ANNUAL REPORT

To:
Horticultural Development Council
Bradbourne House
Stable Block
East Malling
Kent, ME19 6DZ

POINSETTIA: ASSESSMENT OF STRATEGIES FOR EFFICIENT UTILISATION OF NURSERY RESOURCES

PC 243

Dr Debbie Fuller
Warwick HRI,
Wellesbourne, Warwick, CV35 9EF

July 2006

Commercial - In Confidence

Grower Summary

POINSETTIA: ASSESSMENT OF STRATEGIES FOR EFFICIENT UTILISATION OF NURSERY RESOURCES

PC 243

Annual Report
(July 2006)

Project title:	Poinsettia: Assessment of strategies for efficient utilisation of nursery resources.
HDC project number:	PC 243
Project leader:	Dr Debbie Fuller, Warwick HRI, Wellesbourne, Warwickshire, CV35 9EF
Report:	PC 243 Annual Report (2006)
Key workers:	Harry Kitchener, Consultant (Agronomy advice). Tim Pratt, FEC Services Limited (Energy analysis). Jayne Akehurst, Pippa Hughes and Mike Mckee, Warwick-HRI
Location:	Warwick HRI, Wellesbourne for production. Warwick HRI, Kirton for shelf life.
Project co-ordinators:	Gary Shorland, Double H (Nurseries) Ltd, Gore Road, New Milton, Hampshire, BH25 7NG Duncan Stevenson, Kinglea Plants Ltd, Shottentons Farm, Pecks Hill, Nazeing, Essex, EN9 2NY
Date commenced:	July 2005
Report date:	July 2006
Keywords:	Poinsettia, *Euphorbia pulcherima*, Long days, Short days, Supplementary lighting, Spacing, glasshouse production, shelf-life testing
Signed on behalf of:	**Warwick HRI**
Signature:	………………………………………………………………
Name:	Professor Simon Bright Director and Head of Department
Date:	………………………………………………………………

The results and conclusions in this report are based on an investigation conducted over one year. The conditions under which the experiment was carried out and the results obtained have been reported with detail and accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results especially if they are used as the basis for commercial product recommendations.

CONTENTS

PC 243

Poinsettia: Assessment of strategies for efficient utilisation of nursery resources

Headline

Marketable quality poinsettias were successfully produced from plants potted 2-4 weeks later than normal and grown using supplementary lighting and CO_2 enrichment. Assuming productive use can be made from the space made available preliminary calculations suggest this method may be cost effective. A second year of work is planned to verify these results.

Background and expected deliverables

Previous work (PC 208) indicated that Poinsettias may be successfully grown from a later than normal potting week in order to free up space which may be used to increase annual throughput of product (i.e. by extending the period for summer pot plant production). The aims of the current project are to verify the results of this previous work and to further develop the technique by (a) combining supplementary lighting with CO_2 enrichment and (b) examining how delaying initiation to increase vegetative growth prior to flowering affects the quality and scheduling of late potted crops.

With quality specifications changing to 4+1 bract stars and 23cm minimum height PC 208 also indicated that late potted crops may be grown at closer spacing and still produce a marketable product which would increase returns and help to offset lighting costs. The project therefore also examines how plant spacing would affect the quality of late potted crops.

Options for finishing the crop under long days given with supplementary lighting to further improve quality were also evaluated as observational treatments.

The following presents the preliminary results from the first year of the project.

Summary of the project and main conclusions

Late potting combined with supplementary lighting and delayed initiation

The varieties Cortez and Infinity were potted in either week 32 or week 34 and grown with supplementary lighting at 10 W/m² (PAR). Lights were on for 20 hours per day during long days (LD) and 11 hours per day during short days (SD) with a threshold of 200 W/m². Plants from both potting dates were transferred from LD to SD weekly from week 38 (i.e. the week of the equinox) until week 42 to give 5 different dates for the start of SD.

A further set of plants were potted in week 30 and grown as a natural season crop (i.e. in ambient light and daylengths) to represent commercial production.

Data from these preliminary experiments suggest that it is possible to pot plants later than normal and produce a marketable product in time for Christmas if supplementary lighting and CO_2 are used to promote extra growth. The timing of the start of SD influenced both the timing of red colour development and the size of the plant at marketing. If short days were started in week 38-40, plants were suitable for marketing in week 48. Delaying the start of SD to weeks 41 or 42 delayed red colour development sufficiently to delay marketing assessment to week 50. However treatments giving the greatest delays in red colour development produced the largest plants (i.e. greatest amount of vegetative growth); which also contributes to final quality. The extra two weeks of growth for these delayed treatments will have affected the measurements taken and should be borne in mind when examining the data.

Height (cm)		**Week 32 potting**					**Week 34 potting**				
Week of transfer to SD:											
	NS	**38**	**39**	**40**	**41**	**42**	**38**	**39**	**40**	**41**	**42**
Cortez:	23.5	24.5	23.9	25.2	26.0	26.4	22.7	24.1	24.0	25.9	25.1
Infinity:	24.0	25.4	25.2	25.1	28.1	27.3	22.8	24.4	24.4	24.1	25.0

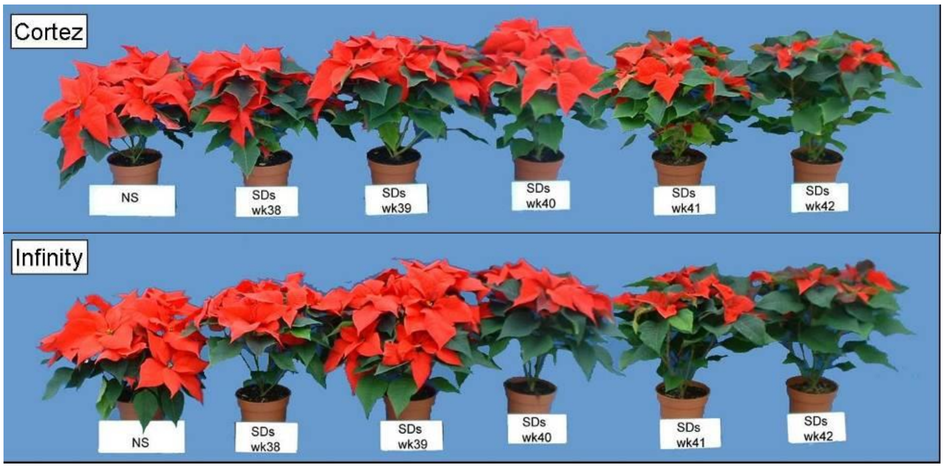
% Red colour		**Week 32 potting**					**Week 34 potting**				
Week of transfer to SD:											
	NS	**38**	**39**	**40**	**41**	**42**	**38**	**39**	**40**	**41**	**42**
Cortez:	86.6	75.3	61.6	49.7	66.3	53.8	81.3	70.0	54.7	72.5	48.4
Infinity:	93.8	73.3	60.0	49.1	74.4	52.8	87.5	70.3	48.1	62.5	43.8

Quality score		**Week 32 potting**					**Week 34 potting**				
Week of transfer to SD:											
	NS	**38**	**39**	**40**	**41**	**42**	**38**	**39**	**40**	**41**	**42**
Cortez:	3.7	3.8	3.9	3.8	3.3	3.2	3.0	3.3	3.1	3.1	3.1
Infinity:	4.5	3.9	3.7	3.7	4.0	3.5	3.3	3.5	3.1	3.4	3.1

NS: Natural Season

A photographic comparison of treatments taken on 06/12/05 is given below (N.B. plants transferred to SD in weeks 41 and 42 had 2 more weeks of growth than the remaining treatments and hence developed further after this photograph was taken).

a, Week 32 potted plants:



b, Week 34 potted plants:

It was clear from plant height tracking during production that plants potted late and lit have different growth curves to the conventional curve produced by HDC Poinsettia Tracker. Further data will be collected in year 2 and growers are advised to use this data to support their own tracking of late potted lit crops.

Along with the increase in vegetative growth, holding plants in LD for longer periods also increased nutritional requirements. In year 1, all treatments were given a ‘commercial’ feeding regime where plants are potted in week 30 and initiate around the date of the equinox. This regime was inadequate for treatments given LD until weeks 41 and 42 which became apparent from leaf yellowing and a decline in nutrient availability in the compost (with N dropping as low as 6-7 mg/l). This problem was addressed through a change in feed inputs and could be prevented by a modification in feed inputs to account for the extra period of vegetative growth.

Experiments in year 1 were designed to screen a large number of treatments which restricted the size of plot. In year 2, treatments will focus on week 34 for potting as this will maximise the extra space freed up and is most in need of verification given that quality produced was closer to the minimum acceptable for marketing. Plot size will then be increased which will allow assessment of uniformity.

Plant spacing

Comparisons of plant spacing were carried out on plants potted in weeks 32 and 34, grown with LD lighting until weeks 38 or 40 and with SD lighting until marketing. In the 'close' spacing treatment, plants were at pot thick for longer than normal and were then moved directly to half space (15 pots/m²). They were then moved according to the space required for the subsequent growth. The densities achieved with the close and standard treatments are summarised below:

Summary of dates of plant spacing by week number of moves.

Potting date	Spacing	Pot thick	30 pots/m²	15 pots/m²	12 pots/m²	9 pots/m²
wk 32	**std**	w32-w39	w38-w39	w39-w43	w43-w45	w45+
wk 32	**close**	w32-w40	-	w40-w43	w43-w45	w45+
wk 34	**std**	w34-w40	w40-w42	w42+		
wk 34	**close**	w34-w44	-	w44+		

Close spacing had little impact on the assessments made of plants at marketing. Height of the more vigorous plants (i.e. week 32 potted Infinity) was increased and also pot spread decreased as might be expected. Hence late potted plants have the potential to be grown at higher densities than for plants potted at the conventional time (week 30). The delay in spacing late potted plants from pot thick also adds to the extra bench space that would be available to extend the production of summer crops. Labour savings would also be achieved if plants were spaced directly to 15/m² from pot thick rather than being moved through an intermediate 30 pots/m² density.

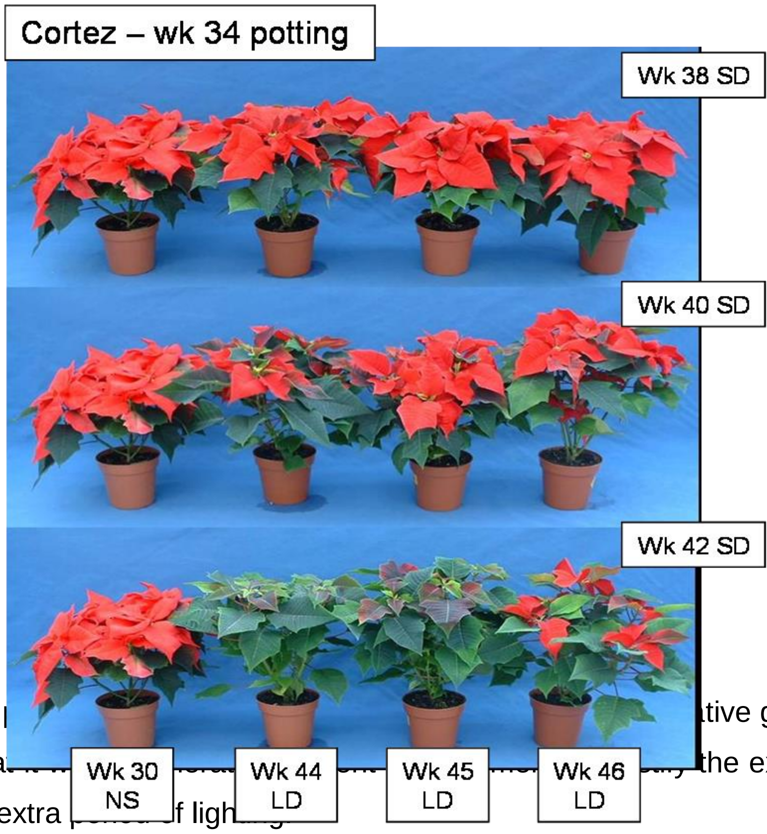
Since the aim of this work was to maximise throughput rather than quality, there appears to be good potential for the closer spacing approach and this will be assessed further in year 2.

Late potted lit treatments returned to LD prior to marketing

Following improvements observed with other species given increased light intensity prior to marketing (PC 92b), observation treatments were included in the trial which were designed to increase light receipt of late potted plants by transferring them back to LD lighting prior to marketing. This increases the daily light integral received by the plant rather than increasing the intensity of lighting as was tested in previous work. Plants potted in weeks 32 and 34 were grown in LD lighting initially and transferred to SD in weeks 38, 40 or 42. To increase light receipt per plant, plots were moved back to LD lighting either 2, 3 or 4 weeks before a planned marketing date of week 48. This gave different periods of time in SD prior to returning to LD as follows:

	Date of return to LD		
Date of SD start	**Wk 44**	**Wk 45**	**Wk 46**
Wk 38	6	7	8
Wk 40	4	5	6
Wk 42	2	3	4

Before imposing these treatments it was unclear how much disruption to flowering would result from exposing initiated plants to LD and some interesting results were found. Plants transferred to SD in week 38 appeared unaffected by the return to LD lighting (i.e. after receiving 6-8 weeks of SD). Plants transferred to SD in week 42 were all affected by the return to LD and those with the shortest initial period of SD responded the most to the return to LD. In the most extreme treatments, plants produced very little red colour by week 50 but did produce a significant increase in vegetative growth (i.e. a 23-60% increase in dry weight depending on variety and potting week). Hence as with the main experiment, the greater the disruption to flowering the larger the increase in vegetative growth.



Whilst returning p ... tive growth, there was no indication tha ... the extra energy costs required for the extra ... f ligh...

Practical and financial benefits

As this report is based on the first year of a 2 year project, data calculated will need further verification in the final report. There are several components to the full financial analysis of the late potting and lighting approach and these have already been summarised in the report for PC 208 Points covered in this previous project are summarised below:

- increased throughput by growing extra crops in the summer in the space made available through late potting (worth approx £2.47/m²)
- increased throughput of poinsettias from the higher densities possible with late potting and lighting (15 pots/m² for late potting compared with 8 pots/m² for natural season production)
- reduced labour inputs through less spacing and lower growth regulation (i.e. spraying) requirements (estimated to be worth £1.04/m²)
- reduced overhead costs (due to the reduction in growing time)
- lower returns per plant for the late potted lit crop due to the reduction in plant quality (estimated at 30 to 50p per plant less than from natural season production)
- increased cost of supplying supplementary lighting (see below for more detail on this).

Taking the above factors into account, it was estimated that late potting and lighting (at 9.6 W/m² PAR) would increase the gross margin for production by £4.55 to £7.64 per m² (based on returns of £1.50 to £1.70 per pot) compared with natural season production from a week 30 potting date.

Work in year 1 of the current project suggests that the plant spacing assumed in these calculations is feasible for a week 34 potted crop but could create problems with the more vigorous week 32 potted crop. Spacing will be further assessed in year 2 and better estimates of uniformity are anticipated from this next phase of work. Since cycocel spraying in the current experiment was for maintaining uniformity rather than controlling height, the week 34 potted crop received only 2 fewer applications and the week 32 potted crop received 2 more applications than the natural season crop.

Detailed energy monitoring was carried out in this project to assist with the financial assessment. The energy consumed by each treatment depended on the potting date as well as the length of time spent in LD and SD. Details of all treatments are included in the main report and some key treatments are summarised below:

	Energy £/plant		
	Gas (at 2.0p/kWh)	**Electricity (at 6.0 p/kWh)**	**Total**
Week 30 natural season	0.12	n.a.	0.12
Week 32 SD wk 38 'std'	0.08	0.25	0.33
Week 34 SD wk38 'std'	0.05	0.09	0.14

Whilst late potting required lighting which increased electricity consumption, later potting reduced total production time and benefited from the contribution that the lights would have made to glasshouse heating. Hence the late potting treatments used less gas than the natural season crop. Furthermore, natural season crops required wider spacing than the late potted treatments (particularly week 34 potted treatments). Assuming all available space could be used, the energy cost per plant for late potted crops was therefore either 2 or 21 p per plant greater than for natural season production for the week 34 and week 32 potting weeks respectively. These costings did not take account of the installation of lighting which would vary according to the number of other crops for which the lights would be used. Estimating the cost of CO_2 inputs is complicated by the range of options available, however assuming the most expensive source (pure CO_2), based on the CO_2 used in these experiments, the cost of enrichment would be around £0.16/m². These increased costs would need to be balanced against the suggested increase in gross margin of £4.55 to £7.64 per m² from PC 208.

Action points for growers

Growers should consider late potting and lighting as a method of optimising nursery throughputs using the plant densities described in this report (e.g. 15 plants/m² final spacing for a week 34 potted crop). Effective use of the space made available is important to justify this technique financially.

The lighting used to achieve a marketable product from late potting may be used to delay the start of SD and hence improve final quality depending on the market specification required. For week 48 marketing however data from the first year of the project suggests SD should start no later than week 40.

The work to date has focussed on Cortez and Infinity which both are reported to have a 7.5 week response. As with all new techniques small scale testing is recommended initially and particularly with varieties that have a slower response.

Week 34 potting produces a better financial analysis than week 32, although quality was poorer for the former than the latter. A balance between potting date and timing of the start of SD is required to optimise the economics of this technique. This will be further analysed for the week 34 potting date in year 2.

Late potting and lighting produces a different growth curve to the standard curve produced by HDC tracker. Growers are advised to refer to data in this report and in the final report when available in order to track the height of late potted plant lit plants.

Returning plants to LD lighting 2-4 weeks prior to marketing appeared unjustified when comparing the extra running cost of the lights against the results achieved. However these treatments suggest that for Cortez and Infinity, 6-8 weeks of SD are sufficient to prevent subsequent LD lighting from disrupting flowering before the normal marketing period. This may be of use where glasshouse space needs to be shared between crops that require different daylengths for example.

Late potting and lighting with a delay in the start of short days, extends the vegetative growth period and hence feeding regimes should be modified to account for this.

SCIENCE SECTION

INTRODUCTION

With growers facing increasing pressures on their finances through high energy costs, climate change levy and decreasing margins there is a pressing need to provide information for growers to enable the most cost effective use of the resources they have available. Start up investment of up to £850K per ha should be sufficient justification for growers to continually evaluate the best means of maximising commercial returns.

Increasing throughput and hence annual returns per ha is one approach that may be taken to address this issue. Projects with pot chrysanthemum have already demonstrated that supplementary lighting can speed up crop production by up to 7 days using high intensity lighting (12 W/m² PAR) during flower initiation (HDC project PC 92). Quality and improved predictability of marketing date can also be achieved with different supplementary lighting techniques (Supplementary lighting of pot chrysanthemum – a grower guide).

HDC Project PC 208 examined the use of supplementary lighting in conjunction with late potting dates for Poinsettia on a commercial nursery during the 2003 season. Plants potted later have less time to develop 'plant bulk' before initiating flowers in time for the Christmas market. It was hypothesised that supplementary lighting could be used to compensate for this. Testing this approach on a commercial nursery demonstrated that there is potential to pot plants later (week 34) when using supplementary lighting but variety selection is important. If this space can be fully utilised to produce another crop, it may be expected to yield an additional gross margin of up to £10K per acre according to financial benefits calculated for PC 208.

Observations on a commercial nursery in the 2004 growing season confirmed the potential of this approach with week 34 potted plants meeting quality specifications if grown using 9.6 W/m² PAR (4000 lux) supplementary lighting. This approach coincides with changes in quality specifications to 4 heads plus 1 which is more in line with the anticipated quality of the late planted crop. The lower initial bulk on plants potted later in the season also reduced the number of spacings (from 3 to 2) and the number of PGR applications required to meet height specifications. Both of these factors result in reducing labour inputs and therefore costs.

The purpose of this project was firstly to verify the results from PC208 in a formal controlled experiment and that this should include the use of CO_2 enrichment along with supplementary lighting. Since poinsettias are short day plants, supplementary lighting also provides the option to manipulate when plants initiate, and delaying initiation may also increase plant size prior to flowering. The project was also designed to examine how delaying initiation of plants potted later in the season might help to increase 'bulk' and therefore quality.

Late potting is designed to optimise throughput, hence the potential to decrease plant spacing was included in the trial which may further increase throughput, and may also improve the economics of providing lighting.

Finally, previous projects looking at supplementary lighting pot chrysanthemum (PC92b) demonstrated that finishing plants under high intensity (12 W/m^2 PAR) lighting, significantly improved petal colour development and upper foliage quality. If poinsettia growers were to adopt the use of lighting, they would also have the option of using this technique. The potential benefits of this approach were examined as an observation treatment in the 2006 experiments.

OBJECTIVES

1. Determine if late (week 32 and week 34) potting dates can produce acceptable quality in time for Christmas marketing if supplementary lighting is used to improve product quality.

2. Combine late lighting treatments with CO_2 enrichment to fully optimise the photosynthetic gains and hence final product quality.

3. Evaluate the possibility of delaying initiation of the late planted crop to improve bulk prior to initiation for improved quality.

4. Examine how closer spacing affects the production and quality of late potted lit crops.

5. Investigate the potential for further increasing quality through using extra lighting prior to marketing.

MATERIALS AND METHODS

Treatments

Late potting combined with supplementary lighting and delayed initiation:
Commercially raised rooted poinsettias were potted in week 30 to represent a standard commercial potting and in weeks 32 and 34 to represent late potted crops.

The week 30 potted crop was grown in ambient light throughout production (i.e. natural season initiation).

The week 32 and week 34 potted crops were grown with supplementary lighting throughout production.

Lit crops were all grown in long days until 22/09/05. Batches of plants were then moved from long days (LD) to short days (SD) at weekly intervals giving five initiation dates (table 1).

Table 1. Summary of initiation date treatments

Date of SD start	Date of move from LD to SD
Week 38	22/09/05
Week 39	29/06/05
Week 40	06/10/05
Week 41	13/10/05
Week 42	20/10/05

Plant spacing:
Two treatments were compared:

- standard (std) spacing where plants were spaced as required by their rate of development which was decided in liaison with the project consultant.
- close spacing where pots were held at pot thick for longer than the standard treatment, with pots then moving directly to 15 plants/m². Pots were then spaced as required in line with the standard treatment. This treatment was designed to maximise space available at the start of production and to also reduce labour through missing out the intermediate spacing of 30 pots/m². The dates of spacing and densities used are summarised below.

Spacing treatments were combined with the week 32 and week 34 potted crops given SD until week 38 and week 40 (table 2). There was insufficient space to combined spacing with all potting dates and transfer dates.

Table 2. Summary of dates of plant spacing by week number of moves.

Potting date	**Spacing**	**Pot thick**	**30 pots/m²**	**15 pots/m²**	**12 pots/m²**	**9 pots/m²**
wk 30	**std**	w30-w35	w35-w37	-	w37-w39	w39+
wk 32	**std**	w32-w39	w38-w39	w39-w43	w43-w45	w45+
wk 32	**close**	w32-w40	-	w40-w43	w43-w45	w45+
wk 34	**std**	w34-w40	w40-w42	w42+		
wk 34	**close**	w34-w44	-	w44+		

Observation treatments to increase lighting prior to marketing:

All late potted treatments were grown in LD conditions initially. Plants potted in weeks 32 and 34 and transferred to SD in weeks 38, 40 and 42, were transferred back to long days in weeks 44, 45 or 46. This gave different periods of SD for the plants to initiate (table 3).

Table 3. Number of weeks in SD for plants given extra LD from weeks 44 onwards.

	Date of return to LD		
Date of SD start	**Wk 44**	**Wk 45**	**Wk 46**
Wk 38	6	7	8
Wk 40	4	5	6
Wk 42	2	3	4

Experimental design:

Three glasshouse compartments in B Block at Wellesbourne were used for the experiment. One remained unlit for natural season production and two were lit for the late potted crops. One of the lit compartments was used to provide the LD environment and the other provided the SD environment.

