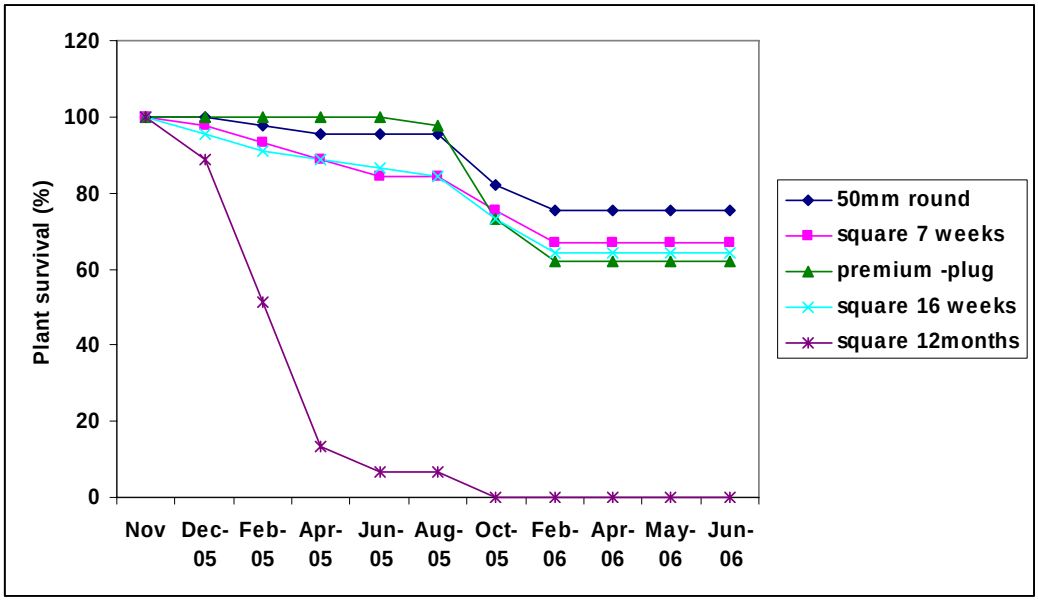

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Fig 12. Survival of plants during 18 month period following planting of Crystal Pearl on flower farm of plants propagated in different tubes types, including cell trays square tubes and round tubes. All plants were 7 weeks old at planting except in the square tubes plants were 7, 16 and 52 weeks in tubes before planting.

In 2006 a harvest was done of the planting trial by use of commercial pickers to give an estimate of commercial stem yield. Stem yield of 50 mm round, are square tubes 7 and 16 weeks old and Premium Plastic 64 was 28, 19, 28, 33 stems per plant. There was no stem yield from square tubes planted at 16 weeks and 12 months old.

4.4 Field establishment trials - Medina Research Station

Round versus square tube trial

The type of tube used to propagate plants had an effect on yield measure 3 years after planting out after propagation (Fig 13). Flowering stem yield (greater than 60 cm length) was almost 2 fold higher in plants propagated in Premium Plastic 64 than any of other tubes used ie Toro (moulded round tubes in grid pattern, Plantell (square cells with no slots in side walls), large 100 mm round tubes (ie volume approximately twice that of round tubes), small round 50 mm tubes and Plantell (Fig 13).

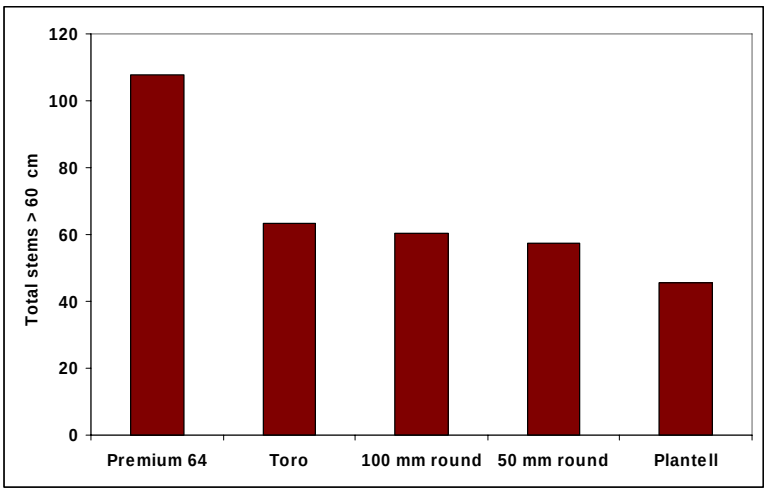


Fig 13. Effect of tube type on stem production of three year old Crystal Pearl waxflower plants

Root curl was lowest in small round tubes and highest in Toro (Fig 14) with premium plastic 64 somewhere in between. It was found that root curl developed in tubes at the time of planting persisted during the growth of plants in the field to plant maturity (Fig 14).

