FINAL REPORT

To:
Horticultural Development Council
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POINSETTIA: ASSESSMENT OF STRATEGIES FOR EFFICIENT UTILISATION OF NURSERY RESOURCES

PC 243

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June 2007

Commercial - In Confidence

Grower Summary

POINSETTIA: ASSESSMENT OF STRATEGIES FOR EFFICIENT UTILISATION OF NURSERY RESOURCES

PC 243

Final Report (June 2007)

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 Final Report (2006)
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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
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Signed on behalf of: **Warwick HRI**

Signature: ………………………………………………………………

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Director and Head of Department

Date: ………………………………………………………………

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Poinsettia: Assessment of strategies for efficient utilisation of nursery resources

Headline

Late potting when combined with supplementary lighting and CO_2 enrichment has potential to increase annual output assuming efficient space use and close attention to crop husbandry.

Background and expected deliverables

Previous work (PC 208) indicated that potting Poinsettias later in the season could free up space which may be used to increase annual throughput of product (by extending summer pot plant production). This coincides with reductions in retail specifications for height and number of bract stars making the production of a marketable pot more feasible from a later potting. The aims of the current project were 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.

The first year of the project illustrated that potting 2 weeks later than normal produced good quality plants if supplementary lighting and CO_2 enrichment was used. Potting 4 weeks later (i.e. week 34) combined with supplementary lighting and CO_2 enrichment produced poorer quality than week 30 potting but plants were considered suitable for marketing. Later potting also allowed for closer plant spacing, especially in the early stages of production, which would further increase the space available for increased summer production in order to optimise nursery throughput. Delaying the start of SD for late potted plants by extending the period of LD lighting beyond week 38, increased plant height but also reduced % red colour at marketing.

The current report details the second year of work on this project that focussed on week 34 potting. Larger plots were used in order to estimate % wastage and further attention was given to plant spacing. Infinity was continued in year 2 but Cortez was replaced by Freedom Early Red to see if the reduction in % red colour resulting from delayed initiation would be minimised by using a variety with a short response time.

Summary of the project and main conclusions

Infinity (8 week response) and Freedom Early Red (7-7.5 week response) were potted in either week 30/31 or week 34. Plants potted in week 34 were grown with supplementary lighting at 10 W/m² PAR (20 hours per day in LD and 11 hours per day in SD) and CO_2 enrichment to 1000ppm.

Week 30/31 potted plants provided a reference crop representing commercial production and were grown in ambient light with night-break lighting until week 38.

Week 34 potted plants were transferred to SD lighting on 3 occasions; week 38, week 40 and week 42, to examine the potential to increase plant size through extending the period of vegetative growth prior to initiation.

Week 34 potted plants were also given two spacing treatments, 'standard' and 'close' as detailed below.

Standard spacing:-	pot thick to 30 pots/m² on 04/10/07 and 30 pots/m² to 15 pots/m² on 26/10/07.
Close spacing:-	pot thick to 15 pots/m² on 26/10/07.

Plants starting SD in week 38 were ready for marketing in week 48. Delaying the start of SD to week 40 and week 42 delayed bract colouring and therefore these treatments were not suitable for marketing until weeks 49 and 50 respectively. Hence whilst early potting reduced production time by 4 weeks, delaying the start of SD reduced these savings by 1-2 weeks, although the extra production time would be at the end of production which has increased energy use implications rather than at the start of production when space would still be available for extra summer cropping.

The week 30/31 reference crop was taller in 2006 than in 2005, but there was no night-break lighting given in 2005 and hence initiation may have been earlier. In contrast the week 34 potted plants failed to meet the 23cm minimum height specification in 2006, with weekly increase in plant height below that recorded in 2005 throughout production. The lack of extension growth impacted on quality with expanding bracts becoming caught in the main green leaf canopy (particularly the larger bracts of Freedom Early Red). Possible reasons

for the short crop in 2006 include, lower achieved temperatures (0.4 °C lower on average compared with 2005), quality of young plants (particularly Freedom Early that was rooted earlier than planned and had a hard pinch as a result), and low initial N concentration.

Late potting did not reduce the extent of red colour development so long as initiation was not delayed. However late potting slightly reduced the number of primary bract stars per plant and increased the number of secondary bract stars per plant. Delaying initiation of late potted plants decreased red colour development and also further reduced the number of primary bracts stars whilst increasing the number of secondary bract stars.

Quality scores allocated to week 34 potted crops were reduced as a result of restricted extension growth although scores were assigned according to bract number and presentation as well as overall balance with less attention to height (since it was possible to meet height specifications in 2005 from week 34 potted plants).