Small plots consisting of 2 rows of plants were used in this first year of the project in order to compare a wide number of treatments. There were 5 or 6 plants per row at final spacing depending on the density used. Spare plants were used initially to provide a full canopy of plants and these were removed as densities were reduced over time. All treatments had 2 replicate rows in different positions within a compartment. There was only sufficient room for one row per plot for the observation treatments where plants were returned to LD after an initial period of SD to increase light intensity prior to marketing. Guards consisted of two rows of plants on the north and south end of benches as well as a single row around the outer edges of the bench. An extra 2 rows of guards were used around the plots given higher densities as part of the spacing treatments. Benches (7.6m by 1.5m) were divided into two sections for the two varieties with treatments arranged within these blocks.

Cultural details

Plant material

Rooted cuttings of Cortez and Infinity were purchased from Yoder Toddington and GASA respectively.

Cuttings were planted into 13cm pots using Bulrush Poinsettia Growing media (details given in Appendix 1) with imidacloprid added as Intercept 5GR at 0.28 g/l.

Plants were pinched, spaced and treated with chlormequat as Cycocel according to their size and habit as recorded in the crop diary in Appendix 1.

Nutrition

Plants were maintained on plain water for the first three weeks from potting.
A calcium nitrate feed (150 mg/l N) was given twice a week from weeks 4-6 from potting.

Peters Excel 15:5:15 (150 mg/l N) was given every 2-4 feeds from weeks 6-10 from potting.

Peters Excel 13:5:20 alternated (130 mg/l N) with 15:5:15 giving 2-3 feeds a week 10 weeks from potting onwards.

Note: plants held in LDs to weeks 41 and 42 began to show nutrient deficiency symptoms at the beginning of October. Feeding in the LD compartment was therefore adjusted to deliver feed at every irrigation using Peters Excel 15:5:15 to increase N levels. Plants returned to the standard feeding regime once they were moved to SD.

Environment

Compartments were initially set to give a 21°C day and a 19°C night with venting at +2°C whilst plants established.

In LD, day was 01:00-21:00 and in SD, day was 6:30 – 17:30. HID lighting (using 400W high pressure sodium Osram Plantastar lamps) and blackouts were used to control day length. The week 30 potted natural season crop received ambient day length according to dawn and dusk, but blackout screens were used on dawn/dusk settings to prevent light spill.

CO_2 enrichment was used in both lit and until compartments to achieve 1000vpm during the day period when vents were closed (dropping to 350vpm when vents were 10%+ open).

Shade screens were used to help plants establish and blackouts were used to conserve energy during the night and prevent light spill between LD and SD compartments.

Temperature integration was introduced from week 37.

Details of climate control set points are given in Appendix 1.

Facilities

Three identical venlo-type research glasshouse compartments were used for the trial. Each compartment included:

- Total floor area of 95m²
- Supplementary lighting installation designed to deliver a light intensity of 10 W/m² PAR
- Hot water heating system
- Independent measurement and control of the greenhouse environment

Assessments

Records taken during production:

- Date of pinching.
- Number of breaks per treatment and plant uniformity recorded 4 weeks after pinching.
- Plant height measured weekly to assess requirements for growth regulation. Data was compared against 'Tracker' and also data from the previous season from a commercial nursery.
- Date and rate of each Chlormequat application.
- Date of each spacing per treatment.
- Weekly record of bract colour development per treatment from the appearance of first bract colour to 100% of plants showing colour.
- Date of appearance of first visible cyathia per pot in each treatment.

- Mineral nutrition monitored via media sampling and analysis every two weeks. This started in week 32 for the week 30 potted plants, week 34 for the week 32 potted plants and in week 36 for the week 34 potted plants. Pooled samples were taken across comparable treatments. Samples were taken from the bottom of the pot from guard rows and fresh media was used to fill in the gap left behind.
- Dilute liquid feed was also routinely analysed for mineral concentrations.
- The aerial environment was routinely logged and monitored including logging of energy use as heat (via and ultrasonic heat meter installed in the heating loop of each compartment) and electricity (via a panel mounted electricity meter for each compartment)

Records taken at marketing. All treatments were due to be assessed in week 48 (w/c 28/11/05) but due to delays with some treatments a second batch of plants were recorded in week 50 (w/c12/12/05).

- Date of 'marketing'.
- Height of each plant in the pot (from pot rim to tallest apex).
- Pot spread (diameter recorded across the pot in 2 directions).
- Number of primary and secondary breaks per plant.
- Number of green leaves and red leaves/bracts on dominant/upper most break.
- Length and maximum width if largest bract star per plant.
- Percentage cover of red bracts visible over the top of the sleeved plant.
- Average cyathium size score on the dominant break; where score 1 = <2 mm, score 2 = 2-5 mm and score 3 = >5 mm.
- Average stage of cyathium development on the dominant break; where stage 1 = tight green bud, stage 2 = bud colour, stage 3 = pollen showing, stage 4 = stigma open, stage 5 = pollen and stigma and stage 6 = abscission.
- Sleevability score (1-5 scale, 5 = easiest).
- Score of grassy growth (0 = none to 3 = extensive).
- Score of overall plant quality (0-5 scale, 5 = best, 3 = acceptable for marketing).

Shelf life simulation:

3 plants were taken from each plot. These plants were sleeved (clear polythene perforated sleeves) and boxed by mid day prior to delivering to the Ball Colegrave controlled temperature transport facility in Stratford Upon Avon. Care was taken to avoid sleeving plants when too wet or too dry. Boxes of plants were loaded onto Danish trolleys and transported to Kirton early the next day. The transport was set to maintain air temperature above 15°C. Temperature loggers were used to monitor transport temperatures. Plants arrived at Warwick HRI Kirton around 16:00 hrs and were moved directly into the shelf room

held at 18°C. Boxes were unpacked and pots stood out on benches the next day (giving a total of 2 days when plants were sleeved and boxed). Plants were held in their sleeves for a further 5 days. Sleeves were then removed and plants were stood out on the shelf life benches in saucers to mimic store life. After a further 5 days, sleeves were removed and the first assessments made. The shelf life room was set to 18°C +/- 1°C and 65% RH, fluorescent lights were set at 1000 lux at plant height and were turned on for 14 hours per day. Watering was by hand with tap water to the base of the pot as required.

Environment:

Data loggers recorded temperature in representative boxes of plants for each transport run. Temperature and RH were also monitored in the shelf life rooms for deviations from set-points and for calculation of day and night averages.

Plant records:

Weekly shelf life assessments were recorded for the following parameters:

- Leaf drop with a final count of leaves per plant for calculation of % leaf drop figures.
- Red bract drop with a final count of red bracts per plant for calculation of % red bract drop figures.
- Cyathia number (one tagged break per plant).
- Count of broken branches.
- Mechanical damage score on a 0-5 scale; where 0 = no damage, 3 = moderate damage and 5 = severe damage.
- Incidence of bract-edge blackening on a 0 (none) to 5 (severe) scale.
- Green leaf colour score for upper and lower leaves separately; where 0 = severe yellowing, 1 = pale, 3 = slightly pale and 5 = dark green.
- Red bract/leaf colour score; where 0 = no fade (original depth of colour), 1 = slight colour loss, 3 = moderate colour loss and 5 = severe colour loss.
- Overall pot quality score. This started at the score assigned at marketing (written on the pot) and was downgraded as the pots deteriorated. Maximum score = 5 (high quality), 3 = marketable, 1 = poor quality, 0 = discarded.

RESULTS

Data has been analysed by regression analysis, differences between treatment means must exceed the figures quoted for least significant difference (lsd) to be significant at the 95% level.

Late potting combined with supplementary lighting and delayed initiation – marketing records

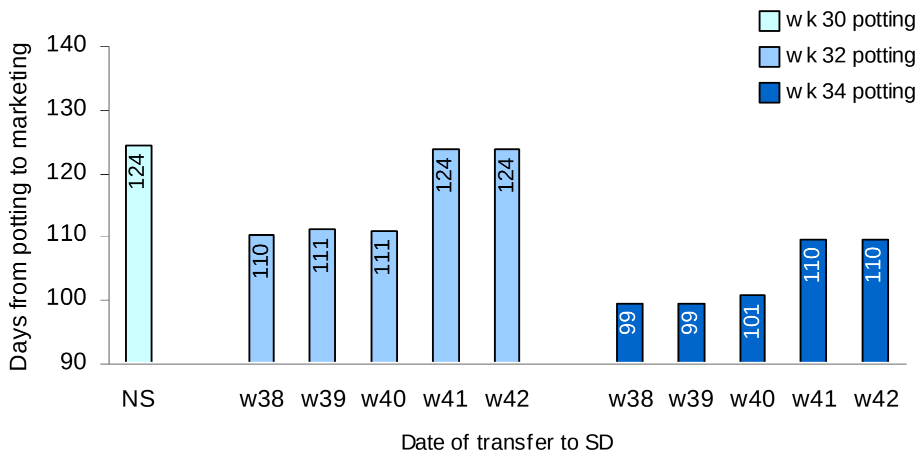
Production time

Late potting is designed to increase the availability of space in the glasshouse prior to starting a poinsettia crop. Plants potted late had reached a suitable stage for marketing by week 48 if they had been transferred to SD between weeks 38 and 40. This gave savings in production time of 14 to 25 days for potting in weeks 32 and 34 respectively.

Delaying the start of SDs to weeks 41 and 42 increased production time as plants had insufficient red colour to be suitable for marketing in week 48. These treatments were therefore assessed in week 50, increasing production time by 9-14 days (but in this case the extra space would be needed in weeks 49 and 50 rather than in weeks 30 to 34).

Figure 1. Days from potting to marketing

NB. Treatments starting SD in w41 and w42 had to be assessed in week 50 rather than week 48 due to the delay in colour development.



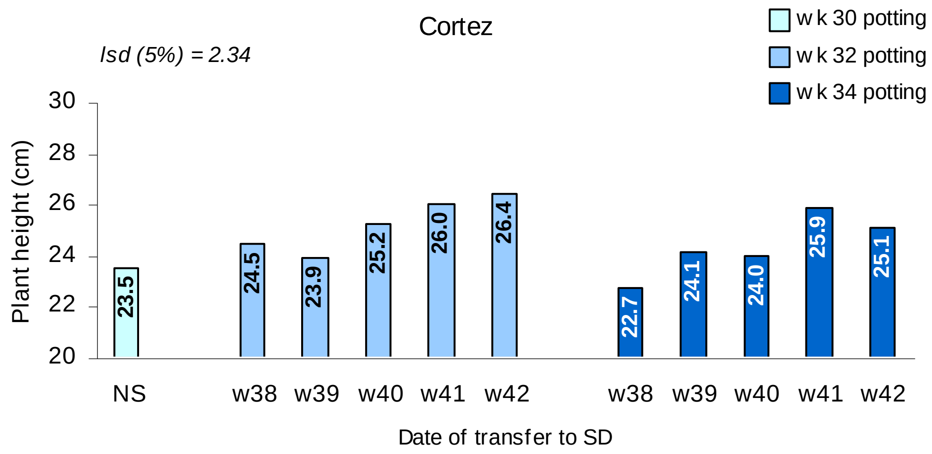
Plant height

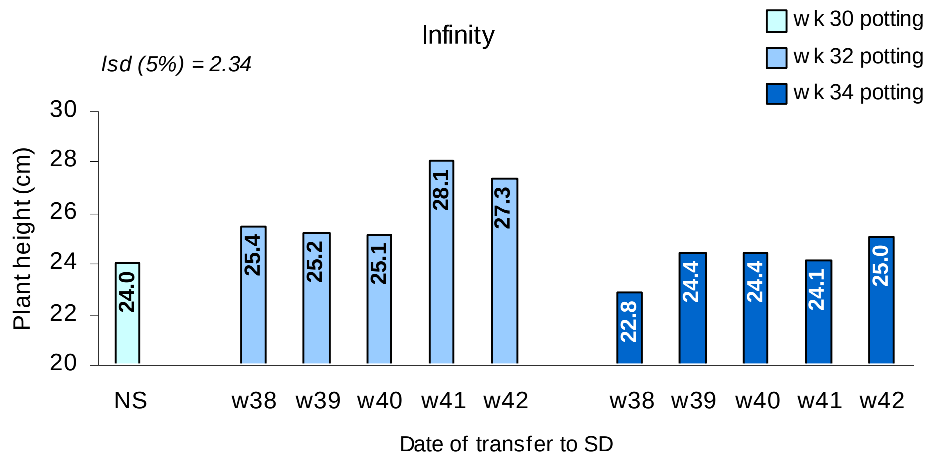
The late potted treatments were at least not significantly shorter than the week 30 crop grown in ambient light. Week 32 potted plants were generally taller than the equivalent week 34 potted treatment (by 1 to 4cm) and plants potted in week 34 and transferred to SD in week 38 were the shortest of the late potted lit treatments. As transfers to SD became later so plant height increased and Infinity plants potted in week 32 were significantly taller at marketing from transfers to SD in weeks 41 and 42 than from transfers in weeks 38 to 40. The extra delay in these treatments meant that they were marketed two weeks later than the rest of the treatments giving extra time for plant growth prior to assessment.

Chlormequat was used throughout production to maintain plant shape (see details in appendix 1). These regular, low concentration, sprays may also have limited plant height and the week 32 potted plants were given two more applications of chlormequat than the week 30 potted plants and 4 more than the week 34 potted plants over the whole production period.

Figure 2. Plant height measured at marketing

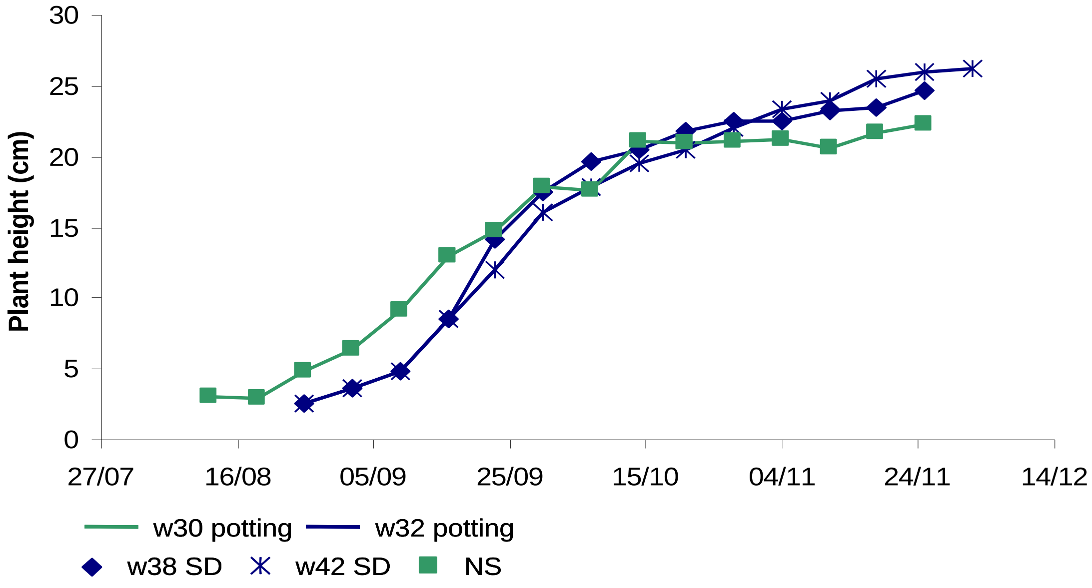
NB. Treatments starting SD in w41 and w42 had to be assessed in week 50 rather than week 48 due to the delay in colour development.





Plant height was measured at weekly intervals during production as well as at marketing for crop management using the 'Tracker' software from HDC. This data demonstrated that growth patterns of late potted lit crops may be expected to deviate from those expected for standard production as included in the data used by the 'Tracker' software. Figure 3 compares the standard week 30 potted crop which started SD at around the date of the equinox with week 32 potted plants starting SD in either week 38 or week 42. The late potted crops fell below the height of the standard crop initially but then increased in height more rapidly later in production, especially where initiation was delayed.

Figure 3. Plant height monitoring during production for Infinity

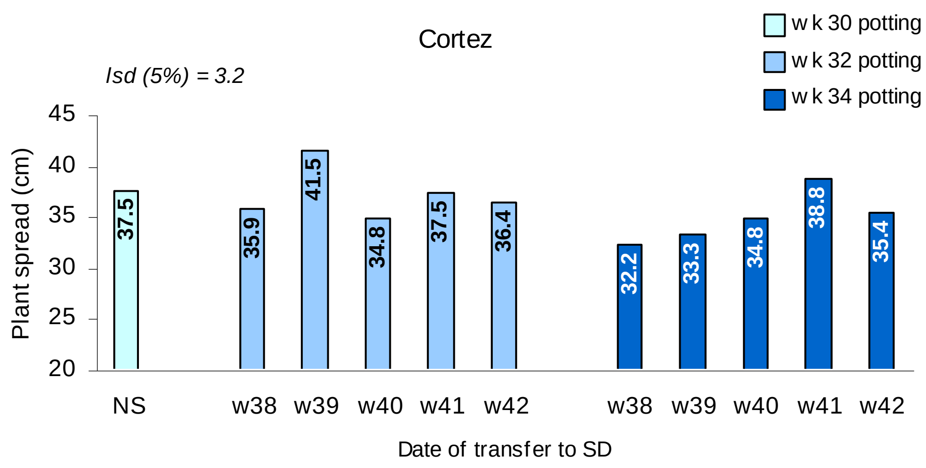


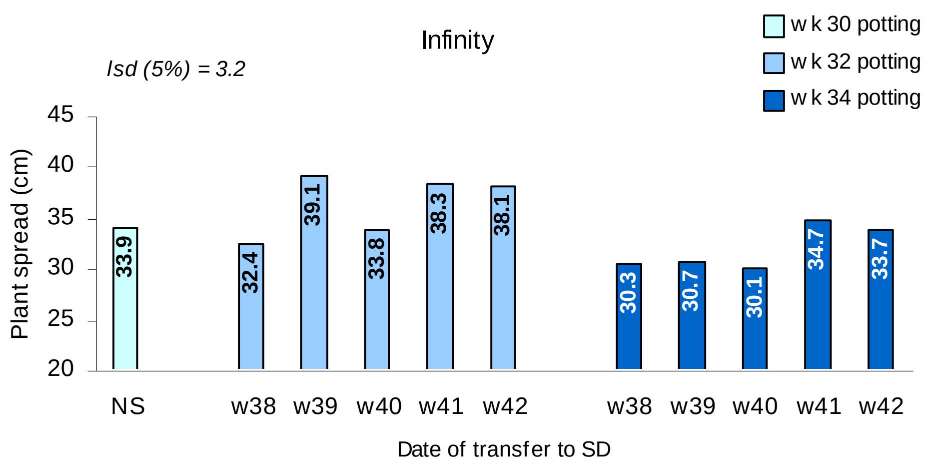
Plant spread

Along with plant height, spread (or diameter) indicates extent of vegetative growth. Plants potted in week 32 at least did not have significantly smaller plant diameter (spread) than the week 30 potted reference crop, and in some cases, (e.g. w39 transfer to SD) had greater diameters (figure 4). Plants potted in week 34 and transferred to SD in week 38 had significantly smaller diameter (by 4-5 cm) than the week 30 crop, although plants transferred to SD from week 39 onwards were not significantly different to the week 30 potted reference crop.

As with plant height, spread was generally greater for the week 32 potted treatment than the equivalent treatment potted in week 34; particularly for Infinity.

Figure 4. Plant spread measured at marketing





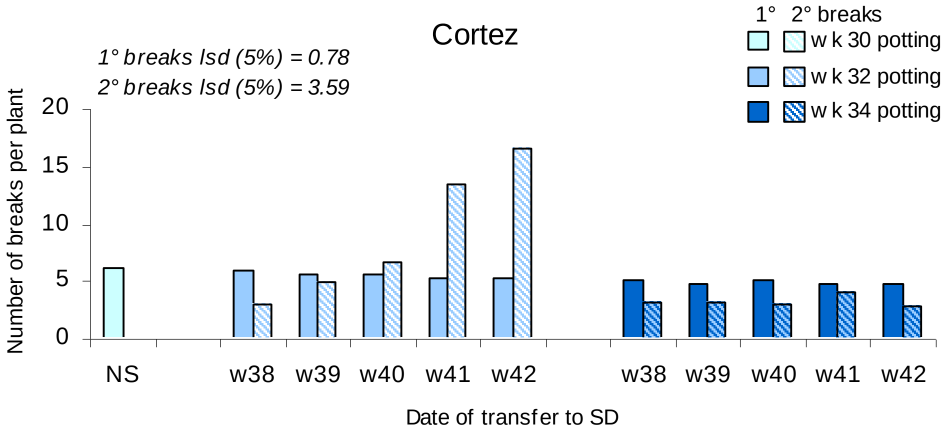
Primary and secondary breaks

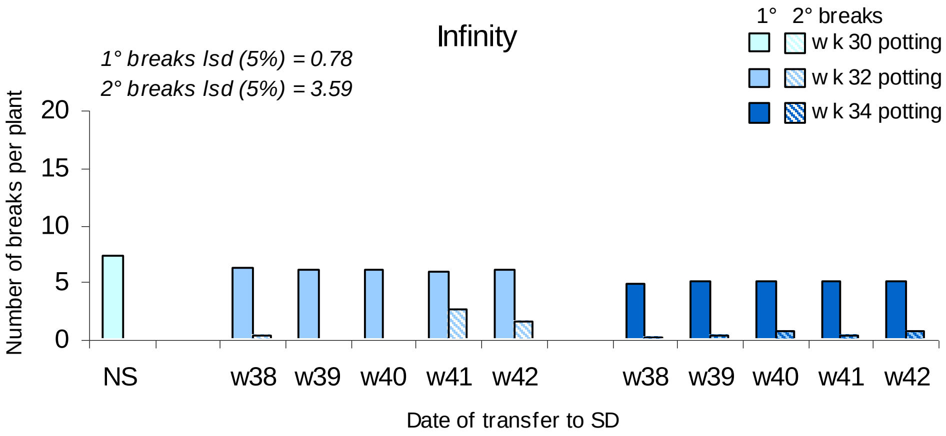
The average number of primary (1°) breaks ranged from 4.6 to 7.2 breaks per plant (figure 5). Potting date decreased the number of primary breaks on Infinity from 7.2 for the week 30 potting to 4.8 – 5.1 for the week 34 potting. Potting date did not significantly affect the number of primary breaks produced by Cortez. Cortez was expected to produce breaks more readily than Infinity which may explain the difference between these 2 varieties in their response to potting date. Whilst a slight difference in number of primary breaks was recorded for Infinity, pinching height would determine how many nodes and hence how many primary breaks could be produced from one plant. This in turn would have limited how much the treatments could influence the number of primary breaks produced.

Delaying transfer to SD had a significant effect on the number of secondary (2°) breaks produced by Cortez potted in week 32. As the transfer to SD became later, the number of secondary breaks increased. Cortez potted in week 34 also produced more secondary breaks than Cortez potted in week 30 but delaying the start of SD did not influence the number of secondary breaks from this potting date. There were no significant differences in number of secondary breaks for Infinity due to potting date or delaying the start of SD.

Figure 5. Number of primary and secondary breaks per plant measured at marketing

NB. Treatments starting SD in w41 and w42 had to be assessed in week 50 rather than week 48 due to the delay in colour development.