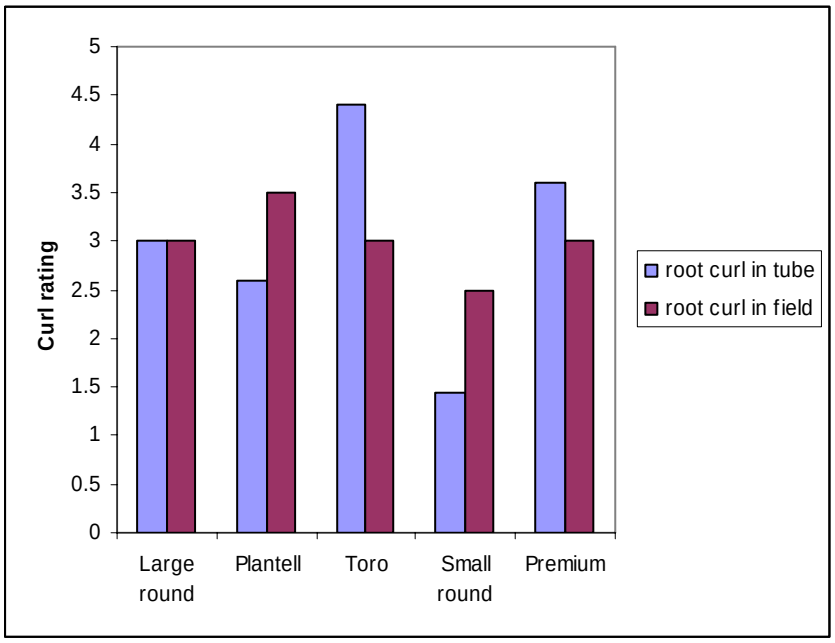


Fig 14. Root curl of plants propagated in different tubes measured at planting and on mature plants in the field 3 years old (Root curling scale 1= none , 2 = < 10%, 3 = 10 – 25%, 4 = 50 – 75%, 5 = 75 -95%, 6 = 100%)

In terms of plant growth there is a direct relationship between the amount of dry matter produced and the length of the main roots present (Fig 15.). Plants with increased root length will produce more growth and yield.

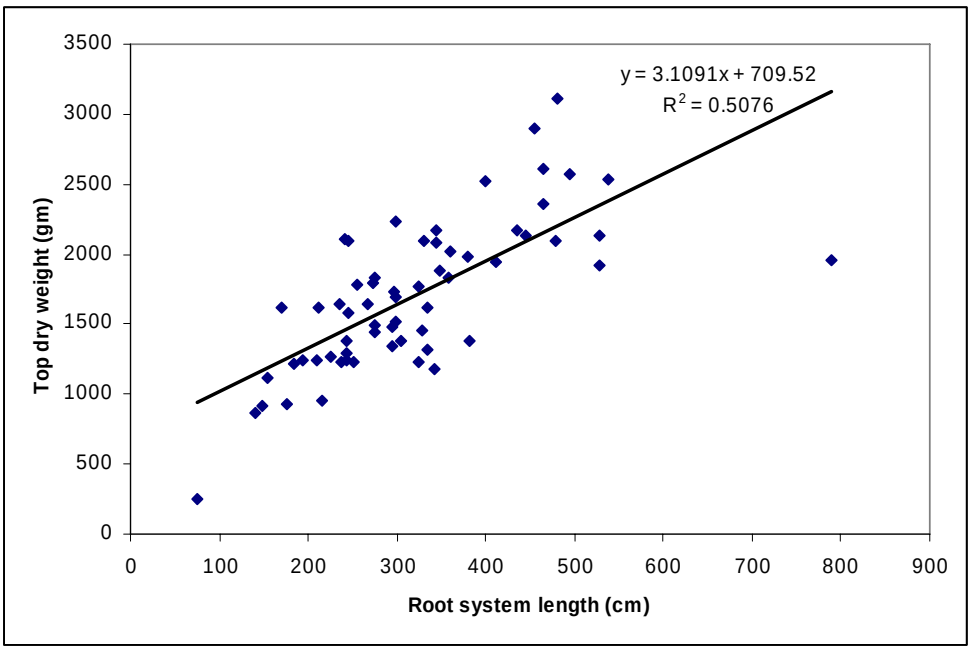


Fig 15. The relationship between the length of the root system (roots greater in diameter than 0.5 cm) **and the amount of dry matter produced by plant tops.**