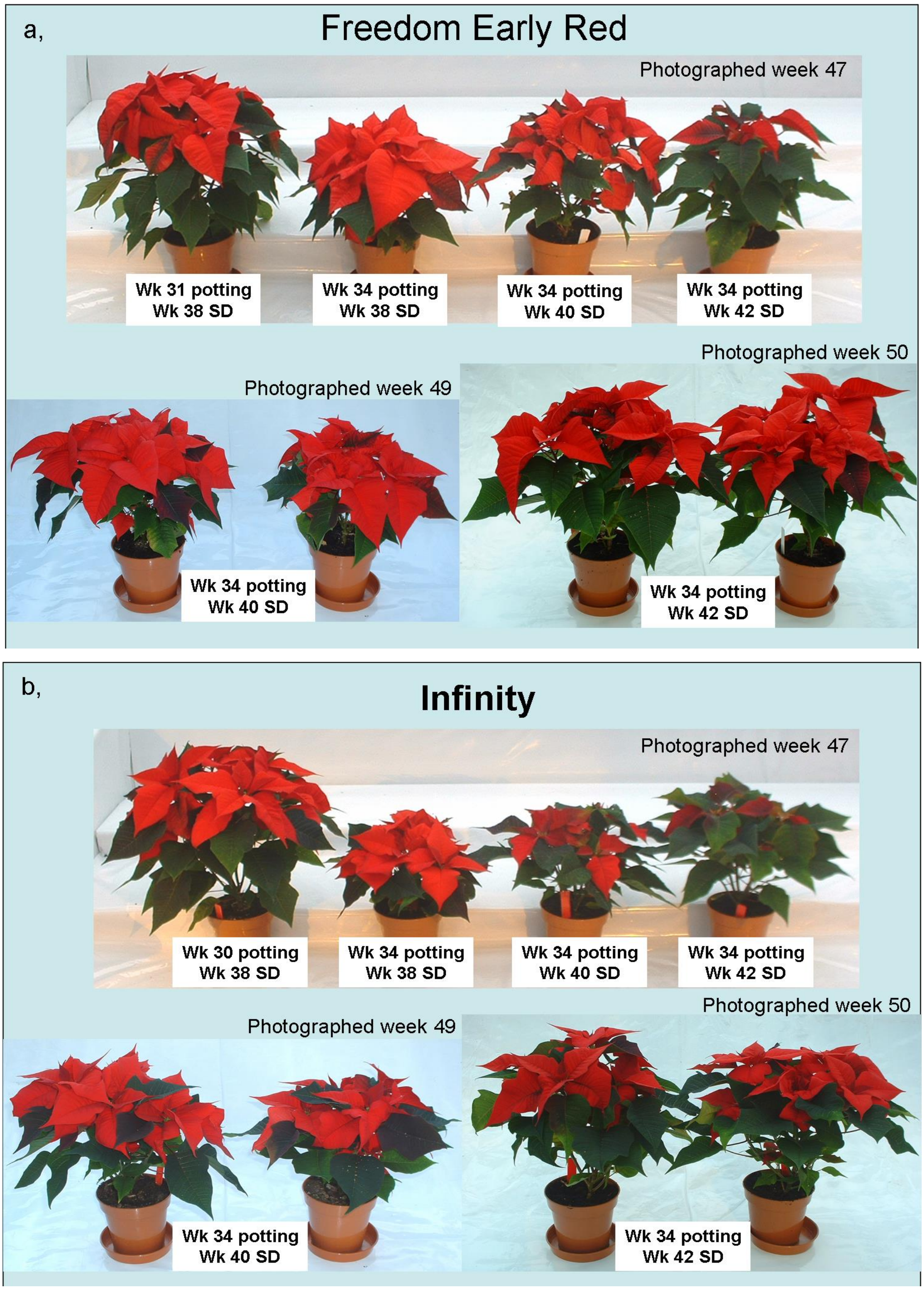
Close spacing combined with late potting increased average plant height by 13% but had no impact on other parameters measured at marketing. Since dry weight was not reduced as a result of the close spacing treatment it is likely that the treatment did not cause sufficient competition between plants to have a commercially relevant impact. This may not have been the case if the late potted plants had been more vigorous.

Plant height (cm)		**Wk 30/1 potting**	**Wk 34 potting**		
Variety	**Spacing**	**Wk 38 SD**	**Wk 38 SD**	**Wk 40 SD**	**Wk 42 SD**
Infinity	**standard**	28.3	16.1	16.8	20.7
	close		20	19.3	22
Freedom Early Red	**standard**	25.6	17.6	19	19.5
	close		20.1	19.6	22.7

% Red colour in sleeve		**Wk 30/1 potting**	**Wk 34 potting**		
Variety	**Spacing**	**Wk 38 SD**	**Wk 38 SD**	**Wk 40 SD**	**Wk 42 SD**
Infinity	**standard**	77.5	89	72.7	62.3
	close		83.7	75.3	65.7
Freedom Early Red	**standard**	89.9	93.2	91.7	80.5
	close		94.5	87	82.8

Quality score (0-5)		**Wk 30/1 potting**	**Wk 34 potting**		
Variety	**Spacing**	**Wk 38 SD**	**Wk 38 SD**	**Wk 40 SD**	**Wk 42 SD**
Infinity	**standard**	4.3	3.2	3.2	3.2
	close		2.9	2.9	3
Freedom Early Red	**standard**	3.7	2.6	3.1	2.7
	close		2.6	2.7	2.9

The quality of the plants at marketing is illustrated in the photograph below which firstly compares all treatments in week 47 (i.e. a week before main marketing records were taken) and also shows what the late potted plants looked like in week 49 and 50 when the delayed marketing assessments were carried out.



Photographic comparison of late potting and delayed initiation treatments.

Shelf life of Freedom Early Red was not affected by the late potting or delayed initiation treatments. Decline in plant quality over the first three weeks from removing sleeves in shelf life was faster for week 30 than for week 34 potted Infinity. This repeats trends observed in 2005 but as the week 30 potted plants in 2006 were delayed with night-break lighting these differences may be due to the use of supplementary lighting during production and/or potting date. Close spacing consistently decreased green leaf and red leaf/bract drop in shelf life although the reasons for this are unclear.