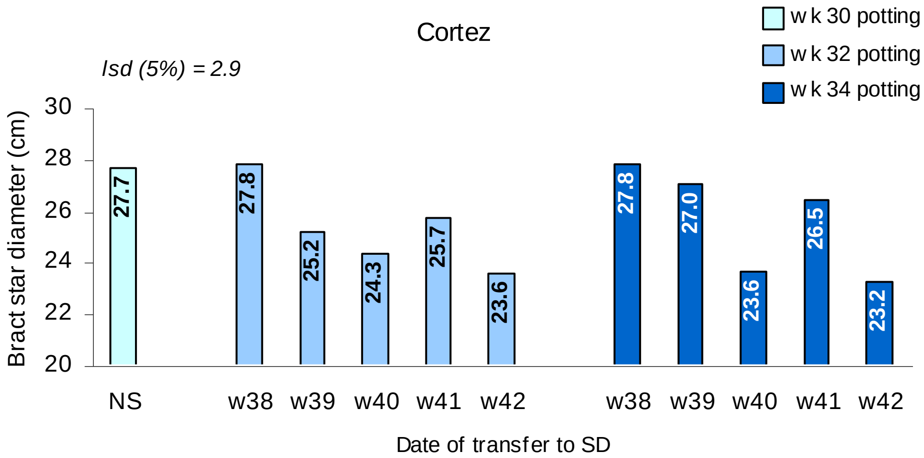
<u>Bract star diameter</u>

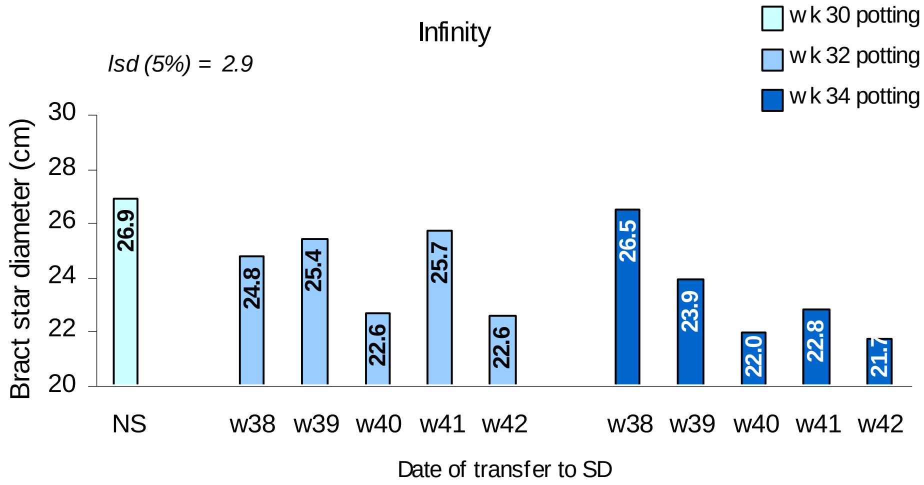
The timing of the transfer to inductive conditions (SD) influenced bract star size. Plants induced in natural season conditions or transferred to SD in week 38/39 had the largest bract stars (figure 6). Delaying the start of SD reduced bract star size by up to 5cm. Bract star size appears to have increased again where plants were moved to SD in week 41, but these plants were also assessed later (week 50 rather than week 48) and hence the bract stars had more time to develop.

Potting date alone did not appear to influence average bract star size at marketing.

Figure 6. Bract star diameter measured at marketing

NB. Treatments starting SD in w41 and w42 had to be assessed in week 50 rather than week 48 due to the delay in colour development.



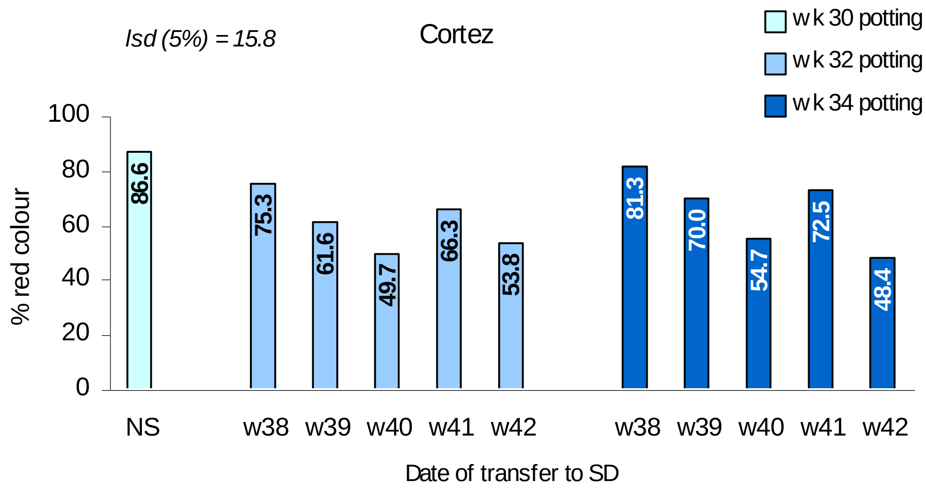


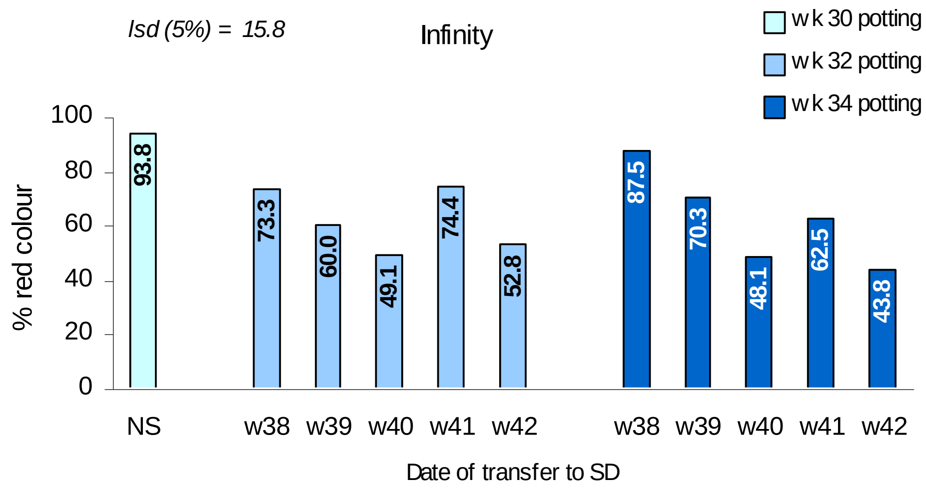
<u>% Red colour</u>

The extent of red colour development across the top of the canopy (and hence visible in the sleeve) followed the same trend as was described for bract star diameter described above (figure 7). That is, timing of the transfer to inductive conditions influenced % red colour development. Treatments that induced flowering the earliest (NS and week 38/9) has the greatest % red colour (73-94%). Plants transferred to SD in week 41 and 42, were allowed more time to develop colour before being assessed for marketing. This increased the amount of colour development and is reflected in an increase in the % red colour score. All treatments were considered to have sufficient colour for marketing, however the week 41 and 42 transferred treatments may be expected to stand out in week 50 marketing period where plants grown conventionally would be expected to have more extensive colour development.

Figure 7. Percentage red colour development measured at marketing

NB. Treatments starting SD in w41 and w42 had to be assessed in week 50 rather than week 48 due to the delay in colour development.





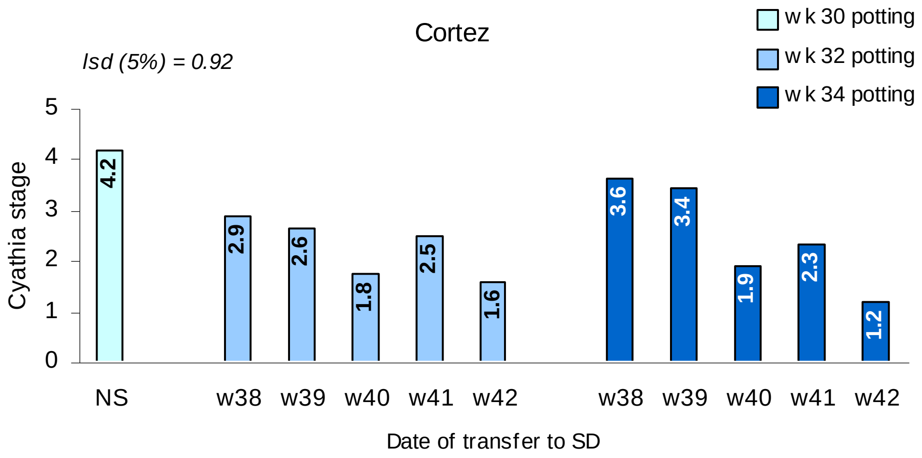
Cyathia stage and size scores

Cyathia developed on Cortez earlier than on Infinity and this is reflected in differences in cyathia stage scores recorded at marketing (figure 8).

Delaying transfer to SD delayed cyathia development as indicated by the lower scores for cyathia stage. As with previous scores for % red colour and bract star size, the extra time given to plants assessed in week 50 rather than week 48 is reflected in more advanced flowering. A similar trend was noted for cyathia size score for Infinity (figure 9) but for Cortez date of transfer to SD had little effect on cyathia size.

Figure 8. Cyathia development stage score measured at marketing

NB. Treatments starting SD in w41 and w42 had to be assessed in week 50 rather than week 48 due to the delay in colour development.



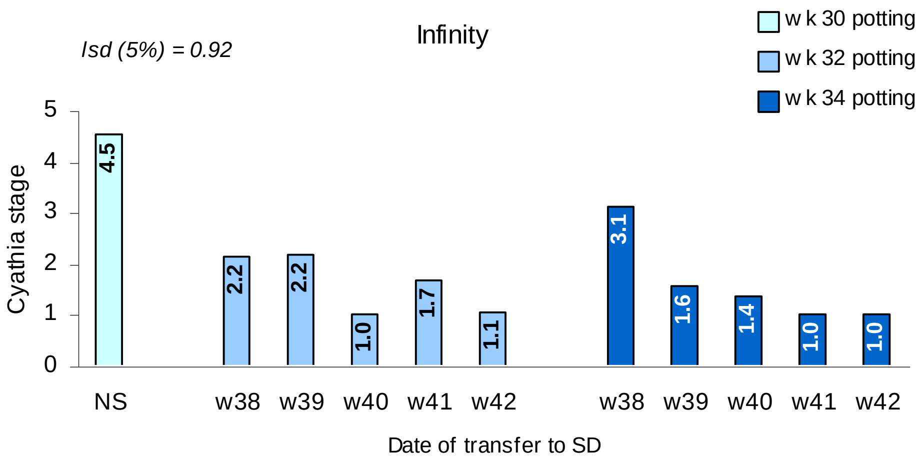
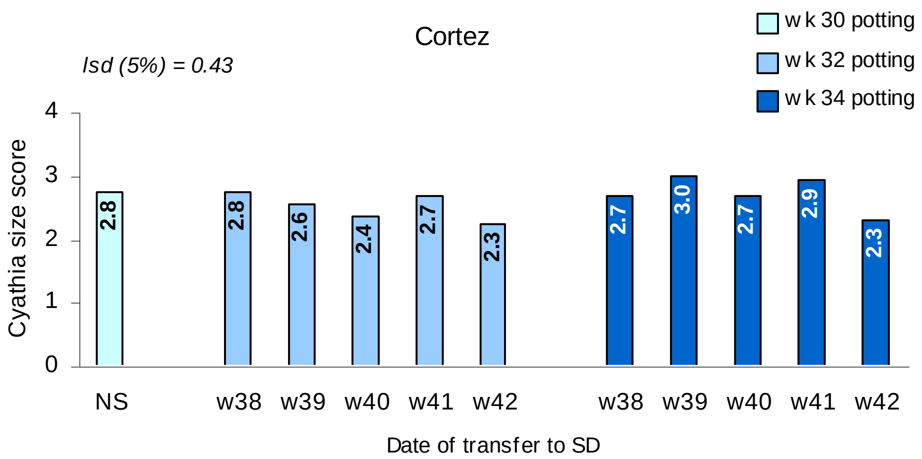
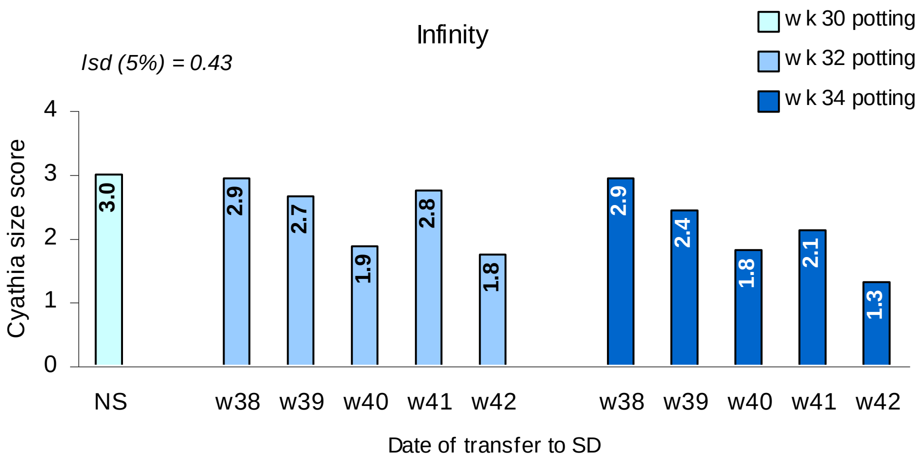


Figure 9. Cyathia size score measured at marketing

NB. Treatments starting SD in w41 and w42 had to be assessed in week 50 rather than week 48 due to the delay in colour development.





Number of cyathia

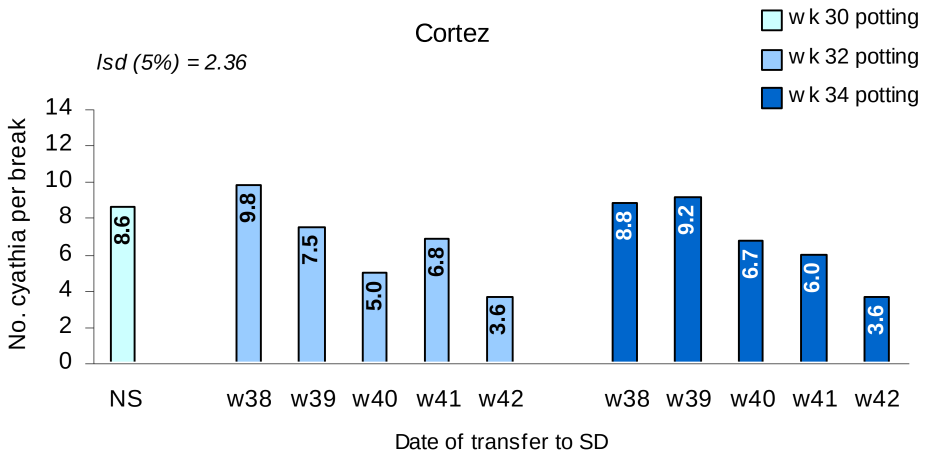
The effects of treatments on number of cyathia varied with variety.

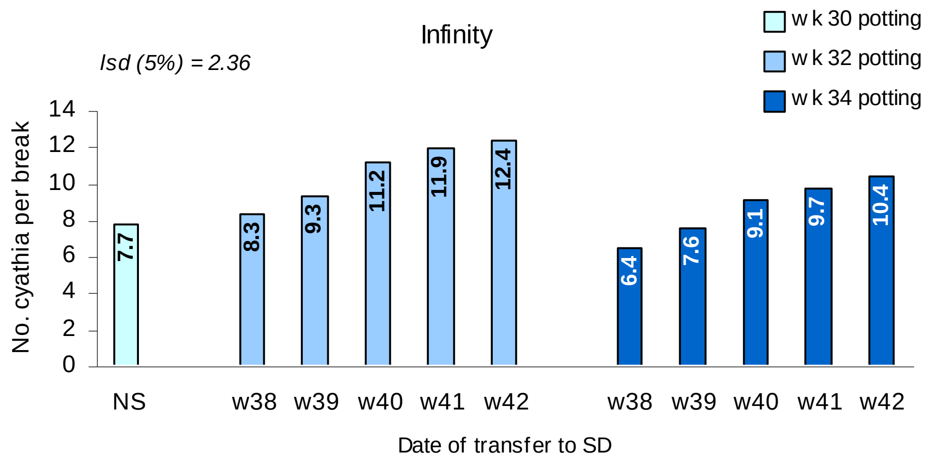
Delaying transfer to SD decreased cyathia number of Cortez (figure 10), although later assessment (i.e. of the weeks 41 and 42 transfers) increased cyathia number as has been mentioned previously for other measures of flowering. In contrast, the number of cyathia produced by Infinity increased as date of transfer to SD increased.

Potting date did not significantly influence the number of cyathia produced of either variety.

Figure 10. Number of cyathia per break measured at marketing

NB. Treatments starting SD in w41 and w42 had to be assessed in week 50 rather than week 48 due to the delay in colour development.





<u>Number of green leaves per break</u>

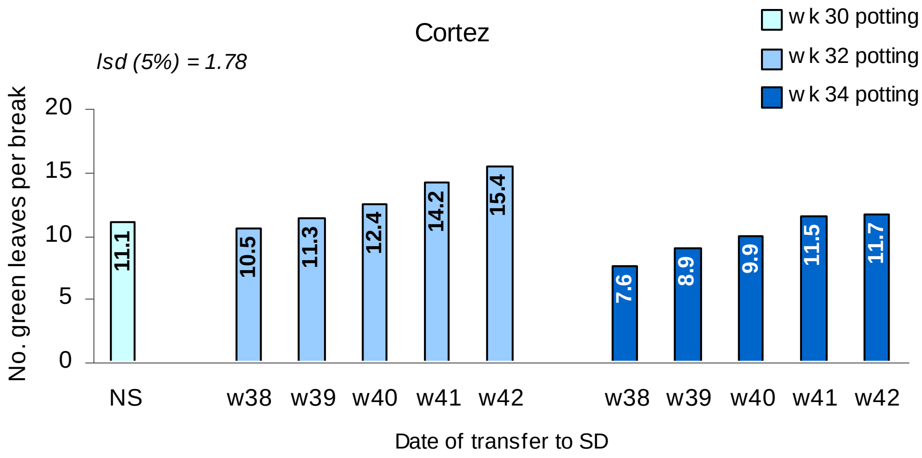
Trends in number of green leaves per break reflect trends described previously for other measures of vegetative growth (height and spread).

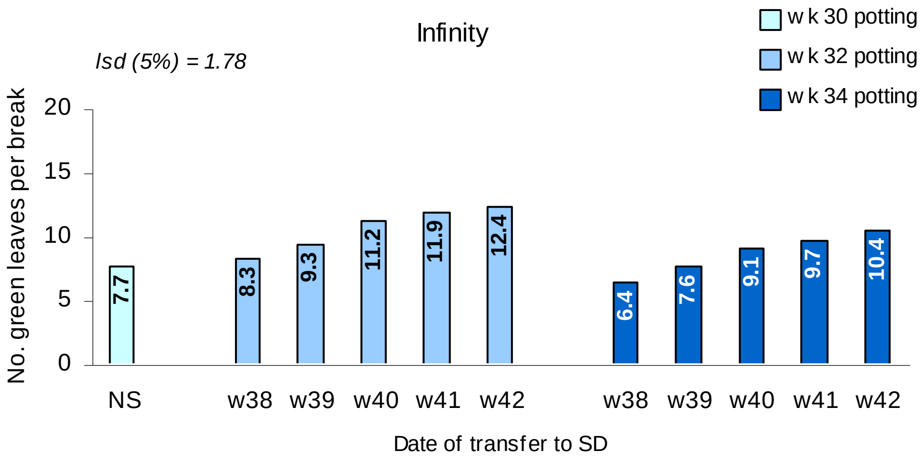
Plants potted late and lit were at least not significantly smaller in terms of number of green leaves per break than the week 30 potted natural season crop. Only Cortez potted in week 34 and transferred to SD in weeks 38 and 39 produced fewer (3.5) green leaves than the week 30 potted treatment (figure 11).

Delaying transfer to inductive conditions (SD) increased the number of green leaves produced on a break by up to 4.7 leaves. Plants potted in week 34 and growing with HID lighting produced 2-4 fewer green leaves per break compared with the comparable treatment potted in week 32.

Figure 11. Number of green leaves per break measured at marketing

NB. Treatments starting SD in w41 and w42 had to be assessed in week 50 rather than week 48 due to the delay in colour development.



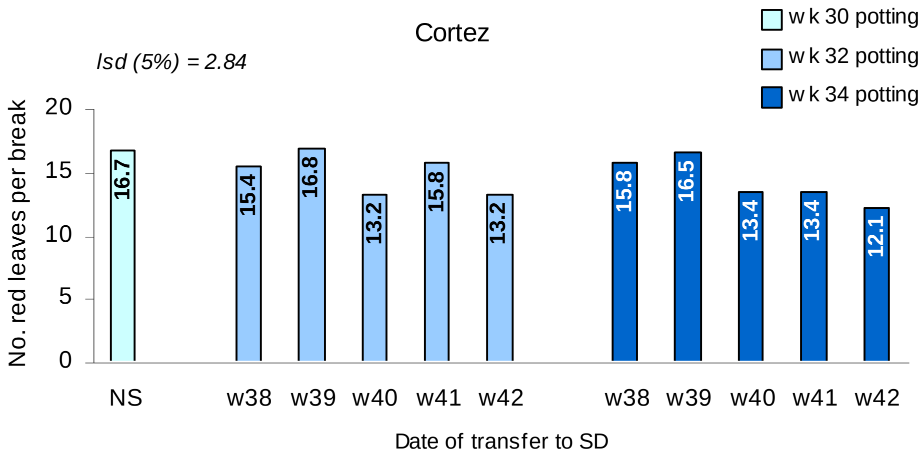


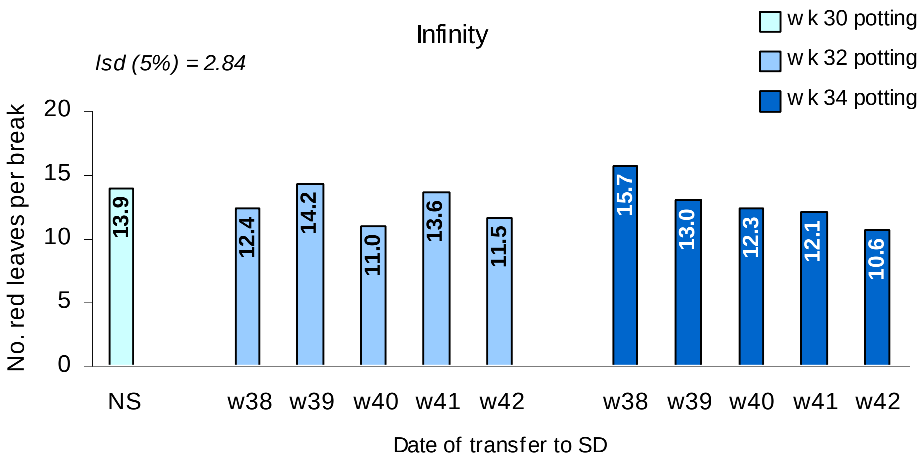
<u>Number of red leaves per break</u>

Treatments had a smaller effect on the number of red leaves per break than green leaves described above. Later potting combined with HID lighting produced equivalent numbers of red leaves/bracts where treatments were transferred to SD in weeks 38 or 39 (figure 12). Delaying transfer to SD beyond week 39 slightly reduced the count of red leaves/bracts, although this number increased again for the week 32 potted plants where plants were also recorded later (i.e. had more time for colour to develop).

Figure 12.   Number of red leaves per break measured at marketing

NB. Treatments starting SD in w41 and w42 had to be assessed in week 50 rather than week 48 due to the delay in colour development.