4.5 Optimising tube stock management

Tube stock management

There are three phases of tube stock management, which need to be considered:
A. *Healthy tube stock* must be free from root spiraling – the way plants are propagated is critical. Propagation tubes need to train newly initiated roots such that they do not spiral but are deflected and guided downwards to the bottom of tubes (research is underway to determine the ideal propagation tube). Trays of plants should be placed on mesh benches to allow air pruning of roots that grow out of the tube.

Fig 16. Photograph of (a) root bound root system and (b) healthy root system

B. *Minimum time lapse* (4 to 8 weeks) between when roots are initiated and planting. Long delays in planting, with plants left in propagation tubes, will cause root binding and greatly diminish the

health of tube stock. No amount of good container design will compensate for holding plants in containers for extended periods.. Another factor in holding tube stock too long in tubes will be the unproportional extension of top growth compared to roots. In conclusion if tube stock are overgrown with large tops and root bound it is not worth planting these, as they will seriously compromise the health and productivity over the life of the plant. Planting old propagation stock will be costly in the long run with loss of plants and loss of production. Plants won't grow out of it and will most likely develop root knotting which will eventually kill the plant.

C. *Planting bed preparation* – attention needs to be paid to planting bed preparation including weed. The site should be tested and if a compaction layer or sub soil clay layer exists this will need to be deep ripped. This will then allow roots to grow downwards and develop an extensive mature root system. Digging a planting hole in a compacted soil is not good enough as this will effectively put the plant in a "pot in the ground" severely restricting root growth. The planting bed may need to be raised if surface drainage is a problem or deep ripped if subsoil drainage is a problem Another considerations for soils with little structure is the addition of organic matter such as compost, although large volumes are need to be effective. This will increase the water holding capacity, aeration and nutrient availability of the soil.

In summary planting of quality tube stock requires:

- Grower needs to determine anticipated planting date for each bed. (Buying plants off the shelf is not recommended).
- Propagator needs to work out when to start propagating to meet that target planting date This will depend on variety, time of year, phenological stage of cutting material, propagation facilities (whether bottom heat is available etc).
- Grower needs to prepare site well ahead of planting date. This mean removal of weeds, setting up irrigation and fertigation systems.
- One to two weeks before planting, irrigation system should be turned on to thoroughly wet bed up.
- When tube stock arrives these should be inspected (ie tap some plants out of tubes and inspect root system) and if plants are root bound or over grown these should not be planted but sent back to propagator.
- During plant, any tube stock that are root bound should be rejected. This includes any tube stock with matting at the base or with extended tops (remember smaller is better).
- Minimise time plants are held at the farm before planting out in the field.
- It is better to plant in warmer weather when soil temperatures are above 10°C to encourage early growth provided the irrigation system is fully functional.
- Protect new plantings with wind breaks such as tree guards or grow cones as necessary, but remember to remove these early ie within the first 3 months.
- Adjust fertiliser mix for young plants to $1/10^{th}$ of that for mature plants to prevent salt build up around root systems.
- Prune back new plant after 6 months to half their height.

4.6 Minimising root spiralling by good container design

Essential ingredients to good propagation cell design are:

1. root trainer ribs
2. splayed corners
3. cell volume of 30 to 50 cc
4. air slots on side walls
5. open base to cell
6. tapered walls at least 3 to 7°
7. vertical ribs running down the container wall
8. large bottom hole in container
9. more open cell arrangement to allow good ventilation
10. Some of these features are seen in propagation cells (Fig 17).