Practical and financial benefits

The main benefit of late potting is that it provides extra production space giving the potential to increase annual throughput per m^2 and hence increase income. The approach is underpinned by the assumption that the extra space will be used effectively and that a market exists for the higher number of units produced. It also assumes quality specifications for 13cm Poinsettias which include 23cm as a minimum height and 4 plus 1 for bract stars.

Late potted plants need supplementary lighting in order to produce suitable quality as 13cm plants, but they are also in the glasshouse for a shorter period and hence have potential to use less energy for heating. The energy inputs have been monitored over two years and have produced comparable results as detailed below (where gas = 1.5p per kWh and electricity = 6.0p per kWh). For environmental impact, the basic figures for electricity use should be multiplied by a factor of 2.6 to reflect the efficiency of electricity generation and distribution and therefore its environmental impact.

	Treatment	**kWh/m² basic energy**			**kWh/plant**		
		Gas	Elec.	Total	Gas	Elec.	Total
2005	NS	66.0	0.0	66.0	5.8	0.0	5.8
2006	w38 (NB)	66.8	1.2	68.0	4.5	0.0	4.5
2005	w38 (HID) std	46.0	39.0	85.0	2.5	1.5	4.0
2006	w38 (HID) std	43.8	38.1	81.9	2.3	1.4	3.7
2005	w38 (HID) close	46.0	39.0	85.0	2.4	1.4	3.8
2006	w38 (HID) close	43.8	38.1	81.9	2.2	1.2	3.4

	Treatment	**£/m²**			**pence/plant**		
		Gas	Elec.	Total	Gas	Elec.	Total
2005	NS	0.99	0.00	0.99	9	0	9
2006	w38 (NB)	1.00	0.07	1.07	7	0	7
2005	w38 (HID) std	0.69	2.34	3.03	4	9	13
2006	w38 (HID) std	0.66	2.29	2.95	4	8	12
2005	w38 (HID) close	0.69	2.34	3.03	4	9	13
2006	w38 (HID) close	0.66	2.29	2.95	3	7	11

Where, NS = week 30 potting no night-break, w38 (NB) = week 30 potting with night-break, w38 (HID) = week 34 potting with supplementary (HID) lighting

The estimated increase in gross margin for potting poinsettias 4 weeks later and using the increased available space productively was calculated as part of project PC 208 to be £4.55 to £7.64 /m² (assuming returns of £1.50 to £1.70 per pot). The increased energy costs associated with potting in week 34 have been comparable in 2005 and 2006 at an average of £1.96/m² above the cost of a standard week 30 potted crop. There is also a smaller cost associated with the supply of CO_2 at around £0.16 /m² assuming pure CO_2 is used. Taking these extra costs from the predicted increased margin from PC 208 gives a margin of £2.44 - £5.53 /m² for week 34 potting. This margin would reduce to £1.71 to £4.80 /m² if the week 34 potted crop was also delayed to week 40 before transferring to SD. This treatment would represent a compromise between the delays in marketing resulting from transferring to SD in week 42 and the smaller plant size as a result of transferring to SD in week 38. As emphasised previously these figures assume fully efficient space use which includes extra cropping in the 4 weeks prior to a week 34 potting as well as using the space available until the week 34 crop is moved from pot thick (around week 40).

Action points for growers

Potting in week 32 produced better plant quality than potting in week 34 but also saves less space and hence reduces the potential to maximise annual throughput. Date chosen for potting later would need to consider the balance between these two aspects that will best suit the market supplied.

Potting in week 34 has produced plants very close to and sometimes below market specifications. Production would need to be closely monitored to avoid any limitation to growth which could have a significant impact on % wastage which in itself has potential to eliminate the benefits of increasing available space. Plant height tracking for example would need close attention with reference to tracking data provided in the main report since growth curves for late potted lit crops are different to those for conventional production.

The suitability of this type of production depends on markets supplied. It may be that a minimum specification is all that is required and there is no achievable price increase for exceeding this level. In this case, it would be possible to improve returns by increasing throughput per m² (e.g. by late potting which can be grown closer and also making use of the space made available by extra summer production).

Financial analysis suggests the late potting approach may be viable, if efficient use of the extra space can be achieved and that supplementary lighting is already available.

Combining late potting with delayed initiation to maximise quality will increase energy inputs and the benefits achieved need to be balanced against this increase in cost.

SCIENCE SECTION

2.1. 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 in 2003. 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 (SD) 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 2005/6 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.

2.2. MATERIALS AND METHODS

2.2.1. Treatments

Two potting dates were compared in 2006, week 30 (conventional), and week 34 (late).

Week 30 potted plants were given night-break lighting using compact fluorescent lights from 31 August to 20 September.

Week 34 potted plants were grown using supplementary (HID) lighting set at an average of 10 W/m² (PAR).

Late potted plants were initially grown in long days (LD) using 20 hours of HID lighting per day. They were then transferred to short days (SD), using 11 hours of HID lighting per day on three occasions, week 38, week 40 and week 42 to examine how delaying initiation would affect final quality.

Late potted plants were also grown using 2 different spacing regimes. These were:

Standard spacing	pot thick to 30 pots/m² on 04/10/07 and 30 pots/m² to 15 pots/m² on 26/10/07.
Close spacing	pot thick to 15 pots/m² on 26/10/07.