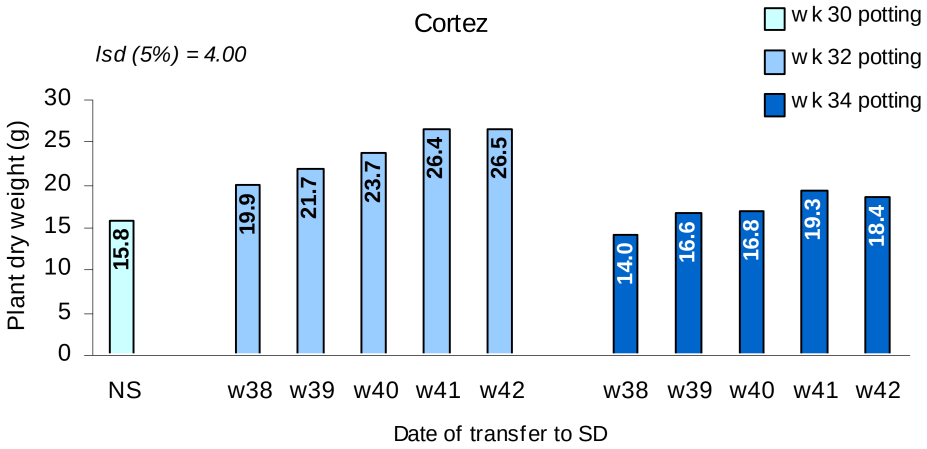


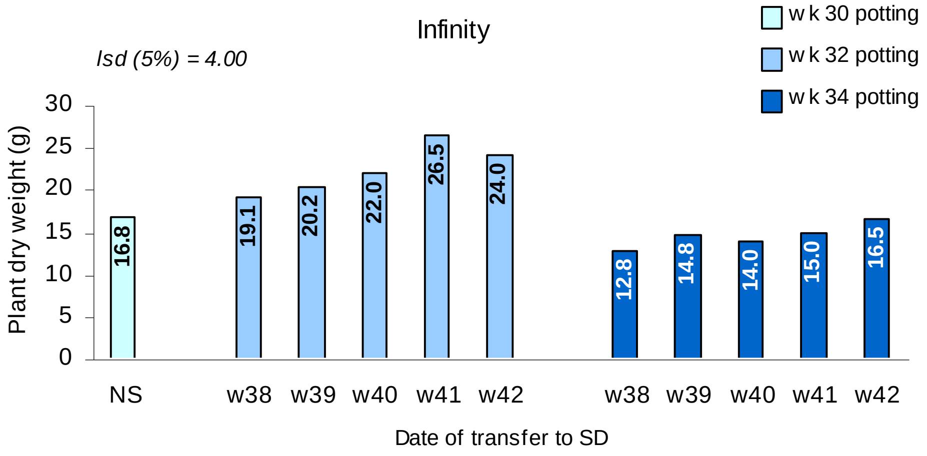
Plant dry weight

Dry weight of the late potted plants was at least not significantly less than that of the week 30 natural season crop. Plants potted in week 32 had higher dry weight than the week 30, natural season crop (figure 13). Delaying the transfer to SD increased plant dry weight at marketing for plants potted in week 32. For the week 34 potted Cortez, transferring plants to SD in weeks 41 and 42 produced higher dry weight than transferring plants to SD in week 38 (although again these treatments had extra time to develop given the delay in colouring up resulting from the delay in initiation). The dry weight of Infinity potted in week 34 however was not affected by date of transfer to SD.

Figure 13. Plant dry weight measured at marketing

NB. Treatments starting SD in w41 and w42 had to be assessed in week 50 rather than week 48 due to the delay in colour development.





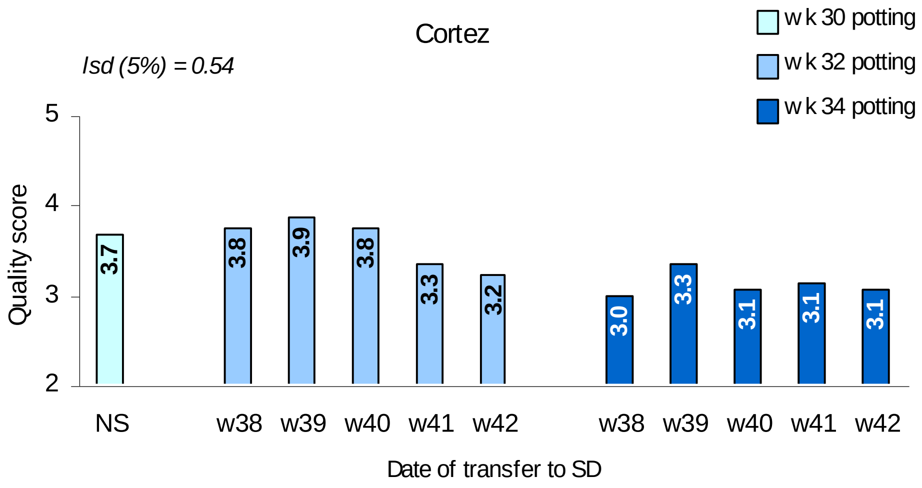
Quality score

All treatments were above a quality score of 3 suggesting all were acceptable for marketing. Potting week influenced quality score, and week 34 potted plants had quality scores that were up to 0.8 lower than the comparable week 32 potted treatments (figure 14).

Delaying transfer to SD did not increase quality score, despite the increases seen in vegetative parameters such as height and spread. The latest transfer weeks had less colour development which caused a downgrading in quality.

Varieties differed in their comparison with the week 30 potted natural season crop. For the week 32 potted Cortez, none of the treatments except for plants transferred to SD in week 42, had a significantly lower quality score than the week 30 potted natural season crop. However for the week 32 potted Infinity, only the treatment transferred to SD in week 41 had equivalent quality to the natural season crop. The photographs presented in figure 15 illustrate how the treatments compared with each other and also with the 'reference' treatment (i.e. week 30 potted crop grown without lighting).

Figure 14. Quality score measured at marketing



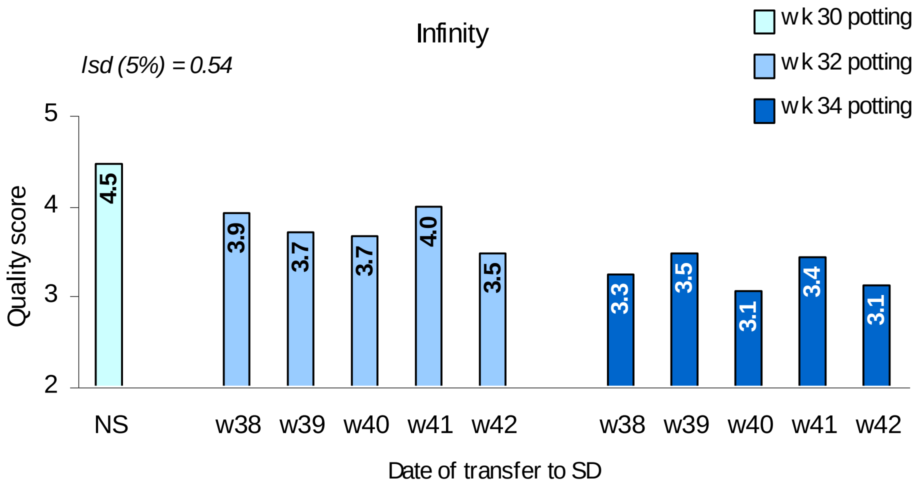
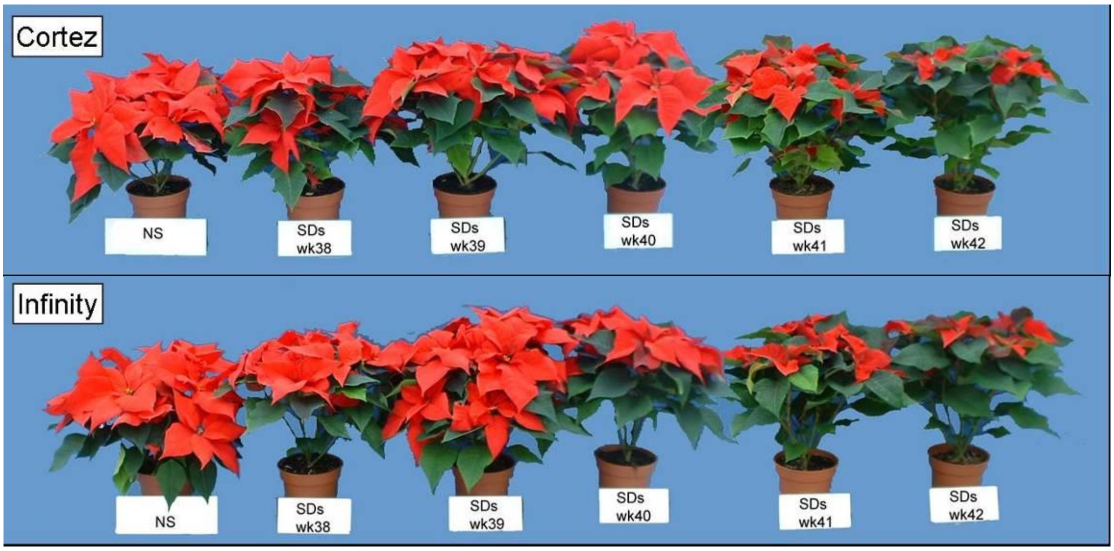


Figure 15. Photographic comparison of treatments a, from the week 32 potting and b, from the week 34 potting dates (photographed 06/12/05).

a, Week 32 potted plants:



b, Week 34 potted plants:

Late potting combined with supplementary lighting and delayed initiation – shelf life records

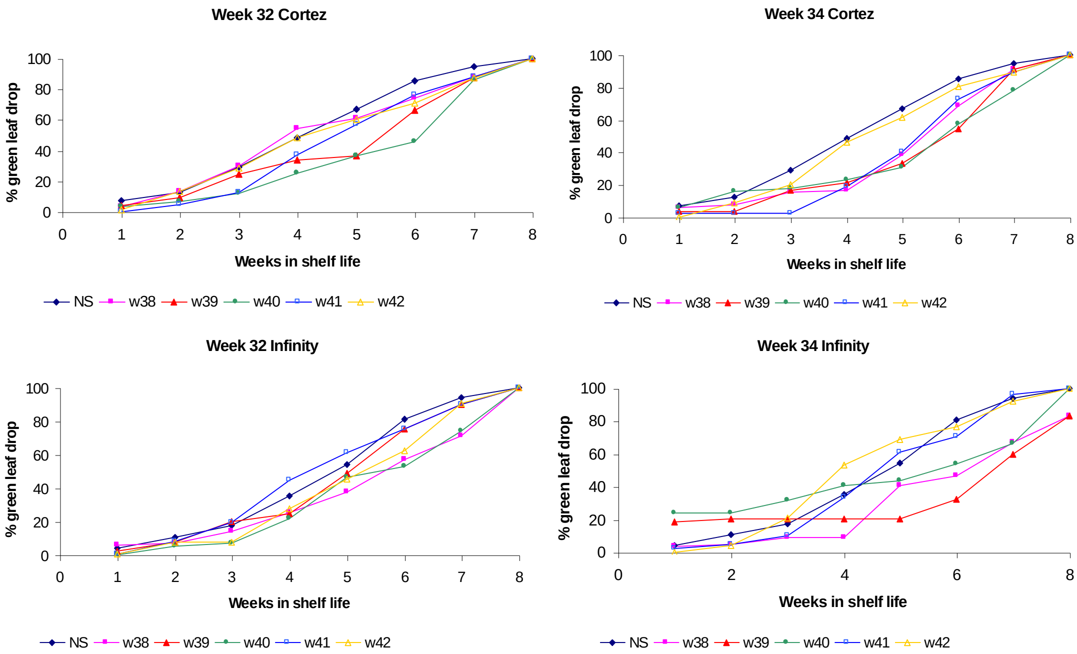
Mean data and their relevant L.S.D. figures have been summarised in appendix 3.

Percentage green leaf drop

As would be expected, the number of leaves lost from each plant increased with time in shelf life (figure 16). Plants potted in week 30 and grown without lighting had high levels and rate of green leaf drop towards the end of shelf life (i.e. from 5 weeks onwards) compared to lit treatments overall. Differences between the lit plants varied with potting date and variety, although there is some evidence to suggest that earlier transfer to SD resulted in lower green leaf drop than later transfer to SD.

Figure 16. Percentage green leaf drop during shelf life.

NB. Weeks in shelf life relates to the time from which shelf life assessment started and hence accounts for the fact that the w41 and w42 treatments were marketed in week 50 rather than week 48.

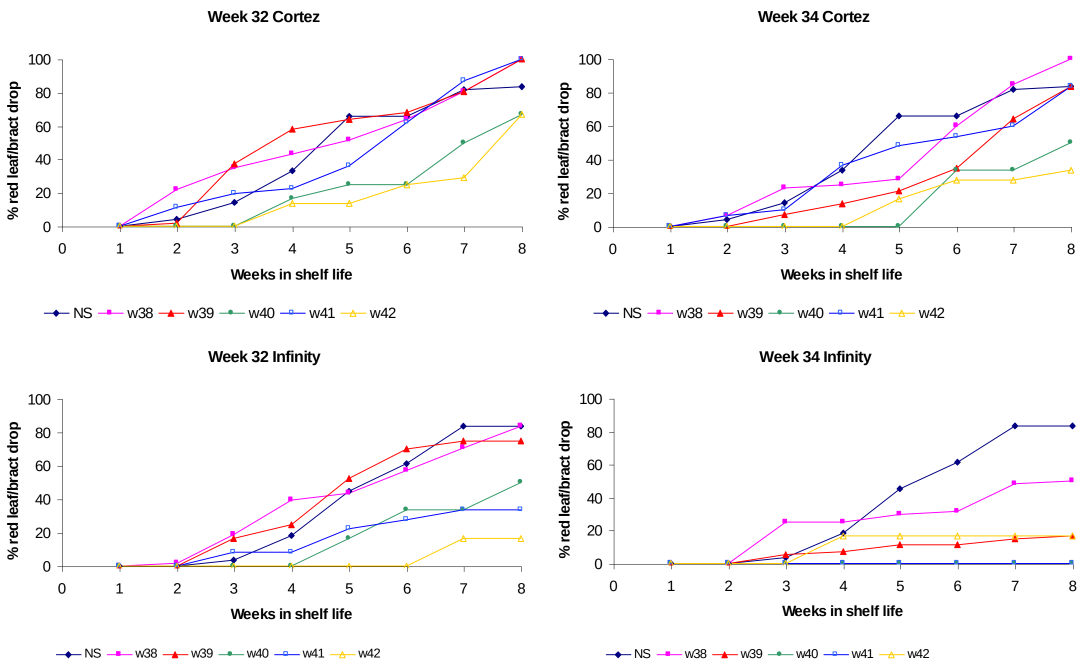


Percentage red leaf drop

As with green leaves described above, loss of red leaves or bracts from plants potted in week 30 (NS) tended to be higher than from plants potted in weeks 32 and week 34, particularly from week 5 onwards for the week 34 potted Infinity (figure 17). Lit treatments moved to short days in weeks 38-40 tended to have higher levels of red bract/leaf drop in shelf life than those transferred to SD in weeks 41-42. These effects may however be linked to the age of the red leaves / bracts since the treatments with the highest loss of red leaves/bracts were also the varieties that coloured up first and hence were more mature at marketing.

Figure 17. Percentage red leaf/bract drop during shelf life.

NB. Weeks in shelf life relates to the time from which shelf life assessment started and hence accounts for the fact that the w41 and w42 treatments were marketed in week 50 rather than week 48.

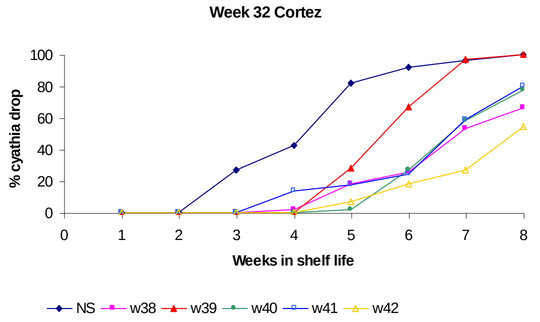


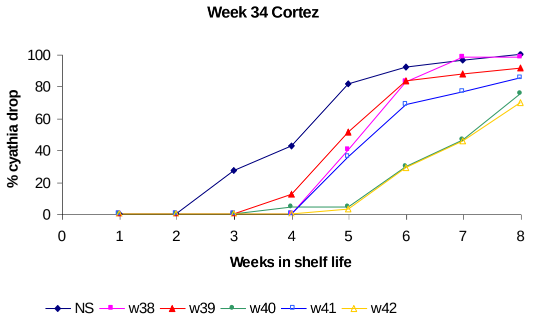
Percentage cyathia drop

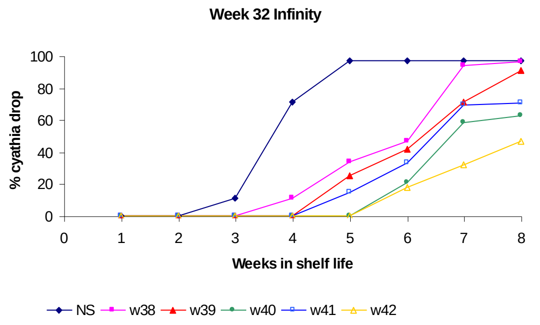
As with green leaf and red leaf/bract drop, loss of cyathia during shelf life was greater for the week 30 potted natural season crop than it was for the late potted lit treatments (figure 18). Cyathia drop started 1-2 weeks earlier for the week 30 treatment and was also higher until around week 7 when plants from other treatments had also lose majority of their cyathia. Percentage cyathia drop was also lower as plants were delayed from the later transfer to SD (e.g. weeks 41/42). As mentioned above, this result may in part be due to the stage of development of the cyathia when assessed which would have been less advanced the more the plants had been delayed.

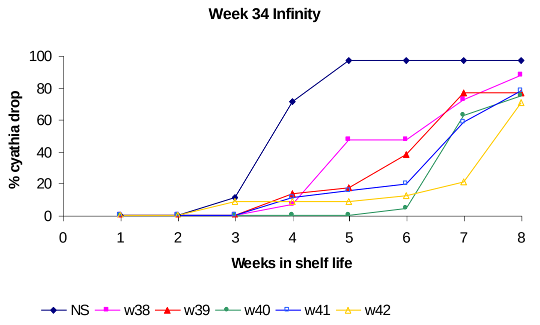
Figure 18. Percentage cyathia drop during shelf life.

NB. Weeks in shelf life relates to the time from which shelf life assessment started and hence accounts for the fact that the w41 and w42 treatments were marketed in week 50 rather than week 48.









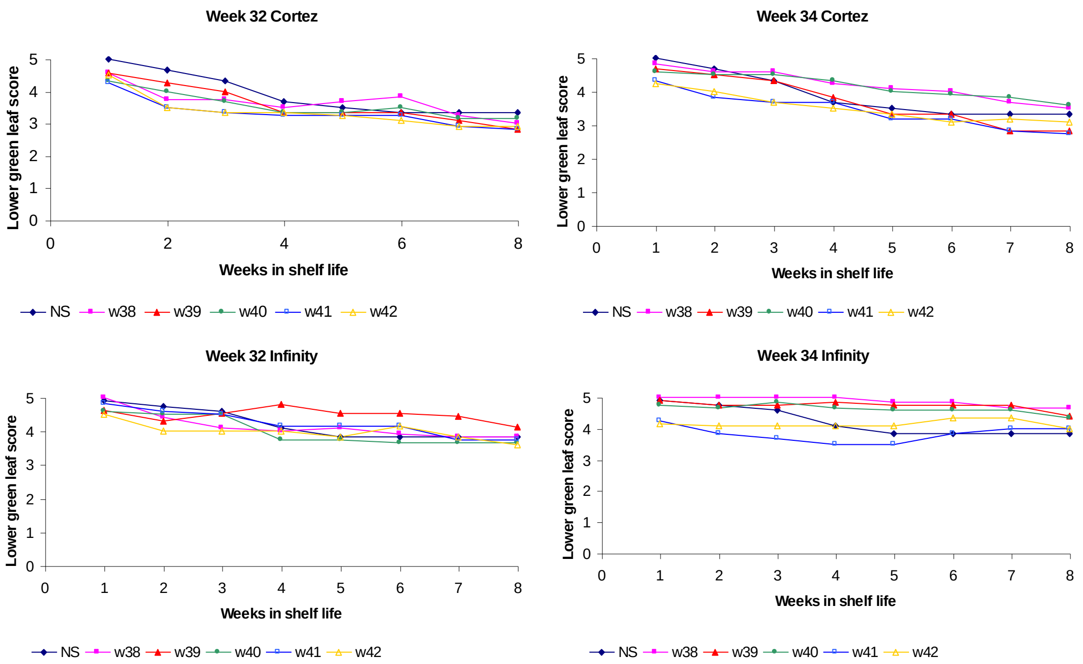
<u>Colour fade of leaves/bracts</u>

Differences in colour score of upper and lower green leaves varied with treatment and time in shelf life, but there were no overriding trends indicating that any one treatment was consistently better or worse than the others throughout shelf life. What is apparent in the leaf colour score data is that over time the week 30 potted treatments grown without lighting commenced with one of the higher scores but this score then dropped more rapidly over time than seen for the lit treatments. This is demonstrated with the data for lower leaf colour in figure 19. As with data discussed previously this may have been a result of the difference of stage of development of the plants when assessed at marketing with the week 30 plants being more advanced by the week 48 assessment date than all of the lit treatments.

There were no consistent differences due to treatments in red bract colour fade, although clearly plants commencing shelf life with less colour (due to delay) would have different extents of red colour on display in shelf life according to % red colour development as scored at marketing.

Figure 19. Lower green leaf colour score during shelf life.

NB. Weeks in shelf life relates to the time from which shelf life assessment started and hence accounts for the fact that the w41 and w42 treatments were marketed in week 50 rather than week 48.



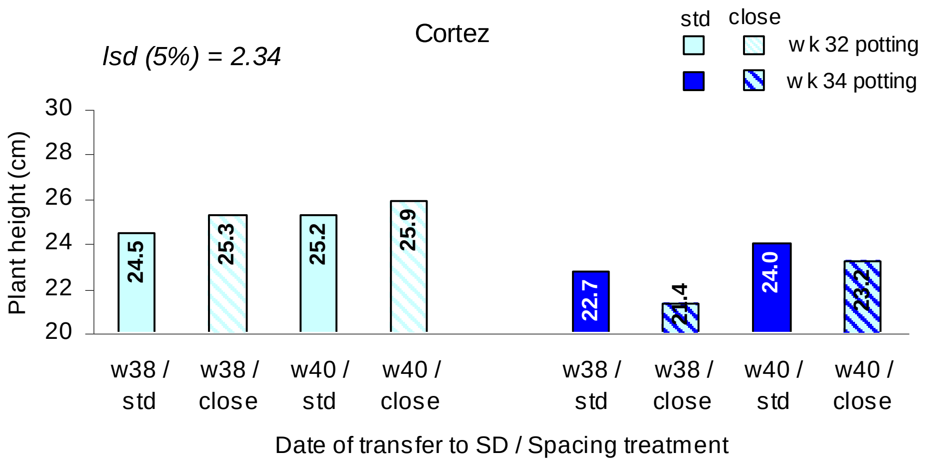
Plant spacing treatments – marketing records

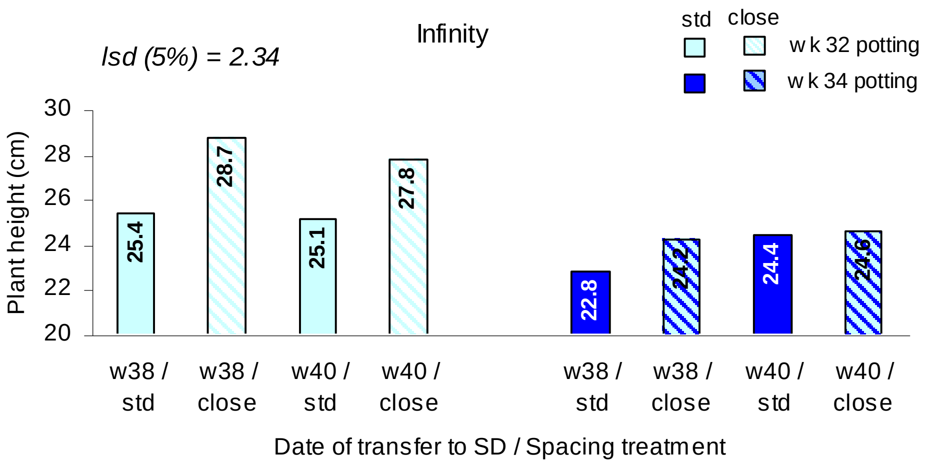
Both the week 32 and week 34 potted plants were moved from pot thick directly to 15 pots/m² on their first spacing (i.e. missing out the intermediate spacing of 30 pots/m² as used for the standard spacing treatment). The timing of spacing the close treatments to 15 pots/m² varied with potting date. Hence the week 32 potted plants were spaced in week 39 which gave an extra 2 weeks with pots at pot thick compared with standard spacing. The week 34 plants were spaced in week 44, giving an extra 4 weeks at pot thick compared with the standard treatment potted in week 34. This extra time spent at pot thick provides additional extra space which could be used to grow other species. Plant spacing after this initial move also varied with potting week. The more vigorous plants from the week 32 potting were subsequently moved to 12 and then 9 pots/m² in line with spacing given to the standard crop. The week 34 crop however remained at 15 pots/m² until marketing.