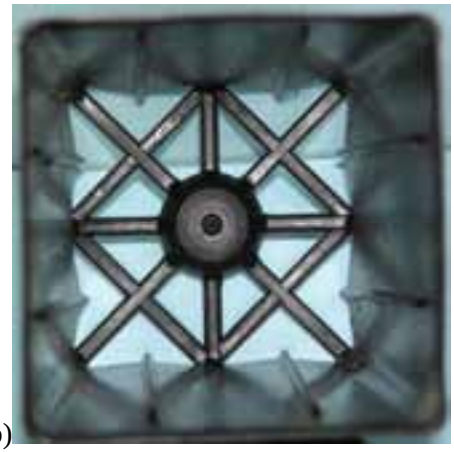
(a)  (b) 

Fig 17. Side and above view of (a) Premium Plastics 64 propagation cell and (b) square tube

4.7 Extension

The project has delivered a number of extension activities including:

- Protocol on best practice for tube stock management, pre planting and field establishment
- Workshops on tube stock management best practice
- Poster publication on tube stock management of waxflower which include photographs of root spiralling and non-root spiralling tube stock.
- Field days.
- Multiple articles in Floriculture newsletters
- Final report for RIRDC on details of research results

5. Discussion

The aim of this project was to provide a strategy that would allow growers to optimise root systems of waxflowers. The project acknowledges that very little is known of what influences growth of root systems of wildflowers and in particular of waxflower. However it is acknowledged that the type of root system can have major effects on the performance of plants under intensive cultivation using irrigation. This may be particularly true of the new hybrid varieties of waxflower that are assuming prominence in the market place. This research project deals with the effect of tube design, and time in tubes on root curling. The project has shown that nursery practice can influence tube stock root systems. It uses both controlled nursery trials (small short term trials (3 to 6 months) testing different tube types and field trials (2 to 3 year) on research stations and growers properties. These trials were used to gain an understanding of the effect of root systems on performance of waxflower. Most trials were conducted on the hybrid waxflower "Pearl flowers".

Surveys of nursery practice and root systems developed on waxflowers used on flower farms in Australia, showed that there are large variation in the type of root systems developed. Wax flower root systems are very sensitive to conditions during propagation. Developing good root systems require active input otherwise very poor root systems and plants can result. Failure to produce healthy even root systems can't be ignored. The effects of a poorly developed root system in nursery tubes will continue to affect the wax plant as it grows, and a small curl or kink in the root system will eventually result in a wax plant as it matures with a major root binding problem which will eventually kill the plant.

In terms of root systems developed by waxflower there can be large variations from partially curled to completely curled. This appears to be dependent on propagation method. There are a wide range of tubes available on the markets. Trials showed that the best types of tubes used were square tubes with aeration slots in the sides and open ends for air punning and with root trainer fins. These tubes produced better root systems than tubes without these features. Noticeable air pruning was observed where there were these features in tubes.

A relationship exists between root curling and the length of the root system, which is controlled by time in tubes. Holding plants in tubes too long will lead to root curling and eventual root failure. Therefore holding plants in tubes for too long is just as critical as the type of tube used. Better quality plants are produced if the plants' time in propagation tubes is minimised.

The project also showed that timing of tube stock production and farm establishment are critical. Orders for plants should anticipate when those plants are required to be planted, so that there are no delays, with tube stock being held in tubes for a much longer time. Planting beds need to be prepared well ahead of the time that tube stock arrive. This means good weed control and establishment of irrigation lines are required. It also includes having in place a fertigation system so that plants can receive appropriate nutrition from the start of establishment (see Seaton 2008). Delays in planting will result in a compromise of the quality of the root system.

6. Implications

Before now there were no definitive strategies for managing root systems for waxflower. It was thought that plants wax plants robust and would grow easily. However the project shows that producing good quality roots can have large effects on yield and this will help the industry to remain competitive by maximising production. It is important to get the nursery propagation program right to produce healthy plants with healthy root systems. This is a relatively cheap cost of production compared to other inputs needed during the productive life of the plant. The other advantage of the findings of this project is that, having an effective root system allows growers to capitalise on returns from growing newer waxflower hybrid varieties and maximising yield. Poor plant management can not only cause loss of yield but affects the soil environment in terms of increased leaching of nutrients past the root system.

The project shows that tube stock management cannot be done in isolation, but requires correct timing. This involves coordination of the nursery and the grower to time production of tube stock ready for planting in the field. Holding tube stock too long in nurseries or delays in planting can have a large and devastating effect on the quality of wax flower root systems and plant survival. Propagating is a dynamic process that depends on the rate of growth of tube stock at different times of the year, the conditions during propagation and ease of particular varieties to strike roots.

Consequence of getting the timing right is the production of healthy tube stock for planting. Timed establishment results in plants with healthy root systems. This has the advantage of enabling the plant to absorb both water and fertilisers, a characteristic particularly important on sandy or gritty soils where waxflower performs best. A plant with a compromised root system is not able to cope with high water demand times when evaporation rates are high and there is the possibility that fertilisers and water will be leached from the root zone.