Two varieties were compared, Infinity (8 week response) representing a widely grown variety that was also assessed in 2005, and Freedom Early Red (7 to 7.5 week response), representing a short response group.

Experimental design:

Three glasshouse compartments in B Block at Wellesbourne were used for the experiment. One had compact fluorescent lighting for daylength extension and two were lit (as above) for the late potted crops. One of the lit compartments was used to provide the LD environment and the other provided the SD environment.

Plots consisting of 4 rows of plants were used with 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 two plots in different positions within a compartment. 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.

2.2.2. Cultural details

Plant material

Rooted cuttings of Freedom Early Red and Infinity were supplied by Ecke / Lazzeri and GASA respectively.

Cuttings were planted into 13cm pots using Bulrush poinsettia growing medium 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 from weeks 4-6 from potting.

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

Peters Excel 13:5:20 alternated (130 mg/l N) with 15:5:15 from 10 weeks from potting onwards.

Although it was planned to alternate the above feeds with plain water according to irrigation frequency, in practise plants were fed at every irrigation because of low N from the start of production.

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 for energy saving and to prevent light spill between compartments at night. The week 30 potted crop were lit from 31/08/07 to 20/09/07 with compact fluorescent bulbs to prevent initiation and received ambient daylength for the remaining time (tungsten bulbs had to be used for the first 4 days of this period).

CO_2 enrichment was used in both lit and unlit compartments at a set point of 1000vpm during the day period when vents were closed (dropping to 350vpm when vents were 10%+ open). Average achieved CO_2 concentrations depended on amount of venting and hence time of year. In August and September average daily CO_2 concentrations were 500-575 ppm, in October this increased to around 820 ppm and by November and early December concentrations were between 880 and 945 ppm.

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 designed to deliver a light intensity of 10 W/m² PAR
- Hot water heating system
- Independent measurement and control of the greenhouse environment

2.2.3. 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.
- 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 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 an 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

Week 30/1 and week 34 potted plants transferred to SD in week 38 were assessed for marketing records in week 48 (w/c 27/11/07). Due to delays in initiation, week 34 potted plants transferred to SD in week 40 were assessed on 04/12/07 and week 34 potted plants transferred to SD in week 42 were assessed on 11/12/07. The following data were recorded for each batch of plants assessed.

- 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 of 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. The first of the six weekly assessments were then 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.

2.3. RESULTS

Analysis of variance has been used to test for differences between treatments. To be considered significantly different treatments must be separated by the figures quoted for the least significant difference (lsd) at the 95% level.

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

<u>Production time</u>

The reference crops (week 30 potting for Infinity or week 31 potting for Freedom Early Red) were ready for marketing in week 48 and hence had a production time of 118-125 days. Since Freedom Early Red was potted a week later than planned, the remaining comparisons will refer to week 30 as the standard potting date. The four weeks of time saved by potting in week 34 rather than in week 40 needs to be offset against any delays in marketing resulting from transfer of plants to SD after the equinox (table 1). Late potted plants transferred to SD in week 38 were also ready for marketing in week 48 and were therefore in production for 29 days less than the standard week 30 potted plants. Transferring plants to SD in week 40 or 42 delayed marketing to week 49 and 50 and hence reduced production time by 23 and 16 days respectively compared with a week 30 potted crop.

	Number of days in production	
	Infinity	Freedom Early Red
Ambient light & daylength		
SDs week 38	125	118
HID lights and delayed initiation		
SDs week 38	96	96
SDs week 40	102	102
SDs week 42	109	109

Table 1. Number of days in production (from potting to marketing) for late potted Infinity and Freedom Early Red.

Plant height

Plants potted in week 30/31 and grown in ambient light with night-break lighting from week 35 to week 38, had the greatest average plant height ($P<0.05$). The week 30 potted plants in 2005 were shorter (around 24cm) than those from the same treatment in 2006 (26-28cm). This may be a result of using night-break lighting in 2006 which would prevent early initiation and hence prolong vegetative growth (fluorescent bulbs were used to prevent stretching that may result from tungsten bulbs). In contrast, week 34 potted plants in 2005 were taller (23-26cm) than in 2006 (16-23cm). All week 34 potted plants in 2006 were short compared with market specifications.

Delaying the start of short days to week 42 significantly ($P<0.01$) increased average height of late potted plants by 14% compared with SD starting in week 38 or 40 but there was no difference in average height between the late potted plants moved to SD in week 38 or week 40.

Growing plants at a closer spacing with just one move from pot thick to final spacing significantly ($P<0.01$) increased plant height by 13% on average.

There were no significant interactions on the main effects of potting date due to varieties, SD date or spacing on plant height (figure 1).