Plant height

Close plant spacing significantly increased plant height of the week 32 potted Infinity by 11-13% but did not affect height of the week 34 potted Infinity or either potting date for Cortez (figure 20). Timing of transfer to SD did not appear to interact with this effect.

Figure 20. Plant height at marketing for close and standard spaced treatments.

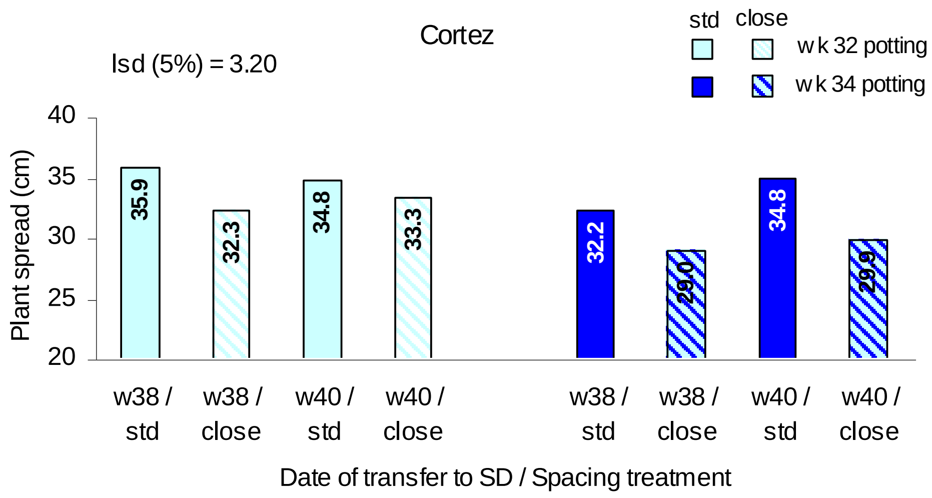


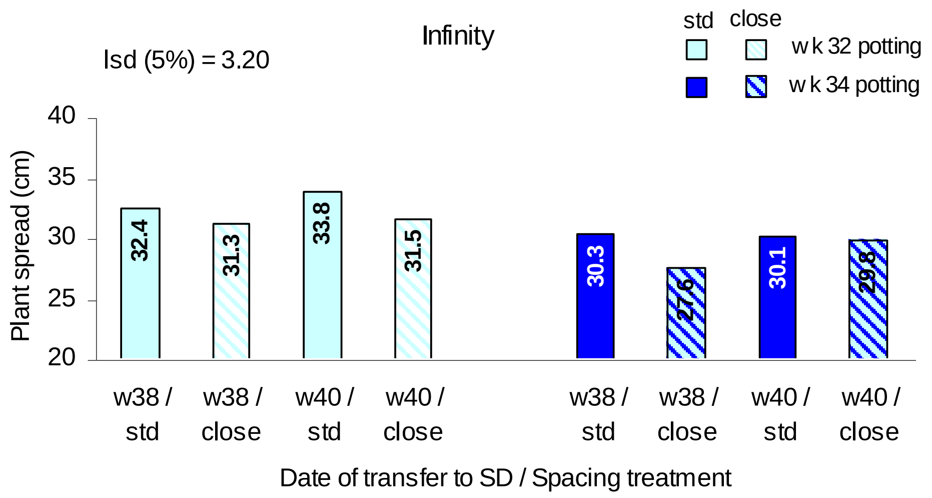


Plant spread

Closer spacing reduced plant spread (by around 10%) of Cortez plants moved to SD in week 38 from both potting dates and also plants moved to SD in week 40 from the week 34 potting date (figure 21). Similar trends are apparent for Infinity and also the week 34 potted Cortez moved to SD in week 38 but these were not statistically significant.

Figure 21. Plant spread at marketing for close and standard spaced treatments.





Other parameters measured at marketing were not affected by the closer spacing treatment and there were no significant differences recorded between spacing treatments for performance in shelf life.

Observations on late potted lit treatments returned to LD prior to marketing

Plant height

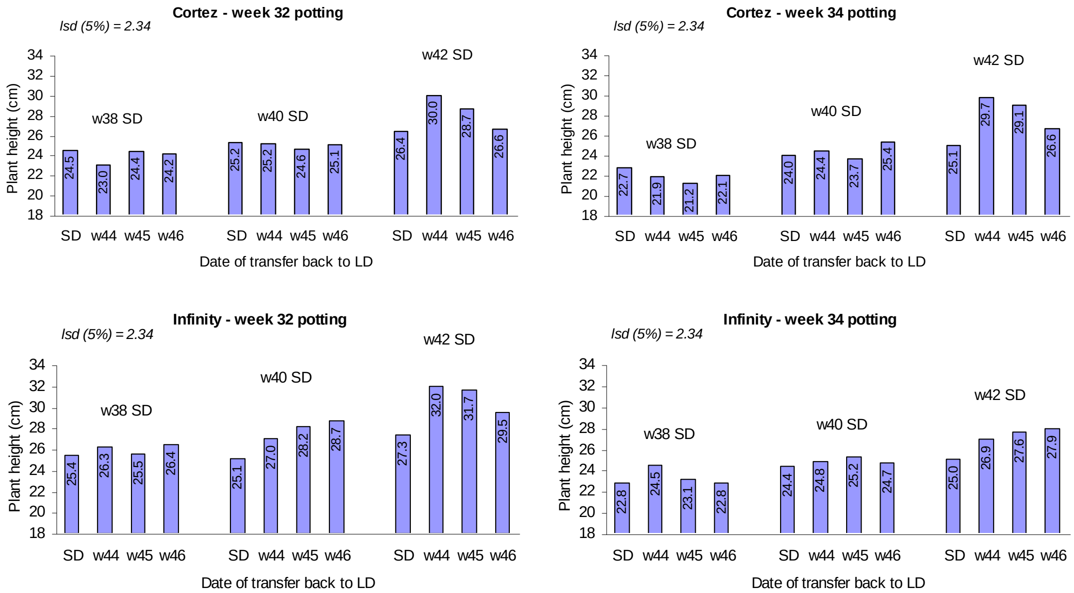
The effects of LD lighting prior to marketing (i.e. after a period of SD) varied according to initial date of transfer to SD and therefore the amount of time spent in SD before the transfer back to LD (figure 22).

For plants transferred to SD in week 38, returning to LD lighting from week 44-46 has no significant effect on plant height. These treatments had received SD for 6-8 weeks before being returned to LD.

Varieties had different responses to being returned to LD lighting when they had been transferred to SD in week 40. Plant height of Cortez was not affected by the return to LD in weeks 44-46 (i.e. after 4-6 weeks of SD). Plant height of week 34 potted Infinity was also not affected by the return to LD in weeks 44-46. Plant height of the week 32 potted Infinity however was increased as a result of returning to LD in weeks 45 and 46.

For plants transferred to SD in week 42, returning to LD in weeks 44-46 (i.e. after 2-4 weeks of SD) generally increased plant height. The week 34 potted Infinity were the exception to this general trend with return to LD lighting having little effect on plant height.

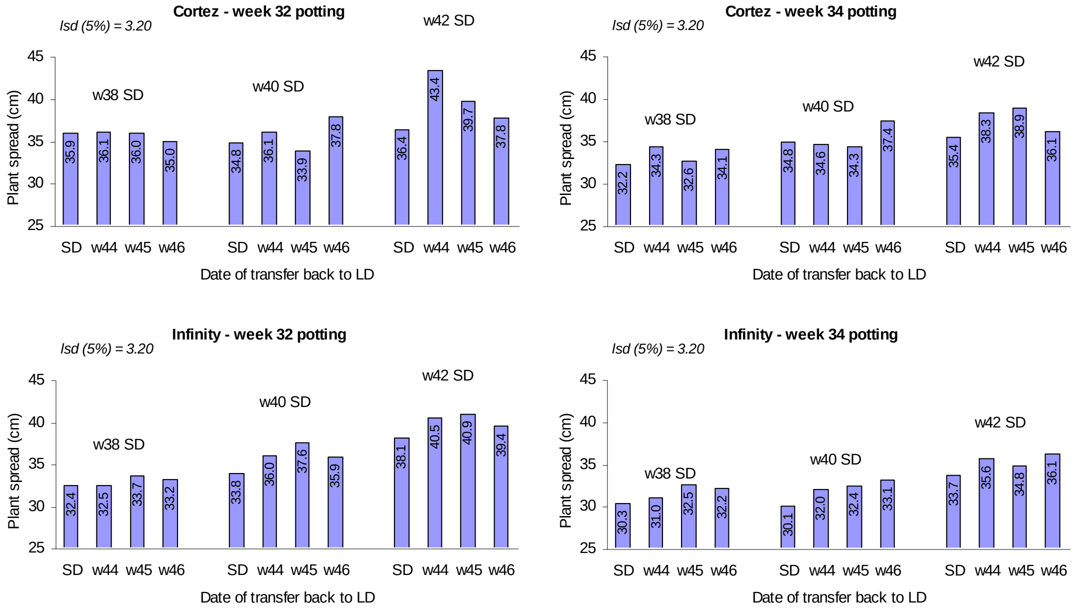
Figure 22. Plant height in response to transferring plants to LD near to the end of production.



Plant spread

Transferring plants back to LD after a period of SD had less influence over plant spread than height. The only significant difference for plant spread was for Cortez potted in week 32 and moved to SD in week 42. Retuning plants to LD in week 44 (i.e. having been in SD for 2 weeks), increased plant spread (figure 23). This coincides with the treatment that had the greatest influence over plant height as described above.

Figure 23. Plant spread measured at marketing.



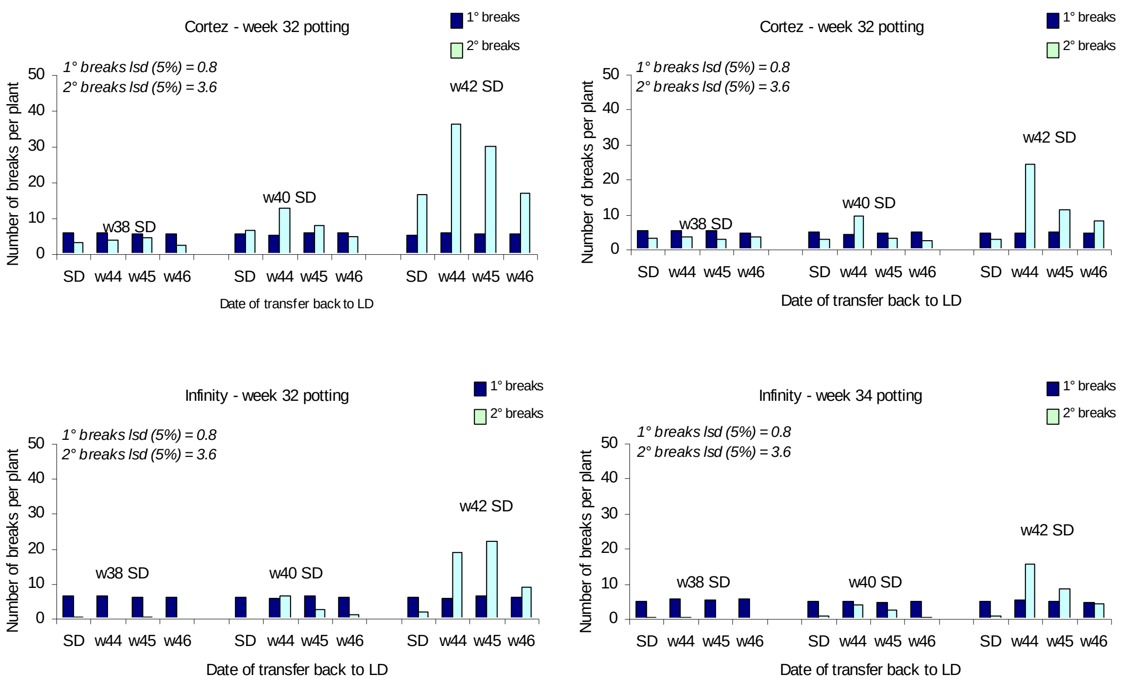
Primary and secondary breaks

The number of primary (1°) breaks per plant was not influenced by transferring plants back to LD after a period of SD.

Transferring plants to LD after a period of SD had a significant influence over the number of secondary breaks produced (figure 24). Trends in response follow those described previously for plant height. That is where plants were transferred to SD in week 38 and given 6-8 weeks of SD, returning to LD conditions had no significant influence over the number of secondary breaks produced. Plants transferred to SD in week 40 produced significantly more secondary breaks if they were returned to LD 4 weeks later but not if they were returned to LD 5 or 6 weeks after the start of SD. Plants transferred to SD in week 42 all produced more secondary breaks when returned to LD 2-4 weeks later with the shorter period in SD resulting in the highest number of secondary breaks.

In the more extreme cases, the extra secondary growth resulting from transferring plants to LD conditions prior to marketing, was detrimental and appeared as grassy growth (see figure 31 below).

Figure 24. Number of primary and secondary breaks per plant measured at marketing.



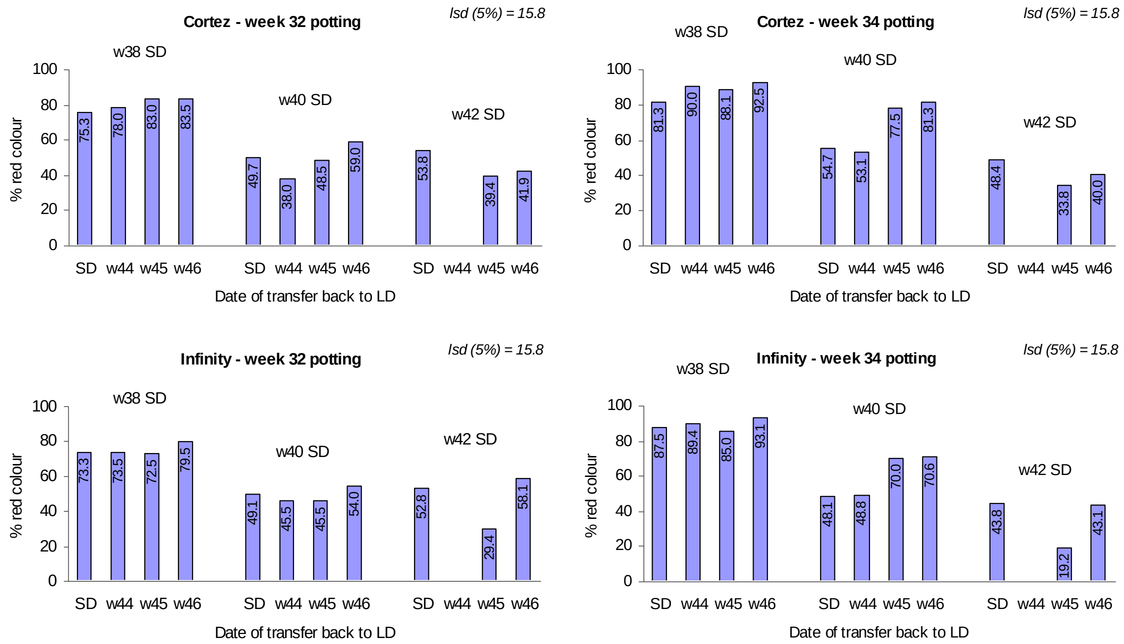
Bract star diameter

Transferring plants back to LD after different periods in SD had no significant influence over the diameter of bract stars, however the design of treatments means that bract star development would also be influenced by the delay resulting from the later transfers into SD and hence a further experiment designed to assess plants at a set stage of bract star development would be required to further evaluate this factor.

% Red colour

In some cases, transferring plants back to LD reduced the %red colour in the top of the plant (figure 25) at final assessment. This effect was found for treatments that were transferred to SD late initially (week 40 and 42) and then returned to LD after a short period of SD (2-4 weeks). Hence plants transferred to SD in week 40 or 42 and returned to LD in week 44 for the former or weeks 44-46 for the latter were delayed as a result of receiving the extra period of LD. In the most extreme case (i.e. week 42 SD and week 44 LD), no red colour had developed by the final assessment date of week 50.

Figure 25. % Red colour measured at marketing.

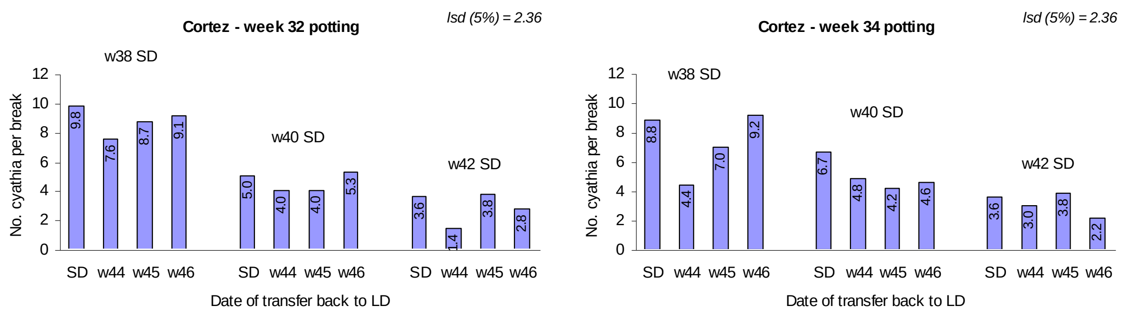


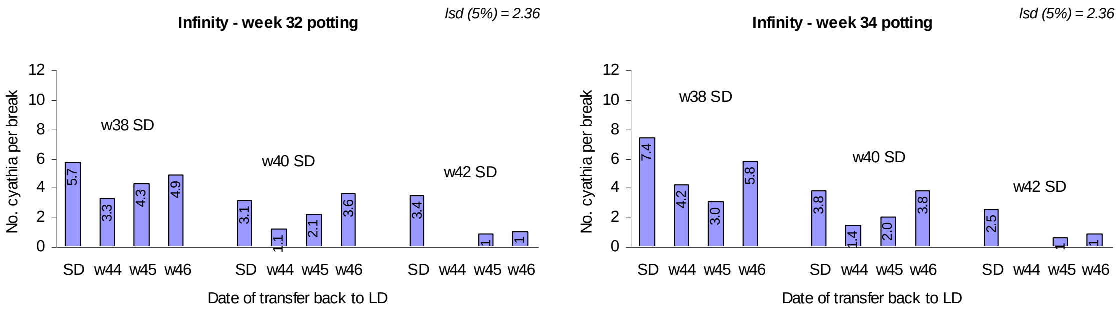
Cyathia number

LD at the end of production had a slight effect on the number of cyathia produced per break (figure 26). There were significantly fewer cyathia on the week 34 potted Infinity plants given SD in week 42 and returned to LD in weeks 44-46. Although mean number of cyathia is smaller for other treatments compared with the relevant treatment maintained in SD through to marketing, these differences were not found to be significant. Hence the latest start to SD (week 42) combined with returning to LD 2-4 weeks later had the greatest affect on the number of cyathia produced.

Returning plants to LD conditions did not influence the stage or size scores for cyathia.

Figure 26. Number of cyathia per break measured at marketing.

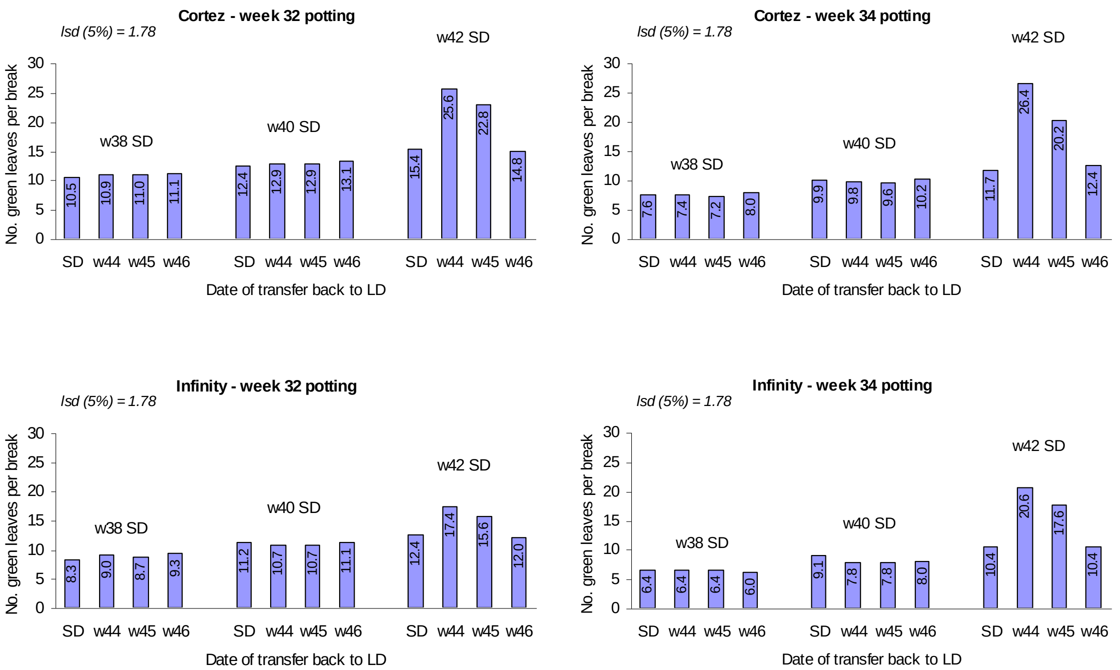




Number of green leaves per break

In accordance with other measures of vegetative growth described previously, returning plants to LD had the greatest effect on the number of green leaves produced per break for plants with the latest start to SD and hence shortest period in SD before returning to LD (figure 27). Plants transferred to SD in week 42 and returned to LD in weeks 44 and 45 had significantly more green leaves per break than plants remaining in SD until marketing.