7. Recommendations

It is now possible to produce waxflower plants with healthy root systems. Significant gains are possible by propagating plants with good root systems. This leads to plant longevity and has the added advantage of significant yield gains thereby maximising production of hybrid waxflower

Growers can maximise root quality by:

1. Use propagation tubes that incorporate flat surfaces, root trainer fins and air pruning slots.

2. Introduce propagation methods to ensure plants spend a minimum time in tubes.

3. Ensure plants are grown in free draining mixes of sufficient water holding capacity.

4. Coordinate nursery production and plantation orders to minimise time in tubes.

5. Ensure early bed preparation for early planting of new plants in the field.

8. Publication as a result of this project

Seaton K A (2005) Maximising waxflower planting stock quality -field day Nov 5 2004. *Floriculture News* Nov 2005 No 66. pp13.

Seaton KA (2004) Containers and planting techniques for waxflower. Workshop presented at Waxflower Conference 2006. Western Australian Department of Agriculture and Food. 16 -17 March 2006 Technology Park Western Australia. Pp 27, 28.

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Seaton K A (2004) Maximising root quality of waxflower tube stock suitable for field planting *Floriculture News* Nov 2004 No 63. p22.

9. Appendices

Appendix I - Poster

Poster used at a practical workshop demonstrating the way to manage planting tube stock. Presented at Waxflower Conference 2004 (see section 8 of Publications list)

Containers and planting techniques for waxflower

Kevin Seaton

Aim: To produce quality tube stock that successfully establish in the field

Straight roots

Twisted roots

1. Root curling. – *this is where roots twist around in the propagation tube*

2. Causes of curling – *deflection off side of propagation cell wall.*

3. Solutions –
Square Cell shape
Air pruning slots
Fins

4. Timing–
minimise time in tubes
plant in several batches
plant as soon as stock is delivered

5. Prepare site ahead *of time –*
Deep rip
Control weeds
Set up irrigation ahead of time

Appendix II Propagation cells dimensions

Table 11.1 Characteristics of propagation cells available to nurseries

Propagation system	Dimensions (width x breadth x depth) (cm)	Vol/cutting (cc)	Walls tapered	Air slots in walls	Open base	Root trainers	Space between cells
Punnet	5.6x12.8x4.8	17.2	y	n	n	n	n
green flimsy	3.5x4.0x5.6	57.9	Y	n	n	y	n
Brown flimsy	3.1x3.1x1.8x5.0	33.5	y	n	n	y	n
Small square	4.4x4.5x7.4	127.4	y	n	y	y	y
Tree tube	4.9x4.9x11.6	224.6	y	n	y	y	y
Small round	5.0 (diam)x6.7	106.6	y	n	n	n	NA
Large round	7.0 (diam)x11.0	311	y	n	n	n	NA
Toro	4.0 (diam)x7.5	62.2	y	n	n	y	y
Premium 64	3.1x3.1x6.6	48.4	y	y	y	y	y
WACAP	3.3x3.3x5.3	44.6	y	n	y	y	
Lannen 64*	4.2x4.2x6.0	76.4	y	y	y	y	n
ColMax	3.4x3.4x5.0	44.5	y	n	y	y	y
Plantell 64	4.6x4.6x7.3	118	y	y	y	y	y

***** Lannen Plantex side slot trays

Appendix III – Bibliography

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Appendix IV Waxflower 2004 Workshop pictures

Examining roots of plants from propagation cells and discussions on planting methods at Waxflower conference 2004.

Maximising Root Quality of Waxflower Tube Stock Suitable for Field Planting

RIRDC Publication No. 09/006

The use of quality tube stock for waxflower plantations is imperative for plant performance in terms of stem yield, flower quality and plant longevity. Having plants that maintain production over an extended period has economic advantages in flower production. Failure of root systems and loss of plants can have a major effect on production and profitability.

Little is known of how the choice of propagation method and design of planting tubes affect the quality of wax flower plants. This report determines the method for managing propagation and tubing up to achieve healthy non compromised root systems in waxflower. This study concentrates mainly on hybrid waxflowers.

This report is targeted at nurseries and growers of waxflower in the Australian cut flower industry. It provides information on the nature and occurrence of root failure in waxflower. Knowledge gained from this project should enable better management of plant production of native Australian flowers, particularly new hybrid waxflowers.

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