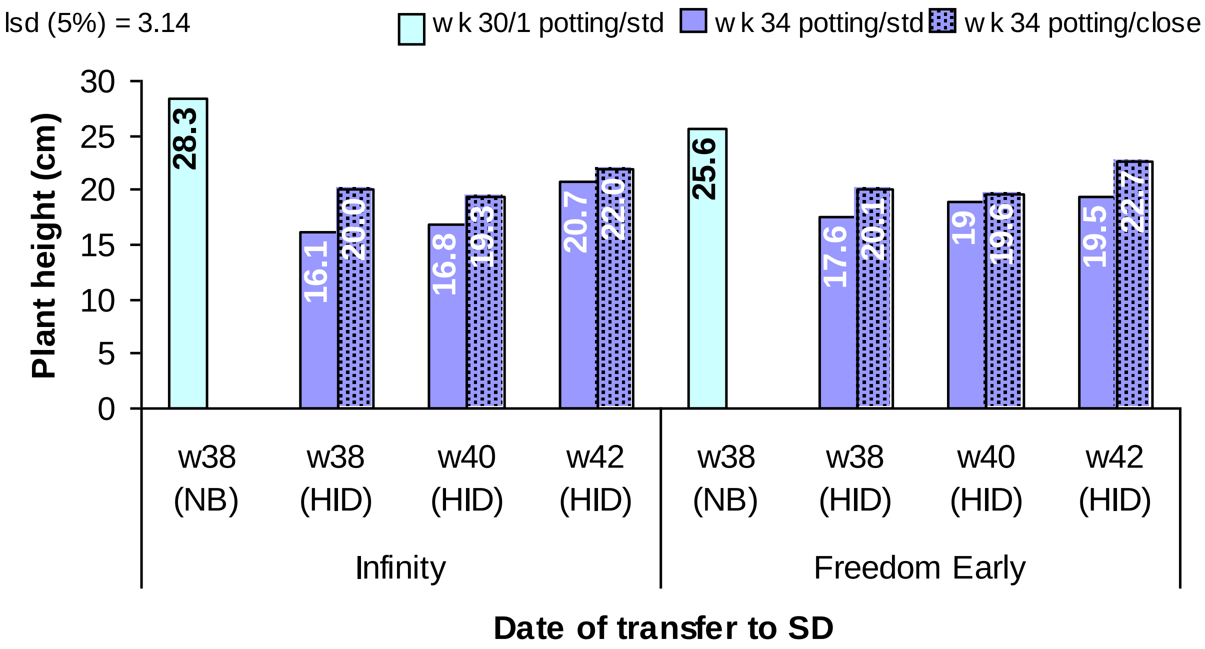


Figure 1. Plant height measured at marketing, where w38-w42 = date of start of SD, NB = night-break lighting (week 30 potting only), HID = supplementary lighting (week 34 potting only).

Since several plants were below the 23cm minimum specification for height, the percentage of plants per treatment within current marketing specifications for height were calculated (figure 2). Clearly week 34 potted plants would have suffered high percentage wastage due to failure to meet minimum height as a result of late potting in the 2006 experiment since fewer than 37% of the pots assessed met the minimum height specification. By contrast, 56-94% of Infinity plants grown in 2005 from a week 34 potting were above the minimum height specification with comparable times for moving to SD, indicating that it is possible to meet height specification from week 34 potting. Height tracking during production suggested that plants were shorter in 2006 than in the 2005 experiments but the mix of treatments in one house prevented the use of increased temperature to increase plant height. It is possible that the regular cycocel treatments to maintain plants shape (see appendix 1) could have been cut back to improve plant height but it is not clear how uniformity would have been affected as a result. There were 15% fewer applications of cycocel applied to the week 34 potted plants compared with the week 30 potted plants because of the shorter production time. Close spacing increased the percentage of plants achieving the minimum height specification but wastage based on height alone would be too high even for these treatments.

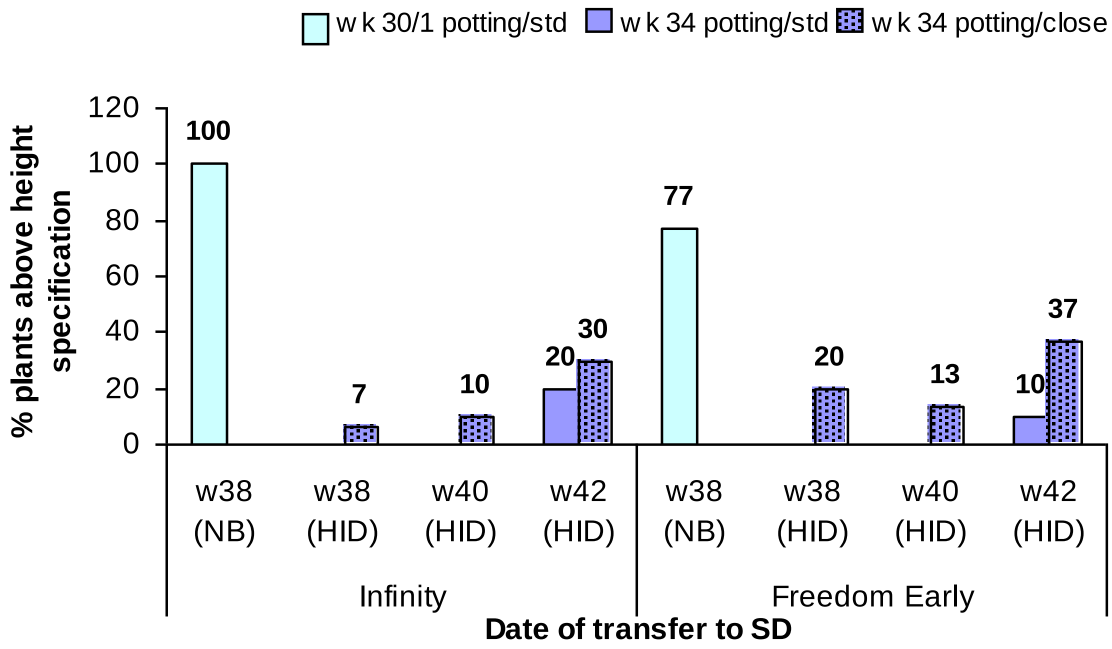


Figure 2. Percentage of plants meeting height specifications at marketing.