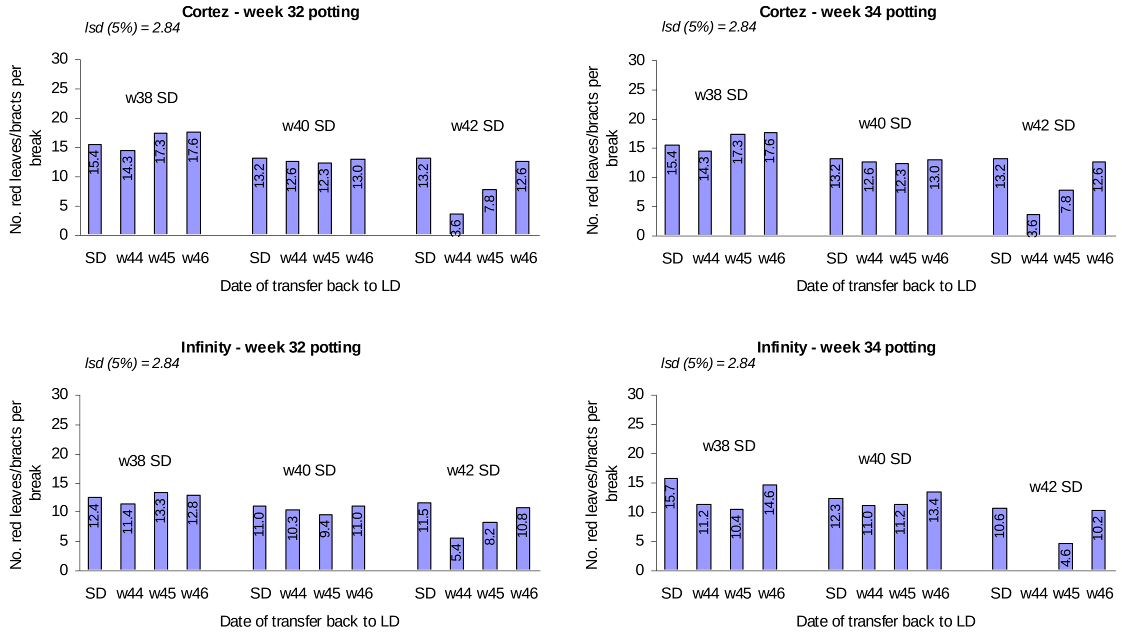
Figure 27. Number of green leaves per break measured at marketing.



Number of red leaves/bracts per break

The delays in plants developing red colour resulting from plants initiated late (i.e. week 42 SD) and returning to LD early (i.e. weeks 44 and 45), resulted in a decrease in the number of red leaves per break (figure 28). In the most extreme case (Infinity week 34 potting), SD in week 42 followed by LD in week 44, no red leaves had developed by the week 50 assessment week.

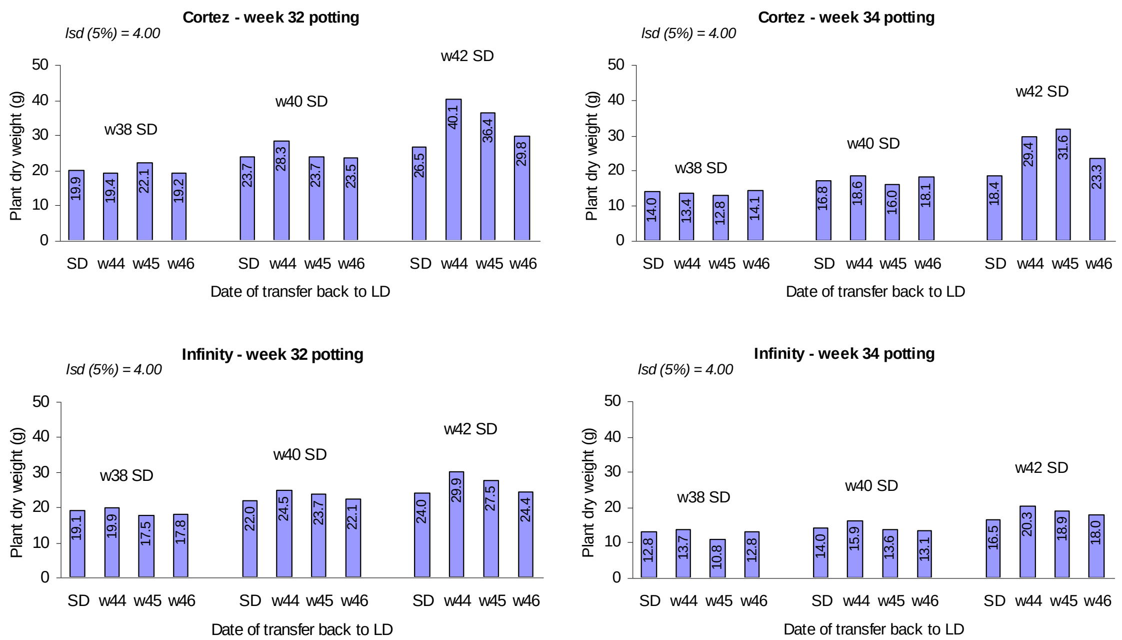
Figure 28. Number of red leaves/bracts per break measured at marketing,



Plant dry weight

The increase in vegetative growth described previously, was sufficient for Cortez to increase plant dry weight (figure 29). Differences in average dry weight for Infinity were not significant which is in accordance with the smaller changes in other factors for this variety, in particular, number of secondary breaks.

Figure 29. Plant dry weight measured at marketing.

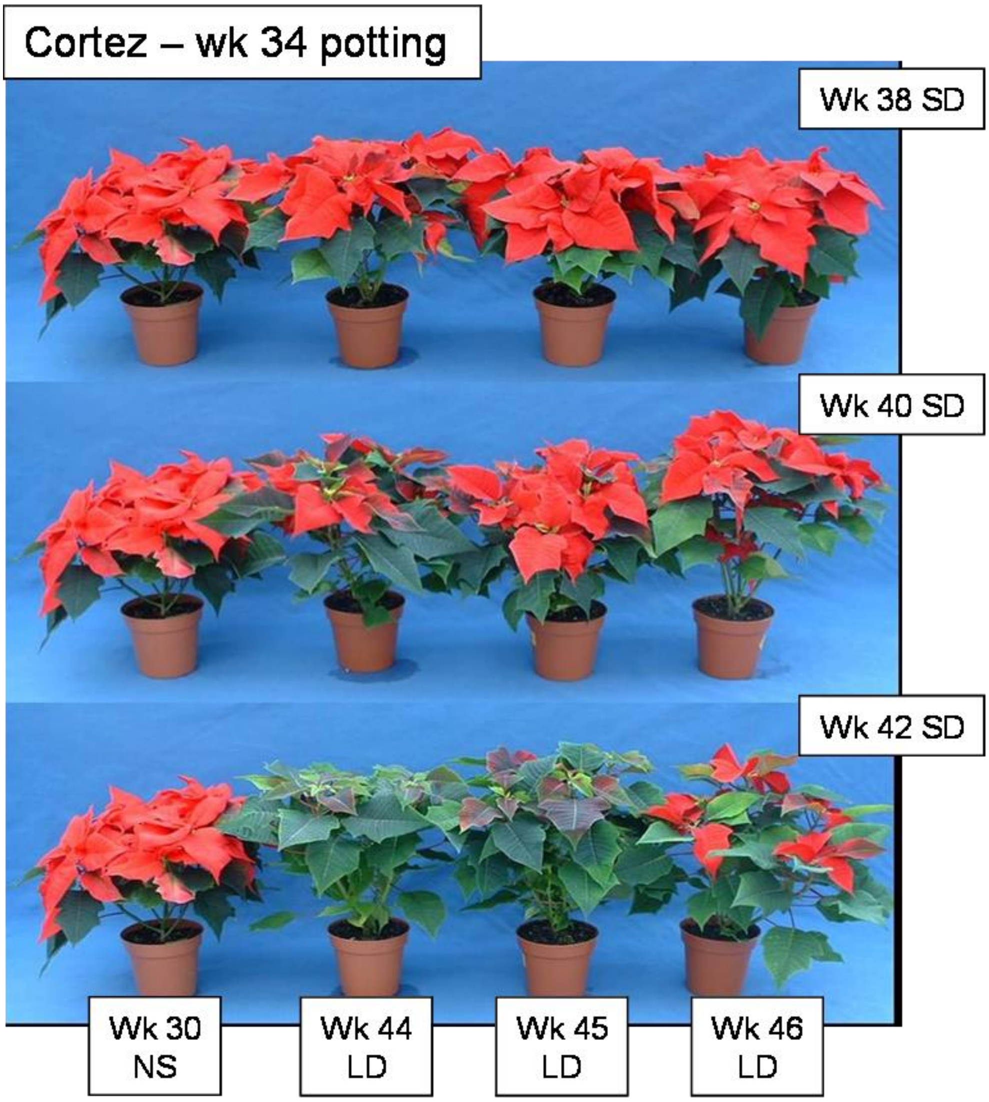


Quality score

Overall quality score was not improved as a result of transferring plants to LD prior to marketing. Scores were lower for delayed plants due to poor colour development by the time of final assessments in week 50, despite achieving a favourable increase in plant canopy.

The photographs presented in figure 30 illustrate how the treatments compare with each other and also with the ‘reference’ treatment (i.e. week 30 potted crop grown without lighting).

Figure 30. Photographic comparison of treatments a, from the week 32 potting and b, from the week 34 potting dates (photographed 06/12/05).



In the more extreme treatments (i.e. week 42 SD and weeks 44-45 LD), the long day lighting apparently switched the plant from generative growth (initiated by the SD) back to vegetative growth (due to the return to LD). This was not only seen in the measurements described previously and also by the production of new green leaves in the centre of the red coloured bract stars (figure 31a and b). In other cases an increase of grassy growth was seen (figure 31c). Hence, returning plants to LD conditions after a period of SD with minimal disruption to flowering with appropriate timing. The extra energy costs relating to a return to LD may not be justified based on the results observed. These observations do suggest however that there may be more flexibility for day length manipulation after the start of SD for poinsettias than one might expect which may be useful if other crops with a LD requirement are moving in to production as poinsettias are being finished.

Figure 31. Quality problems resulting from returning plants to LD too soon after the start of SD: (a and b) Bract stars with new green leaves developing in the centre as a result of returning to LD; (c) Grassy growth at the base of the plant.

<u>Shelf life</u>

A limited number of unreplicated plots were assessed for shelf life performance but no consistent differences were found as a result of providing plants with extra LD prior to marketing.

Mineral analysis

Growing media samples from plants potted in weeks 30, 32 and 34 were analysed. These indicate that despite being potted earlier and therefore having a longer period for growing, the week 30 potted plants of both Cortez and Infinity had higher levels of feed available during the later stages of production (i.e. October and November) than the week 32 and week 34 potted plants. This is illustrated by Ec levels in the growing media (figure 32). Data for the analysis of most major nutrient elements (total N, K, Ca and Mg) reflect this trend in Ec levels, although trends in P concentration were less consistent. Total N data also suggests that growing media from the week 32 potted plants had lower available N than from the week 34 potted plants (figure 33). These trends are less consistent for other elements. Figure 32 also illustrates that total N levels became very low (6-7 mg/l) for the week 32 potted plants from 21st October. This low N level was also visible as pale upper foliage colour as illustrated in figure 34 and affected plants transferred to SD in weeks 41 and 42. Feeding was modified to alleviate this problem as described in section 2.2.2.

Figure 32. Ec measured in samples of growing media during production.

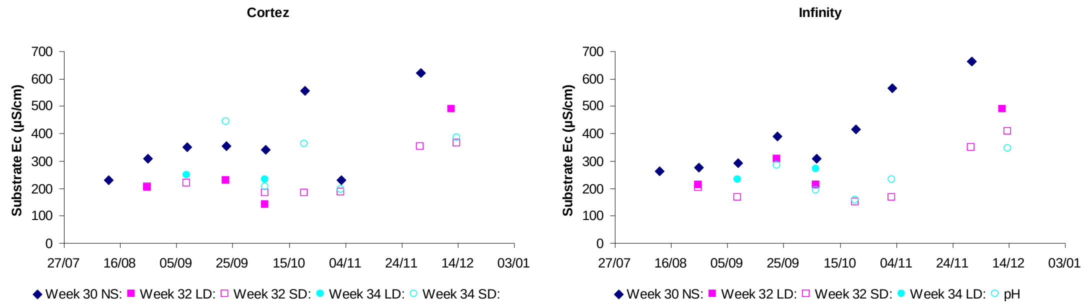


Figure 33. Total N measured in samples of growing media during production.

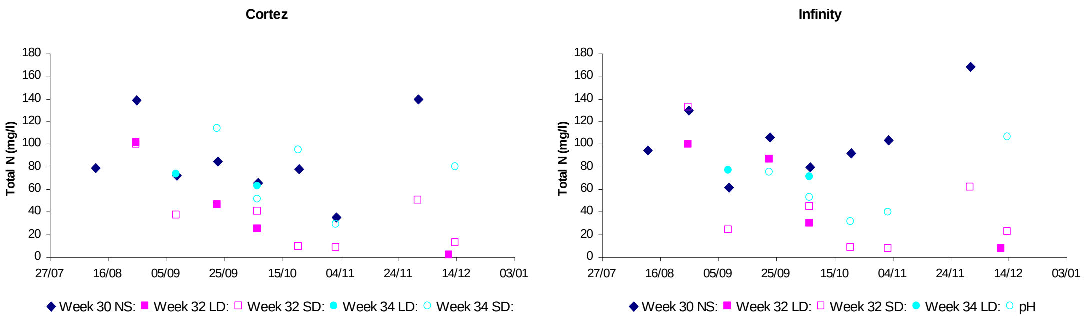


Figure 34. Illustration of the effects of low N levels for plants transferred to SD in week 42 compared with plants transferred to SD in week 38.

Photographed 14/11/05

These data suggest therefore that the late (week 32 and 34) potted plants required higher levels of feed than the week 30 potted plants, and the more vigorous growth of the week 32 potted plants in particular may require additional feed levels to those given to plants grown in conventional natural season production.

Leaf tissue samples were taken for analysis when plants were assessed for marketing (table 4). N concentration was lower for the week 32 potted plants than the week 30 or week 34 potted plants which reflects observations made above on the nutrient analysis of the growing media. The leaf tissue samples were taken 6-8 weeks after the low total N was measured in the growing media, and hence 6-8 weeks after changing the feeding regime to increase N availability and the consequent improvement in foliage colour. The leaf tissue may therefore have had higher N levels at marketing (early to mid December) than they had in October.

Plants potted in week 30 and grown without lighting had higher leaf tissue concentrations of the N, P, Cu, Mn and Zn than plants potted later and grown with lighting. This again may be a consequence of the more vigorous growth of the lit plants, although the delay in initiating plants did not appear to reduce the leaf tissue concentrations of any other elements than N as described previously. Infinity has become known by growers as a variety that requires higher nutrition which is reflected in the leaf tissue analysis data taken at marketing. For example for the major nutrient elements (N, P, K, Ca, Mg) concentrations were 5-15% higher for Infinity than for Cortez. Differences were greater for the minor nutrient elements B and Fe at 20-28%, but there were no consistent differences between the two varieties for the minor elements Mn, Cu or Zn.

Table 4. Data from mineral nutrient analysis of plant tissue harvested when plants were assessed for marketing.

Potting week	Date of transfer to SD	N (%)	Ca (%)	Cl (%)	K (%)	Mg (%)	P (%)	S (%)	Na (%)	B (mg/kg)	Cu (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	Zn (mg/kg)
Infinity														
30	NS	3.9	1.3	1.5	3.1	0.8	0.7	0.4	0.2	25	1.2	138	88	28
32	w38/9	3.8	1.2	1.3	3.1	0.8	0.6	0.4	0.1	22	0.9	92	63	24
32	w41/2	3.6	1.2	1.5	3.5	0.8	0.6	0.4	0.1	23	0.9	83	59	19
34	w38/9	3.9	1.2	1.3	3.1	0.8	0.7	0.4	0.1	24	0.8	81	71	18
34	w41/2	4.1	1.3	1.3	3.2	0.8	0.6	0.4	0.1	23	0.8	86	59	18
Cortez														
30	NS	3.8	1.2	0.8	2.8	0.7	0.7	0.4	0.2	20	1.1	86	75	27
32	w38/9	3.4	1.1	0.9	2.8	0.6	0.5	0.3	0.1	15	0.8	88	62	22
32	w41/2	3.3	1.2	1.1	3.0	0.7	0.5	0.3	0.1	17	0.9	73	59	23
34	w38/9	3.6	1.2	0.9	2.8	0.7	0.6	0.3	0.1	18	0.9	69	62	19
34	w41/2	3.7	1.2	0.9	3.1	0.7	0.6	0.3	0.1	18	0.9	79	59	20

FINANCIAL ANALYSIS

The financial implications of potting poinsettias later and growing them with supplementary lighting were described in PC 208 (annual report 2004).

Factors considered included;

- increased throughput by growing extra crops in the summer in the space made available through late potting and lighting (estimated to be worth approx £2.47/m²)
- increased throughput of poinsettias from the higher densities possible with late potting and lighting (15 pots/m² for late potting compared with 8 pots/m² for natural season production)
- reduced labour inputs to the poinsettia crop through less spacing and lower growth regulation (i.e. spraying) requirements (estimated to be worth £1.04/m²)
- reduced glasshouse costs on the poinsettia crop (given the reduction in growing time)
- lower returns per plant for the late potted lit crop due to the reduction in plant quality (estimated at 30 to 50p per plant less than from natural season production - although

the current project demonstrates that the technique may be manipulated to minimise the loss in quality)

- increased cost of supplying supplementary lighting (see below for more detail on this).

Taking the above factors into account, it was estimated that late potting and lighting (at 9.6 W/m² PAR) would increase the gross margin for production by £4.55 to £7.64 per m² (based on returns of £1.50 to £1.70 per pot) compared with natural season production from a week 30 potting date.

The cost implications in terms of energy use were examined in more detail in the current project as well as ongoing work on how spacing and cycocel applications may be affected.

Logged energy use data from each compartment was used to calculate the total energy use per treatment (table 5). An ultrasonic heat meter measured the heat used in the form of hot water delivered to the greenhouse. To convert this into the amount of gas used a heating system efficiency of 85% was assumed. This represents an efficient, modern hot water heating system. Older systems can have an overall efficiency as low as 65%.

Three main treatments have been highlighted in table 5 which represent the standard week 30 potted reference crop and the late potted treatments moved to SD in week 38 (i.e. treatments that were the most comparable to the reference crop for timing of initiation). These treatments have formed the focus of later calculations to simplify comparisons.

As would be expected, electricity consumption per m² was highest for the late potted treatments due to the use of HID lighting. The longer the period spent in LD lighting the higher the electricity consumption because of the extra hours of lighting given in LD compared with SD as well as the delay to marketing which increased total production time. Gas consumption however was higher for the week 30 natural season crop than the late potted crops (except the week 32 potted crops delayed until week 50 for marketing). The week 30 treatment not only spent the longest period in production, but it also did not benefit from the heating effects of HID lighting.

Table 5. Energy use per m² for the main treatments.

Potting week	SD start week	Energy kWh/m²

		Gas	Electricity
Wk30	NS	66	0
Wk32	38	49	48
Wk32	39	49	50
Wk32	40	48	52
Wk32	41	67	60
Wk32	42	67	63
Wk34	38	46	39
Wk34	39	45	41
Wk34	40	45	44
Wk34	41	65	53
Wk34	42	65	55

Energy use per m² has been further broken down to a unit (i.e. plant) basis by dividing by the density of plants at each stage of production using the information in table 2, section 2.2.1. Data calculated on a per plant basis (table 6) gives a different comparison of energy consumption between treatments than on an area basis as described above. For example, plants potted in week 32 and transferred to SD in week 38 consumed 47% more energy/m² than the reference crop, but when plant density is taken into account, this late potted crop consumed only 13% more energy/plant than the natural season crop. For the week 34 potted crop transferred to SD in week 38, energy consumption per plant was actually less (4.0 kWh) than for the week 30 natural season treatment (5.8 kWh). However, from an energy efficiency / climate change levy point of view it is the amount of fossil fuel used that is important. The efficiency of electricity generation means that 2.6 kWh of fossil fuel are required to produce 1 kWh of electricity. Once this is taken into account, the higher electricity use in the week 34 'std' treatment means that the total fossil fuel energy use increases to 6.4 kWh per plant. Therefore from a fossil fuel energy use and CCL point of view the week 34 'std' treatment actually used 10% more fuel than the week 30 natural season treatment.

Changing spacing from 'standard' to 'close' made only a small difference to the energy consumed (reduced by 0.2 kWh per plant), however this treatment does have potential to save on labour inputs since fewer pot moves were associated with the close spacing treatments.

Table 6. Energy use for plants moved to SD in week 38 at different spacings compared with the natural season reference crop.

	Gas – kWh/plant	Electricity – kWh/plant
Week 30	5.8	n.a.
Week 32 standard	4.2	2.4

Week 34 standard	2.5	1.5
Week 32 close	4.1	2.3
Week 34 close	2.4	1.4

Energy use data has been converted to cost assuming a gas price of 2.0p/kWh and an electricity price of 6.0p/kWh (table 7) and the energy input costs per m² are higher for the late potted treatments due to the use of HID lighting.

Table 7. Total energy cost per m^2.

	Energy £/m²		
	Gas	**Electricity**	**Total**
Week 30 natural season	1.33	0.00	1.33
Week 32 SD week 38	0.98	2.85	3.83
Week 34 SD week 38	0.91	1.97	2.88

Energy cost per m² is a common way of assessing the financial impact of different treatments on production costs. However, the lower plant densities used for the week 30 crop in particular has a marked impact on the cost per plant produced (table 8). Against a benchmark figure of £0.12 per plant for the natural season (no supplementary lighting) treatment, the week 34 'std' treatment is the most competitive at £0.14 per plant. Whereas the week 32 'std' treatment which combined 2 weeks more energy consumption and lower densities resulted in a cost per plant of £0.33 (135% more).

Table 8. Total energy cost per plant.

	Energy £/plant		
	Gas	**Electricity**	**Total**
Week 30 natural season	0.12	n.a.	0.12
Week 32 SD wk 38 'std'	0.08	0.25	0.33
Week 34 SD wk38 'std'	0.05	0.09	0.14
Week 32 SD wk38 'close'	0.08	0.14	0.32
Week 34 SD wk38 'close'	0.05	0.09	0.14

These energy costs assume that it is practical to fill the greenhouse completely at each density and that 100% of the greenhouse area is utilised. This means that each time the density is reduced some plants have to be removed to release additional space and moved to another production area. In many cases, especially when the crop is grown on the floor, the plants are grown close together but only occupy 30% of the floor space at the first spacing after rooting. In this situation the cost per pot is equal to the cost per m² divided by the final plant density. To fully realise the potential of late potting combined with supplementary lighting, detailed planning of space use would be required with unused space put into productive use as extensively as possible. This is the principle behind the late potting plus lighting work, and assuming productive use can be made of the space available prior to potting a predicted £10K per acre may be generated (PC 208).

It should be noted that these figures do not take account of the capital, operating and maintenance costs of a supplementary lighting installation. This is highly site dependent as it is unlikely that supplementary lighting will just be used for poinsettia production. Growers should factor this in to any detailed costing that they carry out.

Of further note is the impact of efficient use of glasshouse space on the cost per plant produced. Historically labour costs have been the driving factor behind cropping plans. However, in the current era of high energy costs the potential savings in energy cost could contribute significantly to the payback on investments which allow more plants to be grown in a given area of greenhouse.

All treatments in 2005 were grown in compartments enriched with CO_2. Pure CO_2 was added to a target level of 1000 ppm when vents were closed, ramping down to 350 ppm when vents were 10% or more open. This is a departure from previous work carried out for project PC 208 on a commercial nursery where no CO_2 was used. The amount of CO_2 used was monitored throughout the experiment, and while a comparison of treatments with and without CO_2 enrichment was outside of the remit of this project, this data can be used to give an indication of the likely cost implications.

The week 30 potted reference treatment used a total of 2.0 Kg per m^2 of pure CO_2 over the whole production period. The cost of CO_2 enrichment varies with the method used but assuming the most expensive method of enrichment (pure CO_2, £80/tonne), costs would be around £0.16/m^2.

The differences in quantity of CO_2 required for enrichment in the late potted, lit compartments ranged from 90% to 123% of that used in the reference compartment.