As in 2005, the pattern of growth monitored through weekly height tracking was different to that which might be expected for conventional production (figure 3). These data also highlight the differences in growth experienced over the two years of trials discussed previously. Week 30 potted plants continued to extend later in the season in 2006 compared with 2005, possibly as a result of the use of night-break lighting to delay initiation until after week 38 (no night-break was used in 2005). The shorter plants resulting from week 34 potting in 2006 appears to be due to a slow down in extension growth throughout the season. Achieved temperatures measured at the aspirated screen were higher in 2005 than 2006 (figure 4). Average temperature in 2006 was 0.55°C lower than in 2005 in the LD compartment, 0.76°C lower than in 2005 for the SD compartment, and 0.24°C lower than in 2005 in the unlit compartment. These differences may have contributed to the differences in growth between the two years. Low nitrogen concentration in the base fertiliser of the growing medium was also a concern in 2006 and this may have impacted initial plant vigour in particular (see section 2.3.3).

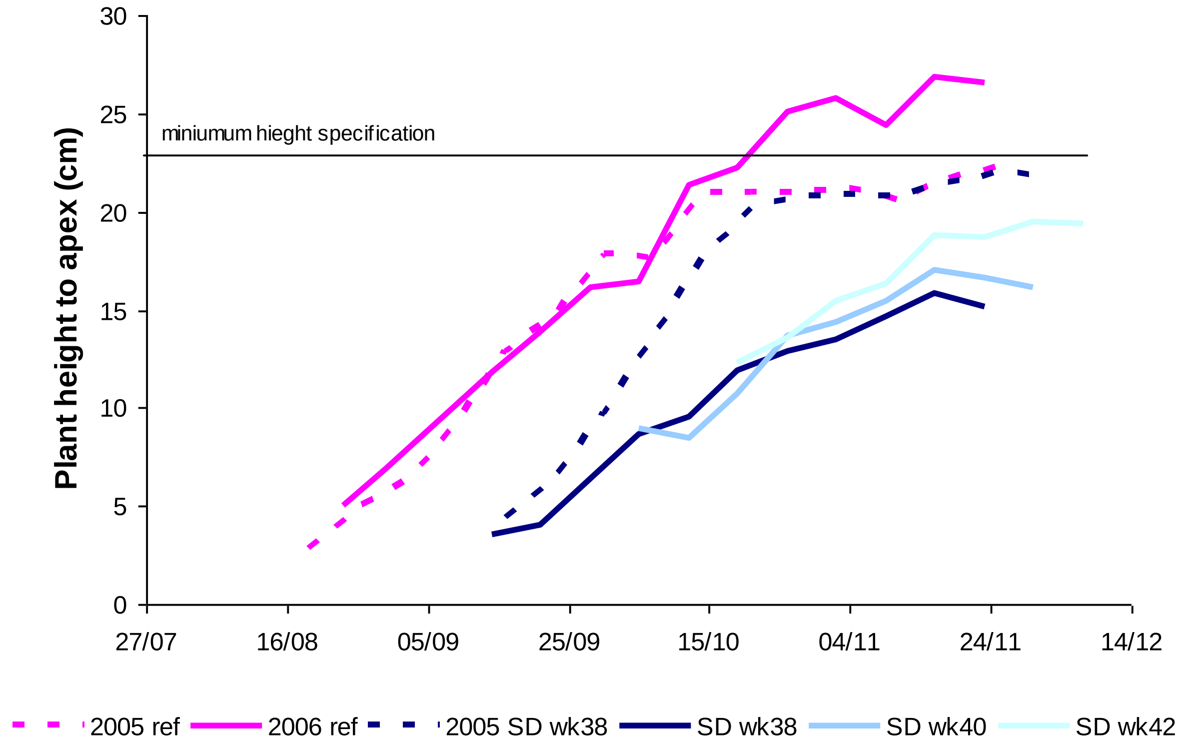
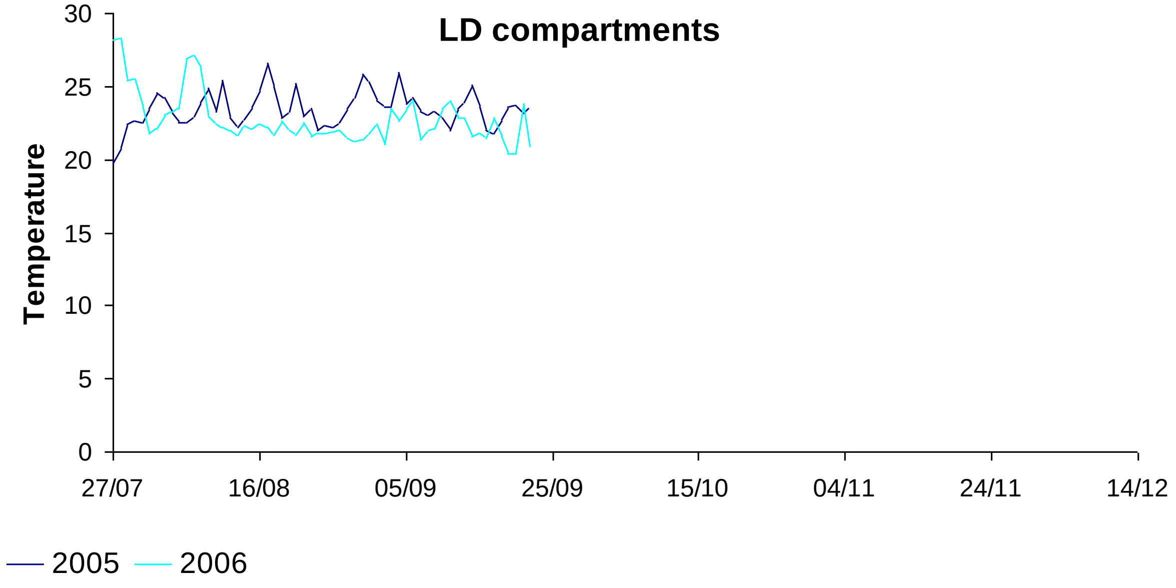


Figure 3. Plant height monitoring of Infinity during production in 2006, compared with selected treatments from 2005 (where ref treatments were potted in week 30 and the remaining treatments were potted in week 34).



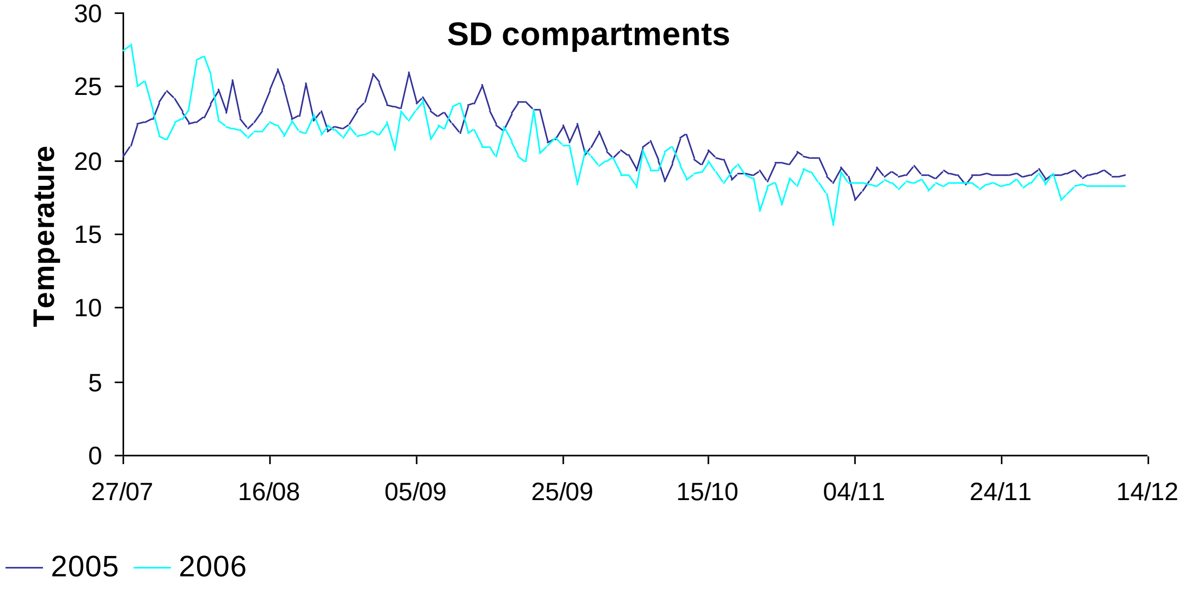


Figure 4. Comparison of average 24 hour temperature in LD and SD compartments in 2005 and 2006 experiments (note LD data is taken to the equinox since this compartment was used for different durations beyond this time in the two years).

Plant spread

Average plant spread for week 30/31 potted plants was significantly (P<0.001) greater than all week 34 potted treatments. Delaying the start of SD significantly increased plant spread of week 34 potted plants (figure 5).

Although the close spacing treatment was sufficient to increase plant height, it had no significant effect on plant spread.

Late potted plants were closer to standard crops in plant spread than they were in height.