Cycocel applications were monitored for all treatments during production. Whilst plants were not above the track for plant height during production, cycocel was applied frequently at low rates in order to maintain plant shape. This meant that the natural season crop received a total of 25 applications during production whilst the week 32 potted crop received 27 applications and the week 34 potted crop received 23 applications (appendix 1, table 10).

Hence there was only a small labour saving on growth regulator applications for the week 34 potted crop and labour increased slightly for the week 32 potted crop.

DISCUSSION

Late potting combined with supplementary lighting

Later potting shortens the time available for the poinsettia to grow vegetatively and develop a reasonable size and shape before it is initiated to produce generative growth (i.e. cyathia and also develop coloured leaves and bracts). Using supplementary lighting on plants potted later than normal is designed to increase the production of vegetative growth via photosynthesis, and enrichment with CO_2 would be expected to enhance this process further. Parameters that indicate the extent of vegetative growth including height, spread, number of green leaves produced per bract and dry weight all demonstrated that it is feasible to pot later than week 30 and compensate for the reduction in growing time. It should be noted that plant height was short overall in 2005, that is the standard week 30 crop was slightly (1-2cm) below the track from the end of October and finished at an average height of 24cm (compared with height specification from different retailers of 23-25cm for minimum height). Whilst only just within the minimum specification for height for some treatments (i.e. those potted in week 34 and transferred to SD in weeks 38/39) late potted plants were at least not significantly shorter than the standard week 30 potted crop.

Growth patterns of late potted lit crops may be expected to deviate from those expected for standard production as included in the data used by the 'Tracker' software available from HDC. Weekly height records have been kept as part of the ongoing monitoring of treatments and this data may be useful in guiding growers who try out growing late potted plants with supplementary lighting. These records will be supplemented in year 2 of the project.

With a 'normal' initiation date (i.e. transferring plants to SD in week 38), plants potted in week 32 had at least equivalent vegetative growth to the standard week 30 potted crop. Plants potted in week 34 however were slightly smaller than the standard week 30 potted crop if initiated in week 38. This in itself may not be a problem if meeting the minimum specification is the target for production. If further improvements in quality are required however, delaying the start of SD up to week 40 was suitable to achieve sufficient colour for Christmas marketing whilst providing extra time for vegetative growth which improved quality.

One implication of the extra vegetative growth resulting from the delay in initiating flowering was that the feeding regime used was based on commercial production where SD started around the date of the equinox. Plants maintained in LD conditions with supplementary lighting for 20 hours per day required higher nutrient levels than those already initiated and only being lit for 11 hours per day. This problem was noted through the visible paling of leaf colour of plants held in LD until weeks 41 and 42. Mineral analysis verified that the paling was a result of low nutrient (in particular N) and as a result the feeding strategy was modified. However it is unclear if this shortage of nutrient may have limited the vegetative growth produced. In year 2, feeding will be modified to prevent these shortages occurring and determine if more vegetative growth will be produced as a result. Growers testing late potting combined with HID lighting should therefore ensure that feeding strategy is suitably modified.

Delaying the start of SD to weeks 41 and 42 delayed the development of colour to the extent that it was decided not to assess these treatments in week 48 as originally planned. Colour development had increased by week 50, when the delayed assessments were made, such that the plants would have been suitable for marketing (50-75% red colour). It may be anticipated that majority of product available for sale in week 50 would be noticeably advanced in colour development. At best this may mean the delayed crop stands out as looking fresher and with more potential to last well, but at worst it may inhibit sales. Certainly the greater the delay in starting SD, the greater the benefits in terms of the structure of plant produced. The split in assessment times has however created complications in interpreting the data since plants transferred to SD in weeks 41 and 42 had an extra 2 weeks to grow prior to assessment. Problems of assessment also extend to shelf life since plants with more delay at the start of shelf life were at a different stage of development than those with no delay (i.e. week 30 potting and late potting combined with a start to SD in week 38).

The first year of this project was designed to screen a number of treatments which limited the size of plot available for any one treatment combination. This limited the number of plants available for assessment and hence the ability to assess treatments for effects on uniformity which may be expected to suffer as vegetative growth increases. This will be addressed in year 2 when a more focussed set of treatments will be evaluated in larger plots providing more material on which to evaluate uniformity.

The idea of late potting is to increase annual nursery turn over by allowing extra production of other crops before the start of poinsettia production, and this was estimated in PC 208 to be worth around £10K per acre (approx £24K per hectare). Late potting will only be worthwhile if the increased cost in production is worth less than the estimated increase from extra production. Costing is always unique to each nursery but energy monitoring in the experimental compartments used, provides an indication of how the treatments compare with each other. These calculations suggest that the energy costs per plant for ‘normal’ production (week 30 potting without HID lighting) were 12p per plant compared with 14p per plant if potted in week 34 and transferred to SD in week 38 and 33p per plant if potted in week 32 and transferred to SD in week 38.

<u>Plant spacing</u>

Plant spacing treatments focussed on increasing available space at the start of production and reducing labour by minimising handling (i.e. reducing the number of times pots were spaced). This was achieved by keeping plants at pot thick for longer than the ‘standard’ treatment but then moving plants directly to 15 pots/m² rather than moving through an intermediate spacing of 30 pots/m². Subsequent spacing was then managed according to plant demands and the standard and close spacing treatments were grown at the same densities for the latter stages of production. Closer spacing had little impact on the parameters assessed either at marketing or in shelf life. The main differences were an increase in height and a slight reduction in plant spread. The more vigorous week 32 potted plants were affected by the spacing treatments more than the less vigorous week 34 potted plants, and in fact despite been grown closer together for longer initially, the close spaced week 32 potted plants required the same spacing as the week 32 standard spacing plants in the later stages of production.

Although closer spacing (and therefore more throughput per m²) decreases production costs per plant, the savings on energy costs were small (1p per pot). This is largely because the spacing treatments focussed on keeping plants closer together in the early stages of production rather than throughout production. An additional financial benefit of closer spacing would be labour savings due to the reduction in spacings used, but this figure would be very variable on different nurseries and hence not practical to include in the financial analysis presented in this report.

As mentioned previously, the high number of treatments included in the trial in 2005 precluded the use of large plots. Whilst extra guarding was used around the close spaced plants, there was insufficient material to test for uniformity which may be expected to decrease as a result of greater competition for space. It is intended to examine spacing further in 2006 using larger plots in order to assess uniformity better.

Returning plants to LD lighting after different periods in SD

The use of long day lighting close to the marketing period is counter intuitive for a crop which has a very specific marketing window and which is carefully protected from light spill in case of delays. These treatments were however considered worth a preliminary investigation based on the positive results achieved with pot chrysanthemums in the past (PC 92b).

Interesting effects were achieved as a result of these transfer treatments. Firstly, if plants had received ‘sufficient’ SD (6-8 weeks) they continued to develop without any outward signs of disruption to flowering or the development of red colour. In this situation however the LD lighting had no influence over vegetative parameters measured or the visual intensity of colour development (either green or red leaves). One reason for this may be that, although 9 hours of extra light were received per day, the intensity used remained the same, whereas in PC 92b the extra lighting given was at a higher intensity over a fixed length of day (11 hours). Since the extra period of lighting required to give LDs increases energy consumption, the treatments appear unjustified from this preliminary investigation. These observations do suggest however that there may be more flexibility for day length manipulation after the start of SD for poinsettias than one might expect which may be useful if other crops with a LD requirement are moving in to production as poinsettias are being finished.

Returning plants to LD conditions had the greatest impact if it was done after only a short period of SD (2-4 weeks) when the non-inductive conditions delayed colour development. The extra light provided (i.e. up to an extra 9 hours of HID lighting at 10 W/m^2) increased vegetative growth and delayed red colour development, to the extent that some treatments were still green in week 50. Cyathia already developed to a visible size under inductive conditions appeared to continue normally under non-inductive conditions (as measured by scores of size and stage of development). However plants transferred to LD did suffer a reduction in cyathia number, which may have been because cyathia initiation was disrupted by the LD lighting. Although these treatments did increase vegetative growth and delay flowering there were no apparent improvements in green leaf colour, possible reasons for this are outlined above. It was not possible to assess if the increase in vegetative growth would have eventually resulted in an improvement in intensity of red colour development since this took the stage of marketing assessment beyond the Christmas marketing period.

Since treatments combined start of SD date with date of return to LD a true comparison of length of SD period prior to returning to LD can not be made because plants in these experiments were at different stages of development when the extra LD lighting treatments commenced. From the range of treatments compared however, with plants from two potting dates, 6 to 8 weeks of SD given before returning plants to LD for up to 4 weeks prior to marketing did not disrupt any visible signs of flowering or development of red colour. In contrast 2-4 weeks of SD prior to returning to LD lighting may be expected to increase vegetative growth at the expense of delaying flowering.

In these comparisons, all plants had been lit and so were benefiting from higher than ambient light levels. Transferring unlit plants for finishing under HID lamps or increasing the intensity of HID lighting may have a greater effect on colour development.

Returning plants to LD lighting near to marketing had no consistent effects on the rate of deterioration of plants in shelf life. In similar experiments with pot chrysanthemum, rate of deterioration of plant quality was also not influenced by the provision of extra lighting prior to marketing. However the extra lighting had improved colour development, and this was maintained throughout the shelf life period providing better overall quality. As noted above, the results from treatments in this experiment may be confounded by the need to assess Poinsettias in the normal period for Christmas marketing and hence further work based on the results of these experiments would be required to evaluate more fully how LD lighting at the end of production may improve quality.

CONCLUSIONS

Late potting can produce marketable Poinsettias for the Christmas market when supplementary lighting and CO_2 enrichment are used.

Potting in week 32 produced larger and better quality plants than potting in week 34.

Delaying initiation of late potted plants (by giving LD using HID lighting) increased vegetative growth but also delayed flowering.

Starting SD by week 40 was necessary to produce sufficient red colour development for marketing in week 48, but delaying SD until week 41 produced sufficient red colour for a week 50 market.

The extra vegetative growth associated with extra LD lighting requires attention to feeding regimes to prevent nutrient depletion from more vigorous growth than would be expected from around the middle of October. Care would then be required not to over feed once plants transfer to SD conditions.

Providing productive use can be made of the extra space made available, provisional financial analysis suggests late potting combined with lighting may be economically feasible. Potting in week 34 was the most competitive treatment compared with the standard crop potted in week 30.

Late potted plants were also grown at closer spacing for a longer period and could be spaced less frequently with little impact on the final product. Closer spacing gave little benefit in terms of the energy costs required to produce a pot, but would have a financial benefit in terms of saving labour.

Returning plants to LD delayed colouring up and increased vegetative growth if only 2-4 weeks of SD had been previously given, however with 6-8 weeks of initial SD, return to LD had negligible effect on final quality above those already achieved with lighting late potted crops as part of the main experiment.

TECHNOLOGY TRANSFER

HDC Poinsettia and Cyclamen Open Day at Warwick HRI Wellesbourne 22nd November 2005.

HDC Poinsettia and Cyclamen Open Day at Warwick HRI Kirton 25th January 2006.

Shaddick, C. (2006) Poinsettia Pointers, HDC News, 121 20-22.

Appendix 1. Summary of key agronomic treatments

Table 9. General agronomy.

Wk 30 plants:

28/07/06	Potted
10/08/05	Pinched Infinity to 6-7 leaves and Cortez to 9 leaves
20/08/05	Re-pinched Cortez to 6-7 leaves
01/09/05	Plants spaced to 30 pots/m²
	Cycocel started as a light spray to even up shoot extension (see table 10 for details of applications)
13/09/05	Spaced plants to12 pots/m²
	Increased cycocel rate to 1.5 ml/l
29/09/05	Spaced plants to 9 pots/m²
28/11/05	Marketing records started

Wk 32 plants:

11/08/05	Infinity potted
12/08/05	Cortez potted
05/09/05	Cycocel started as a light spray to even up shoot extension (see table 10 for details of applications)
08/09/05	Pinched plants to 6-7 leaves
20/09/05	Spaced standard treatment plants to 30 pots/m²
29/09/05	Spaced standard treatment plants to 15 pots/m²
06/10/05	Spaced close treatment plants to 15 pots/m²
25/10/05	Spaced standard and close treatment plants to 12 pots/m²
10/11/05	Spaced standard and close treatment plants to 9 pots/m²
28/11/05	Marketing records started

Wk 34 plants:

05/09/05	Potted
16/09/05	Cycocel started as a light spray to even up shoot extension (see table 10 for details of applications)
19/09/05	Pinched plants to 6-7 leaves
03/10/05	Spaced standard treatment plants to 30 pots/m²
21/10/05	Spaced standard treatment plants to 15 pots/m²
03/11/05	Spaced close treatment plants to 15 pots/m²
28/11/05	Marketing records started

Table 10. Cycocel use.

Date	Week 30		Week 32		Week 34	
	Cortez	Infinity	Cortez	Infinity	Cortez	Infinity
01/09/2005	1.00	1.00				
02/09/2005	1.00	1.00				
05/09/2005	1.00	1.00	1.00	1.00		
08/09/2005	1.00	1.00				
13/09/2005	1.00	1.00	1.00	1.00		
15/09/2005	1.50	1.50	1.00	1.00		
16/09/2005	1.50	1.50	1.00	1.00	1.00	1.00
19/09/2005	1.50	1.50	1.00	1.00		
21/09/2005	1.50	1.50	1.00	1.00	1.00	1.00
23/09/2005	1.50	1.50	1.00	1.00	1.00	1.00
26/09/2005	1.50	1.50	1.00	1.00	1.00	1.00
28/09/2005	1.50	1.50	1.00	1.00	1.00	1.00
30/09/2005	1.50	1.50	1.50	1.50	1.00	1.00
03/10/2005	1.50	1.50	1.50	1.50	1.00	1.00
05/10/2005	1.50	1.50	1.50	1.50	1.00	1.00
07/10/2005	1.50	1.50	1.50	1.50	1.00	1.00
10/10/2005	1.50	1.50	1.50	1.50	1.00	1.00
12/10/2005	1.00	1.00	1.50	1.50	1.00	1.00
14/10/2005	1.00	1.00	1.50	1.50	1.00	1.00
17/10/2005	1.00	1.00	1.50	1.50	1.00	1.00
19/10/2005	1.00	1.00	1.50	1.50	1.00	1.00
21/10/2005	1.00	1.00	1.50	1.50	1.00	1.00
24/10/2005	0.25	0.25	1.50	1.50	1.00	1.00
26/10/2005	0.25	0.25	1.50	1.50	1.00	1.00
28/10/2005	0.25	0.25	1.00	1.00	1.00	1.00
31/10/2005			1.00	0.75	1.00	0.75
02/11/2005			1.00	0.75	1.00	0.75
04/11/2005			1.00	0.75	1.00	0.75
07/11/2005			1.00	0.50	1.00	0.50
09/11/2005			1.00	0.50	1.00	0.50
Total no. applications	***25***	***25***	***27***	***27***	***23***	***23***
Sum of rates applied	***28.75***	***28.75***	***33.00***	***31.25***	***23.00***	***21.25***

IPM Details:

Steinernema drench for sciarid control – 4 applications from 09/08/05 to 14/09/05.

Amblyseius cucumeris for thrips control – weekly from 09/08/05 to monthly from the end of September.

Phytoseiulus for red spider mite control – every 2 weeks from 09/08/05.

Encarsia for whitefly control – weekly from 16/08/05.

Sprayed with Sythane 20 EW at 0.45 ml/l on 06/10/05 as a preventative against powdery mildew.

Vent and pipe settings used for control of humidity below 85%.

Environmental control:
27/07/05
21°C day 19°C night, vent +2°C.
Shade screens on 350 W/m² for weaning plants.
Blackouts on dusk to dawn for energy saving.
CO_2 enrichment to 1000vpm during day* time when vents closed ramping down to 350 vpm when vents 10% open.
Influences to control humidity:

- vent temperature ramped down as humidity increased above 85% by 0.5°C per 5% rise in RH;
- pipe heat of 35°C introduced at 88% RH ramping up by 2°C per 2% subsequent increase in RH;
- at night blackout gapping was used to a maximum 4% gap at when RH exceeded 85%.

** dusk to dawn in unlit compartments or 01:00-21:00 where HID lighting set for long days and 6:30 – 17:30 when HID lighting set for short days.*

10/08/05
Started HID lighting in all late potted treatments (01:00 - 21:00) at 10 W/m² on a threshold of 200 W/m².

12/09/05
Started temperature integration settings as follows:

- 21°C day set point and 19°C night set point;
- temperature allowed to fall to 15°C from 09:00 to 06:00 and to 13°C from 06:00 to 09:00 (i.e. when a DROP treatment might be used);
- three day integration period used;
- vent set to 26°C day and night;
- humidity influences retained.

22/09/05

Started second HID lighting programme to give short days (06:30 – 17:30) at 10 W/m² on a threshold of 200 W/m².

Lowered heating set points to 19°C day and night.

30/09/05

Reduced vent set point to 24°C to reduce 24 hour temperature

03/10/05

Reduced vent set point to 22°C to reduce 24 hour temperature

11/10/05

Vent set point reduced to 21°C when blackouts closed (dusk) and lights on in LD compartment to prevent heat build up from lighting under screens. Turned off temperature gapping of the black out in the SD compartments.

09/11/05

Increase vent set points to 25°C as fewer temperature credits were being accumulated.

Appendix 2. Mineral analysis data

Table11. Leaf tissue mineral analysis data for Cortez.

	Date of sample							
Week 30 NS:	**12/08**	**26/08**	**09/09**	**23/09**	**07/10**	**21/10**	**03/11**	**01/12**
pH	6.1	5.6	5.8	6.1	6.0	6.2	6.7	6.2
Conductivity µS/20°C	228	305	348	352	339	552	227	618
Total N (mg/l)	78	138	72	84	65	77	35	139
Potassium (mg/l)	72	93	47	112	75	128	86	196
Calcium (mg/l)	52	123	116	88	98	230	33	201
Magnesium (mg/l)	31	68	50	31	35	81	11	97
Phosphorus (mg/l)	13.7	8.7	7.1	7.3	9.2	8.1	3.0	6.2
Iron (mg/l)	0.7	1.0	0.7	0.8	0.5	0.7	0.3	0.3
Zinc (mg/l0	0.2	0.4	0.1	0.2	0.1	0.2	0.0	0.3
Manganese (mg/l)	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Copper (g/l)	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Boron (mg/l)	0.1	0.0	0.2	0.3	0.3	0.4	0.3	0.3
Sodium (mg/l)	79	138	147	197	179	168	150	265
Chloride (mg/l)	36	88	74	127	47	164	60	195
Sulphur (mg/l)	58	104	106	90	119	222	49	214

	Date of sample			
Week 32 LD:	**26/08**	**23/09**	**07/10**	**12/12**
pH	5.9	5.9	6.1	6.2
Conductivity µS/20°C	198	223	137	485
Total N (mg/l)	101	45	24	0
Potassium (mg/l)	86	72	33	12
Calcium (mg/l)	64	51	21	147
Magnesium (mg/l)	29	24	9	85
Phosphorus (mg/l)	12.1	7.9	6.9	2.7
Iron (mg/l)	1.5	0.6	0.4	0.5
Zinc (mg/l0	0.3	0.2	0.0	0.2
Manganese (mg/l)	0.1	0.0	0.0	0.0
Copper (g/l)	0.1	0.0	0.0	0.0
Boron (mg/l)	0.0	0.1	0.2	0.2
Sodium (mg/l)	94	121	108	295
Chloride (mg/l)	42	54	16	197
Sulphur (mg/l)	59	62	37	269

	Date of sample						
Week 32 SD:	**26/08**	**09/09**	**07/10**	**21/10**	**03/11**	**01/12**	**14/12**
pH	5.8	5.9	6.0	6.3	6.4	6.3	6.3
Conductivity µS/20°C	202	214	178	179	181	349	362
Total N (mg/l)	98	36	39	9	7	49	11
Potassium (mg/l)	79	61	41	32	43	81	37
Calcium (mg/l)	52	54	30	38	44	98	82
Magnesium (mg/l)	23	26	12	16	17	50	45
Phosphorus (mg/l)	11.2	8.3	8.6	3.8	6.2	4.4	2.5
Iron (mg/l)	1.0	0.6	0.4	0.4	0.4	0.4	0.4
Zinc (mg/l0	0.2	0.1	0.1	0.1	0.2	0.4	0.3
Manganese (mg/l)	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Copper (g/l)	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Boron (mg/l)	0.0	0.1	0.2	0.3	0.3	0.2	0.2
Sodium (mg/l)	90	84	125	122	115	204	255
Chloride (mg/l)	37	40	22	30	45	105	155
Sulphur (mg/l)	51	53	44	76	74	152	173

Week 34 LD:	Date of sample 09/09	07/10
pH	5.9	5.8
Conductivity µS/20°C	245	229
Total N (mg/l)	72	62
Potassium (mg/l)	30	55
Calcium (mg/l)	87	69
Magnesium (mg/l)	38	28
Phosphorus (mg/l)	6.6	10.1
Iron (mg/l)	0.3	0.7
Zinc (mg/l0	0.1	0.2
Manganese (mg/l)	0.1	0.0
Copper (g/l)	0.1	0.0
Boron (mg/l)	0.0	0.1
Sodium (mg/l)	70	106
Chloride (mg/l)	31	17
Sulphur (mg/l)	54	75

	Date of sample					
Week 34 SD:	23/09	07/10	21/10	03/11	14/12	14/12
pH	5.8	6.0	6.2	6.4	6.2	6.4
Conductivity µS/20°C	439	203	358	193	380	361
Total N (mg/l)	113	50	94	28	79	33
Potassium (mg/l)	113	68	107	72	102	56
Calcium (mg/l)	175	49	128	53	129	119
Magnesium (mg/l)	72	17	43	16	65	54
Phosphorus (mg/l)	12.4	10.9	6.8	8.2	6.0	3.3
Iron (mg/l)	1.0	0.5	0.4	0.5	0.4	0.4
Zinc (mg/l0	0.3	0.0	0.1	0.1	0.2	0.1
Manganese (mg/l)	0.1	0.0	0.0	0.0	0.0	0.0
Copper (g/l)	0.0	0.0	0.0	0.0	0.0	0.0
Boron (mg/l)	0.1	0.2	0.4	0.3	0.2	0.2
Sodium (mg/l)	138	112	142	110	148	184
Chloride (mg/l)	91	25	67	34	81	113
Sulphur (mg/l)	140	59	107	68	152	168

Table 12. Leaf tissue mineral analysis data for Infinity.

	Date of sample							
Week 30 NS:	12-Aug	26-Aug	09-Sep	23-Sep	07-Oct	21-Oct	03-Nov	01-Dec
pH	6.2	5.7	5.8	5.9	6.1	6.3	6.2	6.2
Conductivity µS/20°C	260	274	289	387	306	413	564	660
Total N (mg/l)	94	129	61	105	79	91	103	167
Potassium (mg/l)	75	92	46	132	84	133	155	205
Calcium (mg/l)	68	121	90	114	84	148	214	238
Magnesium (mg/l)	39	65	39	35	26	53	85	100
Phosphorus (mg/l)	15.7	12.2	7.7	10.6	12.1	9.1	8.3	7.2
Iron (mg/l)	0.8	1.6	0.4	1.0	0.4	0.3	0.4	0.3
Zinc (mg/l0	0.2	0.2	0.2	0.3	0.1	0.1	0.1	0.2
Manganese (mg/l)	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Copper (g/l)	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1
Boron (mg/l)	0.1	0.0	0.2	0.3	0.5	0.4	0.4	0.3
Sodium (mg/l)	73	129	138	191	162	129	196	253
Chloride (mg/l)	37	77	68	90	36	99	124	170
Sulphur (mg/l)	66	88	80	103	81	122	212	235

Week 32 LD:	Date of sample 26-Aug	23-Sep	07-Oct	12-Dec
pH	5.8	5.8	6.1	6.36
Conductivity µS/20°C	209.5	303.1	209.4	485.3
Total N (mg/l)	98	85	29	7
Potassium (mg/l)	84	109	25	25
Calcium (mg/l)	67	83	43	173
Magnesium (mg/l)	31	42	21	88
Phosphorus (mg/l)	11	12	7	3
Iron (mg/l)	1.7	0.9	0.4	0.4
Zinc (mg/l0	0.2	0.2	0.0	0.4
Manganese (mg/l)	0.1	0.1	0.0	0.0
Copper (g/l)	0.1	0.0	0.0	0.1
Boron (mg/l)	0.0	0.1	0.1	0.2
Sodium (mg/l)	100	129	148	345
Chloride (mg/l)	37	70	20	149
Sulphur (mg/l)	53	89	71	349

Week 32 SD:	Date of sample 26-Aug	09-Sep	07-Oct	21-Oct	03-Nov	01-Dec	14-Dec
pH	5.8	5.9	6.1	6.5	6.4	6.4	6.5
Conductivity µS/20°C	197	162	210	148	164	344	405
Total N (mg/l)	132	23	43	7	6	61	21
Potassium (mg/l)	85	53	48	27	15	92	39
Calcium (mg/l)	74	36	42	25	27	97	103
Magnesium (mg/l)	34	17	16	11	11	48	59
Phosphorus (mg/l)	12.5	7.5	9.5	3.8	2.4	3.6	3.0
Iron (mg/l)	1.0	0.6	0.4	0.4	0.3	0.3	0.4
Zinc (mg/l0	1.0	0.1	0.0	0.0	0.1	0.2	0.2
Manganese (mg/l)	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Copper (g/l)	0.1	0.1	0.0	0.0	0.0	0.1	0.1
Boron (mg/l)	0.0	0.1	0.2	0.3	0.1	0.2	0.2
Sodium (mg/l)	104	69	145	113	141	199	268
Chloride (mg/l)	51	30	20	9	34	87	125
Sulphur (mg/l)	64	36	55	54	68	152	219

Week 34 LD:	Date of sample 09-Sep	07-Oct
pH	5.9	5.8
Conductivity µS/20°C	229.4	268.6
Total N (mg/l)	76	70
Potassium (mg/l)	26	61
Calcium (mg/l)	87	93
Magnesium (mg/l)	37	34
Phosphorus (mg/l)	6	11
Iron (mg/l)	0.3	0.4
Zinc (mg/l0	0.1	0.0
Manganese (mg/l)	0.1	0.0
Copper (g/l)	0.0	0.0
Boron (mg/l)	0.1	0.1
Sodium (mg/l)	76	111
Chloride (mg/l)	31	24
Sulphur (mg/l)	48	93

Week 34 SD:	Date of sample 23-Sep	07-Oct	21-Oct	03-Nov	14-Dec	14-Dec
pH	5.8	6.0	6.1	6.1	6.2	6.4
Conductivity µS/20°C	281	190	152	229	341	326
Total N (mg/l)	74	51	30	39	105	59
Potassium (mg/l)	82	54	48	68	103	83
Calcium (mg/l)	99	51	43	71	129	103
Magnesium (mg/l)	42	17	13	26	56	44
Phosphorus (mg/l)	9.9	10.2	6.0	8.9	6.2	3.8
Iron (mg/l)	0.7	0.4	0.3	0.4	0.3	0.4
Zinc (mg/l0	0.2	0.2	0.2	0.2	0.1	0.2
Manganese (mg/l)	0.1	0.0	0.0	0.0	0.0	0.0
Copper (g/l)	0.0	0.0	0.0	0.0	0.1	0.1
Boron (mg/l)	0.0	0.2	0.2	0.2	0.2	0.3
Sodium (mg/l)	98	97	75	104	129	180
Chloride (mg/l)	51	9	0	29	64	92
Sulphur (mg/l)	87	52	48	86	126	129

Appendix 3. Mean data and L.S.D.s from shelf life assessments

Quality Score		Weeks in shelf life							
Potting week	**Treatment**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Cortez									
30	**NS**	4.3	4.1	3.5	2.8	2.2	2.0	1.7	1.7
32	**w38**	4.4	3.8	3.6	3.3	3.1	2.9	2.2	2.1
32	**w39**	4.3	4.2	3.8	3.3	2.9	2.7	2.2	2.2
32	**w40**	3.9	3.7	3.6	3.3	3.1	2.9	2.6	2.5
32	**w41**	4.5	4.0	3.3	2.8	2.8	2.6	2.3	2.0
32	**w42**	4.3	3.9	3.4	3.2	2.9	2.7	2.4	2.1
34	**w38**	3.5	3.4	3.2	2.7	2.5	2.2	1.4	1.3
34	**w39**	3.6	3.6	3.3	2.8	2.4	2.2	1.3	1.3
34	**w40**	3.3	3.3	3.2	2.9	2.8	2.7	2.3	2.3
34	**w41**	3.6	3.3	2.9	2.8	2.3	1.9	1.6	1.3
34	**w42**	3.3	2.8	2.8	2.8	2.6	2.3	2.0	1.6
32	**w38 close**	4.0	3.8	3.6	3.2	3.0	2.6	2.1	1.7
32	**w40 close**	3.8	3.5	3.4	3.1	3.0	2.8	2.4	2.4
34	**w38 close**	2.8	2.8	2.7	2.5	2.2	2.1	1.6	1.5
34	**w40 close**	2.9	2.8	2.8	2.6	2.5	2.3	1.8	1.8
Infinity									
30	**NS**	4.8	4.6	4.0	3.0	2.6	2.3	2.0	1.9
32	**w38**	4.3	4.0	3.6	3.2	3.0	2.8	2.3	1.8
32	**w39**	3.8	3.6	3.6	3.2	2.8	2.5	2.2	1.8
32	**w40**	3.9	3.7	3.5	2.8	2.5	2.3	1.9	1.8
32	**w41**	4.7	4.4	4.2	3.9	3.3	3.3	2.7	2.2
32	**w42**	4.2	3.7	3.6	3.5	2.9	2.7	2.3	1.8
34	**w38**	3.3	3.1	2.8	2.5	2.3	2.4	2.2	2.1
34	**w39**	3.7	3.5	3.3	3.0	2.9	2.8	2.2	2.1
34	**w40**	3.1	3.0	2.9	2.6	2.5	2.5	2.1	2.0
34	**w41**	3.3	2.9	2.8	2.5	2.5	2.4	2.3	1.7
34	**w42**	2.8	2.5	2.2	2.1	2.0	1.8	1.8	1.3
32	**w38 close**	4.5	4.1	3.8	3.4	2.7	2.3	1.5	1.4
32	**w40 close**	3.7	3.7	3.5	3.3	3.0	2.4	2.0	1.6
34	**w38 close**	3.3	3.1	3.1	2.7	2.6	2.5	2.0	1.8
34	**w40 close**	3.0	2.9	2.9	2.7	2.3	2.2	2.0	1.8
L.S.D. (5%)		0.55	0.88	0.90	0.94	ns	0.87	ns	ns

% Green leaf drop		Weeks in shelf life							
Potting week	**Treatment**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Cortez									
30	**NS**	7	12	29	49	67	85	94	100
32	**w38**	4	13	30	54	61	74	88	100
32	**w39**	4	9	25	34	37	66	87	100
32	**w40**	3	7	12	25	36	46	86	100
32	**w41**	0	5	13	37	57	76	88	100
32	**w42**	1	13	29	48	60	71	87	100
34	**w38**	6	7	15	16	38	69	91	100
34	**w39**	3	3	17	21	33	54	91	100
34	**w40**	6	16	18	23	31	58	78	100
34	**w41**	2	2	2	19	40	73	89	100
34	**w42**	0	9	20	46	61	80	90	100
32	**w38 close**	4	6	14	25	37	48	80	100
32	**w40 close**	0	2	16	35	49	70	92	100
34	**w38 close**	3	3	6	12	19	39	91	100
34	**w40 close**	3	5	5	12	15	41	52	83
Infinity									
30	**NS**	4	11	18	36	54	81	94	100
32	**w38**	6	7	14	25	38	57	71	100
32	**w39**	2	8	20	24	49	75	90	100
32	**w40**	0	6	7	22	47	53	74	100
32	**w41**	1	8	20	45	61	75	90	100
32	**w42**	1	8	8	28	45	63	91	100
34	**w38**	3	5	9	9	41	46	67	83
34	**w39**	19	20	20	20	20	32	60	83
34	**w40**	24	24	32	41	44	54	67	100
34	**w41**	3	5	10	34	61	71	97	100
34	**w42**	0	4	21	53	69	77	93	100
32	**w38 close**	0	17	17	24	39	66	81	83
32	**w40 close**	5	12	12	22	31	47	68	83
34	**w38 close**	0	0	0	0	11	14	31	50
34	**w40 close**	25	28	28	28	44	58	77	100
L.S.D. (5%)		ns	ns	ns	31	34	31	27	22

% Red leaf/bract drop		**Weeks in shelf life**							
Potting week	**Treatment**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Cortez									
30	**NS**	0	4	14	33	66	66	82	83
32	**w38**	0	22	35	43	51	64	81	100
32	**w39**	0	2	38	58	64	68	80	100
32	**w40**	0	0	0	17	25	25	50	67
32	**w41**	0	11	19	22	36	62	87	100
32	**w42**	0	0	0	14	14	25	29	67
34	**w38**	0	7	23	25	28	60	85	100
34	**w39**	0	0	7	14	21	35	64	83
34	**w40**	0	0	0	0	0	33	33	50
34	**w41**	0	7	10	37	48	53	60	83
34	**w42**	0	0	0	0	17	28	28	33
32	**w38 close**	0	5	21	42	46	51	68	100
32	**w40 close**	0	0	1	8	29	59	83	100
34	**w38 close**	0	8	13	17	17	33	46	50
34	**w40 close**	0	0	0	8	8	17	22	50
Infinity									
30	**NS**	0	0	3	18	45	61	83	83
32	**w38**	0	2	19	39	43	57	70	83
32	**w39**	0	0	17	25	52	70	75	75
32	**w40**	0	0	0	0	17	33	33	50
32	**w41**	0	0	8	8	22	28	33	33
32	**w42**	0	0	0	0	0	0	17	17
34	**w38**	0	0	25	25	30	32	48	50
34	**w39**	0	0	6	7	11	11	15	17
34	**w40**	0	0	0	0	0	0	0	0
34	**w41**	0	0	0	0	0	0	0	0
34	**w42**	0	0	0	17	17	17	17	17
32	**w38 close**	0	4	11	30	35	47	67	83
32	**w40 close**	0	0	0	0	0	17	33	33
34	**w38 close**	0	0	0	0	17	17	17	17
34	**w40 close**	0	0	0	0	17	17	17	17
L.S.D. (5%)		ns	ns	21	30	39	44	58	59

% Cyathia drop		Weeks in shelf life							
Potting week	**Treatment**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Cortez									
30	**NS**	0	0	27	43	82	92	96	100
32	**w38**	0	0	0	2	18	26	53	66
32	**w39**	0	0	0	0	28	67	97	100
32	**w40**	0	0	0	0	2	27	58	78
32	**w41**	0	0	0	14	17	24	59	80
32	**w42**	0	0	0	0	7	18	27	55
34	**w38**	0	0	0	0	40	83	98	98
34	**w39**	0	0	0	13	51	83	88	92
34	**w40**	0	0	0	4	4	30	46	75
34	**w41**	0	0	0	0	36	68	77	85
34	**w42**	0	0	0	0	3	29	46	70
32	**w38 close**	0	0	0	6	22	55	76	90
32	**w40 close**	0	0	0	0	7	9	33	57
34	**w38 close**	0	0	0	0	72	98	98	100
34	**w40 close**	0	0	0	3	8	57	61	82
Infinity									
30	**NS**	0	0	11	71	97	97	97	97
32	**w38**	0	0	0	11	34	47	94	96
32	**w39**	0	0	0	0	25	42	71	91
32	**w40**	0	0	0	0	0	21	58	63
32	**w41**	0	0	0	0	15	33	69	71
32	**w42**	0	0	0	0	0	18	32	47
34	**w38**	0	0	0	7	47	47	73	88
34	**w39**	0	0	0	14	17	38	77	77
34	**w40**	0	0	0	0	0	4	63	75
34	**w41**	0	0	0	11	15	20	58	78
34	**w42**	0	0	8	8	8	13	21	71
32	**w38 close**	0	0	0	16	42	73	90	90
32	**w40 close**	0	0	0	0	0	26	51	70
34	**w38 close**	0	0	0	11	26	38	61	69
34	**w40 close**	0	0	0	0	4	21	29	46
L.S.D. (5%)		ns	ns	15	21	33	36	31	27

BEB		Weeks in shelf life							
Potting week	Treatment	1	2	3	4	5	6	7	8
Cortez									
30	**NS**	0.3	0.3	0.5	0.5	0.5	0.5	0.5	0.3
32	**w38**	0.2	0.8	0.5	1.0	0.5	0.7	0.7	0.5
32	**w39**	0.2	0.5	0.5	0.5	0.5	0.5	0.5	1.5
32	**w40**	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.8
32	**w41**	0.0	0.3	0.5	0.3	0.2	0.3	0.2	0.3
32	**w42**	0.0	0.0	0.0	0.2	0.2	0.2	0.2	0.3
34	**w38**	0.2	0.2	0.3	0.3	0.3	0.7	0.7	0.8
34	**w39**	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.5
34	**w40**	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.8
34	**w41**	0.3	0.5	0.5	0.5	0.7	0.8	0.8	1.0
34	**w42**	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3
32	**w38 close**	0.2	0.7	0.7	0.7	0.7	0.8	1.0	1.0
32	**w40 close**	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
34	**w38 close**	0.0	0.0	0.2	0.2	0.2	0.2	0.2	0.2
34	**w40 close**	0.0	0.0	0.2	0.2	0.2	0.2	0.2	0.2
Infinity									
30	**NS**	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
32	**w38**	0.2	0.2	0.2	0.2	0.2	0.3	0.5	0.5
32	**w39**	0.2	0.3	0.3	0.3	0.3	0.6	0.6	0.6
32	**w40**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
32	**w41**	0.0	0.2	0.2	0.2	0.2	0.2	0.2	0.0
32	**w42**	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
34	**w38**	0.5	0.7	0.8	0.8	0.8	0.8	0.8	0.8
34	**w39**	0.0	0.2	0.3	0.3	0.3	0.3	0.3	0.2
34	**w40**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34	**w41**	0.0	0.0	0.0	0.2	0.2	0.2	0.2	0.2
34	**w42**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
32	**w38 close**	0.0	0.5	0.7	0.7	0.7	0.7	0.7	0.7
32	**w40 close**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34	**w38 close**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34	**w40 close**	0.0	0.0	0.2	0.2	0.2	0.2	0.2	0.2
L.S.D. (5%)		ns	ns	0.53	0.64	0.55	0.54	0.51	1.01

Upper green leaf colour score		Weeks in shelf life							
Potting week	**Treatment**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Cortez									
30	**NS**	5.0	4.9	4.7	4.3	4.3	4.3	4.3	4.3
32	**w38**	5.0	5.0	5.0	4.8	5.0	5.0	4.7	4.7
32	**w39**	5.0	5.0	5.0	4.7	4.8	4.8	4.3	4.0
32	**w40**	5.0	5.0	4.8	4.7	4.8	4.8	4.8	4.5
32	**w41**	5.0	4.7	4.8	4.8	4.8	4.8	5.0	4.6
32	**w42**	5.0	4.7	4.8	4.8	4.7	4.7	4.4	4.8
34	**w38**	5.0	5.0	5.0	4.8	4.8	4.8	4.5	4.5
34	**w39**	5.0	5.0	5.0	4.8	4.3	4.3	4.0	4.0
34	**w40**	4.9	4.9	4.9	4.9	5.0	4.8	4.8	4.7
34	**w41**	5.0	5.0	4.7	4.7	4.2	4.3	4.2	4.2
34	**w42**	5.0	4.4	4.6	4.6	4.5	4.6	4.3	4.2
32	**w38 close**	4.8	4.8	4.8	4.6	5.0	4.8	4.6	4.6
32	**w40 close**	4.8	4.8	4.8	4.5	4.8	4.8	4.4	4.6
34	**w38 close**	4.9	4.9	4.9	4.9	4.8	4.8	4.8	4.8
34	**w40 close**	4.8	4.8	4.8	4.9	5.0	5.0	4.9	4.9
Infinity									
30	**NS**	5.0	5.0	5.0	4.7	4.7	4.7	4.7	4.7
32	**w38**	5.0	4.8	4.8	4.8	5.0	5.0	5.0	4.8
32	**w39**	4.9	4.9	4.9	4.9	5.0	5.0	5.0	5.0
32	**w40**	4.8	4.8	4.8	4.7	4.7	4.7	4.7	4.7
32	**w41**	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9
32	**w42**	5.0	5.0	5.0	5.0	5.0	5.0	4.8	4.8
34	**w38**	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
34	**w39**	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
34	**w40**	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
34	**w41**	4.8	4.6	4.5	4.5	4.5	4.9	4.8	4.8
34	**w42**	4.6	4.5	4.6	4.5	4.5	4.8	4.8	4.8
32	**w38 close**	4.8	4.7	4.7	4.8	4.7	4.7	3.8	4.2
32	**w40 close**	4.9	4.9	4.8	4.8	4.8	4.8	4.8	4.4
34	**w38 close**	5.0	5.0	5.0	5.0	5.0	5.0	4.8	4.9
34	**w40 close**	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
L.S.D. (5%)		ns	0.31	0.39	ns	0.59	0.58	0.93	ns

Lower green leaf colour score		**Weeks in shelf life**							
Potting week	**Treatment**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Cortez									
30	**NS**	5.0	4.7	4.3	3.7	3.5	3.3	3.3	3.3
32	**w38**	4.6	3.8	3.8	3.5	3.7	3.8	3.3	3.0
32	**w39**	4.6	4.3	4.0	3.3	3.3	3.3	3.1	2.8
32	**w40**	4.3	4.0	3.7	3.3	3.3	3.5	3.2	3.2
32	**w41**	4.3	3.5	3.3	3.3	3.3	3.3	2.9	2.8
32	**w42**	4.5	3.5	3.3	3.3	3.3	3.1	2.9	2.9
34	**w38**	4.8	4.6	4.6	4.3	4.1	4.0	3.7	3.5
34	**w39**	4.7	4.5	4.3	3.8	3.3	3.3	2.8	2.8
34	**w40**	4.6	4.5	4.5	4.3	4.0	3.9	3.8	3.6
34	**w41**	4.3	3.8	3.7	3.7	3.2	3.2	2.8	2.8
34	**w42**	4.3	4.0	3.7	3.5	3.3	3.1	3.2	3.1
32	**w38 close**	4.4	3.8	3.5	3.7	3.8	3.7	3.2	3.1
32	**w40 close**	4.2	3.4	3.4	3.3	3.8	3.8	3.4	3.2
34	**w38 close**	4.4	4.3	4.1	3.9	3.6	3.6	3.5	3.5
34	**w40 close**	4.3	4.1	4.1	4.3	4.2	3.8	3.5	3.5
Infinity									
30	**NS**	4.9	4.8	4.6	4.1	3.8	3.8	3.8	3.8
32	**w38**	5.0	4.4	4.1	4.0	4.1	3.9	3.8	3.8
32	**w39**	4.6	4.3	4.5	4.8	4.5	4.5	4.5	4.1
32	**w40**	4.6	4.5	4.5	3.8	3.8	3.7	3.7	3.7
32	**w41**	4.8	4.6	4.5	4.2	4.2	4.2	3.8	3.8
32	**w42**	4.5	4.0	4.0	4.0	3.8	4.2	3.8	3.6
34	**w38**	5.0	5.0	5.0	5.0	4.8	4.8	4.7	4.7
34	**w39**	4.9	4.8	4.8	4.8	4.8	4.8	4.8	4.4
34	**w40**	4.8	4.7	4.8	4.7	4.6	4.6	4.6	4.3
34	**w41**	4.3	3.8	3.7	3.5	3.5	3.8	4.0	4.0
34	**w42**	4.2	4.1	4.1	4.1	4.1	4.3	4.3	4.0
32	**w38 close**	4.7	4.3	4.3	4.4	4.1	3.9	3.4	3.3
32	**w40 close**	4.9	4.7	4.5	4.3	4.1	4.1	4.1	3.5
34	**w38 close**	5.0	4.8	4.8	4.8	4.8	4.7	4.3	4.3
34	**w40 close**	4.7	4.4	4.4	4.3	4.3	4.2	4.2	4.0
L.S.D. (5%)		0.59	0.71	0.81	0.87	0.84	0.83	0.99	ns

Red bract/leaf colour score		**Weeks in shelf life**							
Potting week	**Treatment**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Cortez									
30	**NS**	5.0	5.0	4.5	4.2	3.8	3.8	3.3	3.3
32	**w38**	5.0	5.0	5.0	4.4	4.1	3.9	2.9	2.9
32	**w39**	5.0	5.0	4.8	4.3	4.1	3.6	3.1	3.1
32	**w40**	5.0	4.9	4.9	4.4	4.0	4.0	3.4	3.4
32	**w41**	5.0	5.0	4.4	4.0	3.3	3.3	3.3	3.3
32	**w42**	5.0	5.0	4.3	4.0	3.4	3.3	3.2	3.2
34	**w38**	5.0	4.8	4.8	4.3	4.1	3.6	2.9	3.0
34	**w39**	5.0	5.0	4.9	4.3	4.0	2.9	2.4	2.5
34	**w40**	5.0	5.0	4.9	4.6	4.2	3.8	3.3	3.2
34	**w41**	5.0	5.0	4.3	4.0	3.1	3.0	3.0	3.1
34	**w42**	5.0	4.7	4.6	4.1	3.6	3.4	3.1	3.1
32	**w38 close**	4.9	4.8	4.7	4.3	4.0	3.6	2.8	2.8
32	**w40 close**	5.0	5.0	5.0	4.5	4.1	3.8	3.4	3.4
34	**w38 close**	5.0	5.0	4.8	4.4	4.1	3.8	3.0	3.0
34	**w40 close**	5.0	5.0	4.9	4.5	4.2	3.6	3.0	3.0
Infinity									
30	**NS**	5.0	5.0	4.8	4.3	3.8	3.8	3.5	3.4
32	**w38**	5.0	5.0	4.9	4.6	4.5	4.1	3.6	3.6
32	**w39**	5.0	5.0	5.0	4.7	4.5	4.2	3.5	3.5
32	**w40**	5.0	4.9	4.8	4.6	4.1	3.8	3.5	3.5
32	**w41**	5.0	5.0	4.9	4.6	4.0	4.0	4.0	3.9
32	**w42**	4.9	4.8	4.8	4.7	4.1	4.0	3.8	3.4
34	**w38**	5.0	5.0	4.9	4.8	4.5	4.0	3.4	3.4
34	**w39**	5.0	5.0	4.8	4.7	4.4	4.3	3.6	3.5
34	**w40**	5.0	4.8	4.9	4.5	4.3	4.1	3.4	3.4
34	**w41**	5.0	4.9	4.3	4.2	4.1	4.1	3.8	3.7
34	**w42**	5.0	4.8	3.8	3.8	3.3	3.3	3.3	3.2
32	**w38 close**	5.0	5.0	5.0	4.5	4.2	4.0	3.3	3.3
32	**w40 close**	5.0	5.0	4.9	4.8	4.6	4.1	3.4	3.4
34	**w38 close**	4.9	4.7	4.7	4.5	4.2	4.0	3.5	3.4
34	**w40 close**	5.0	4.9	5.0	4.7	4.3	3.8	3.3	3.3
L.S.D. (5%)		ns	0.16	0.35	0.44	0.37	0.56	0.53	0.57