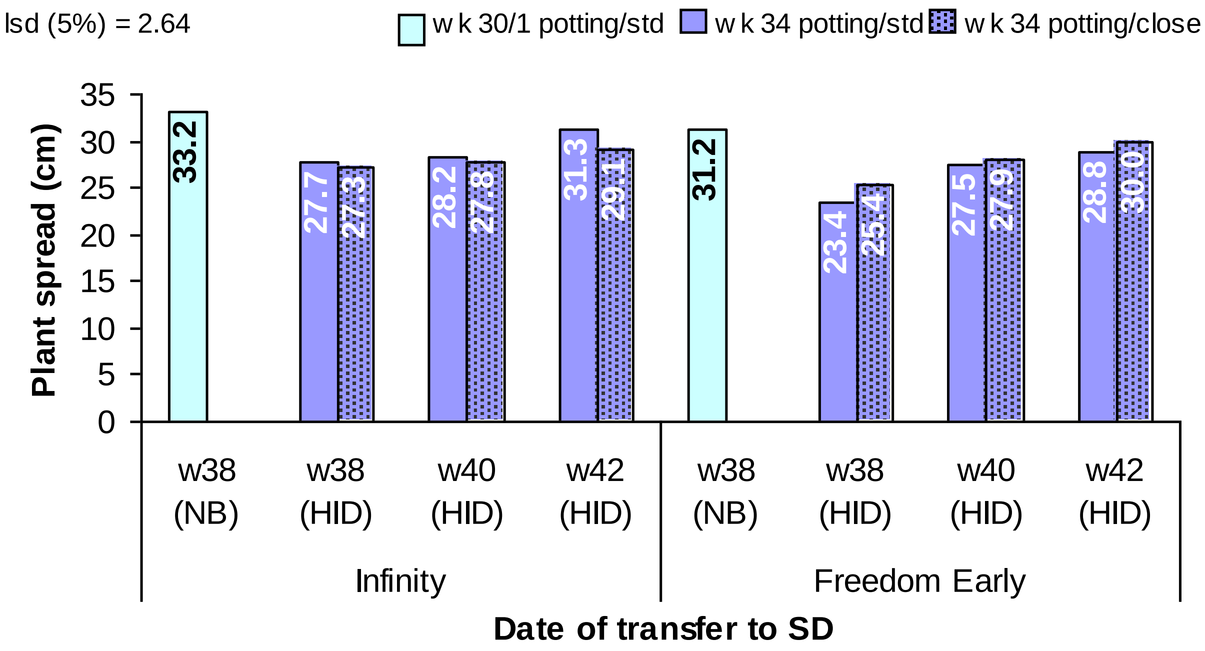


Figure 5. Plant spread measured at marketing.

% Red colour

Delaying the start of SD reduced (P<0.001) the % red colour at marketing of plants potted in week 34, despite delays in date of market assessment to allow further colour development. Plants potted in week 34 and transferred to SD in week 42 had 11% less red colour on average (at a mean of 73%) than the standard week 30/31 potted plants (at a mean of 84%). Freedom Early Red had higher % red cover than Infinity overall in accordance with the differences in response group of these two varieties (figure 6). Plant spacing did not influence % red colour.

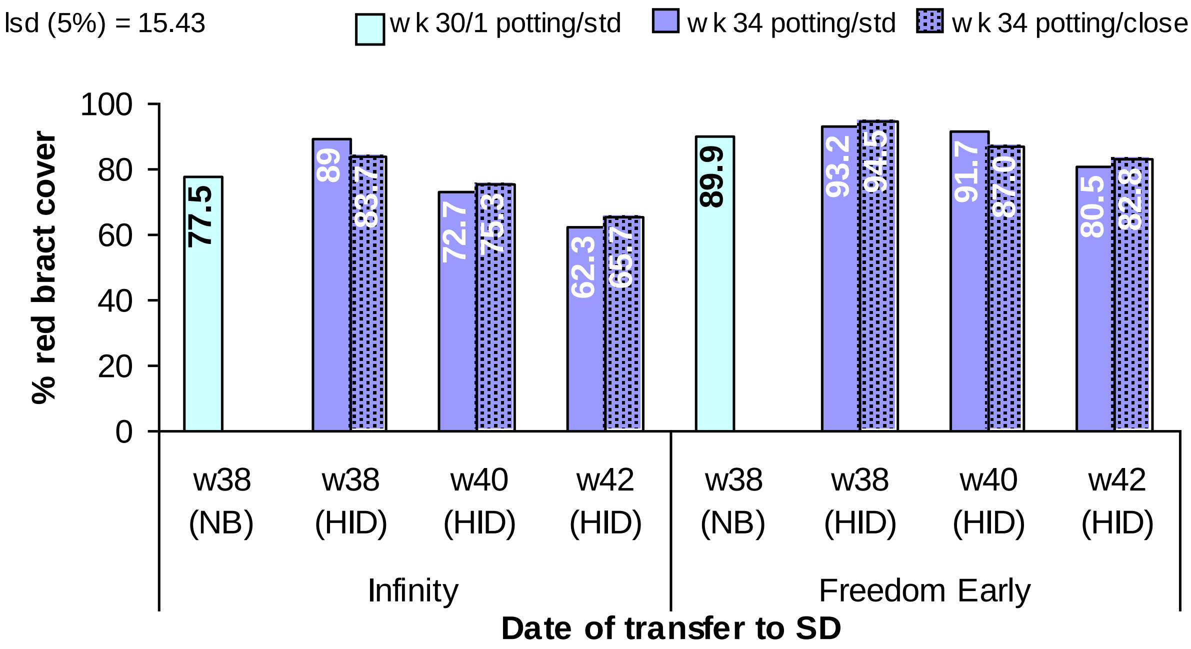


Figure 6. % red colour at the top of the plant assessed at marketing.

Number of primary and secondary bract stars

Potting in week 34 reduced the number of primary bract stars and increased the number of secondary bract stars per pot compared with the week 30/31 reference treatment. Despite this reduction, plants potted in week 34 generally met the marketing specification of 4 primary plus 1 secondary bract star per plant.

Delaying the start of SD to week 42 also gave a small but significant reduction in the number of primary bract stars per plant (by an average of 0.35 stars) compared with starting SD in week 38; and also gave a significant increase in the number of secondary bract stars per plant (by an average of 0.9 bract stars).

Spacing and variety did not interact with the main effects of potting date and date of transfer to SD (figures 7 and 8).

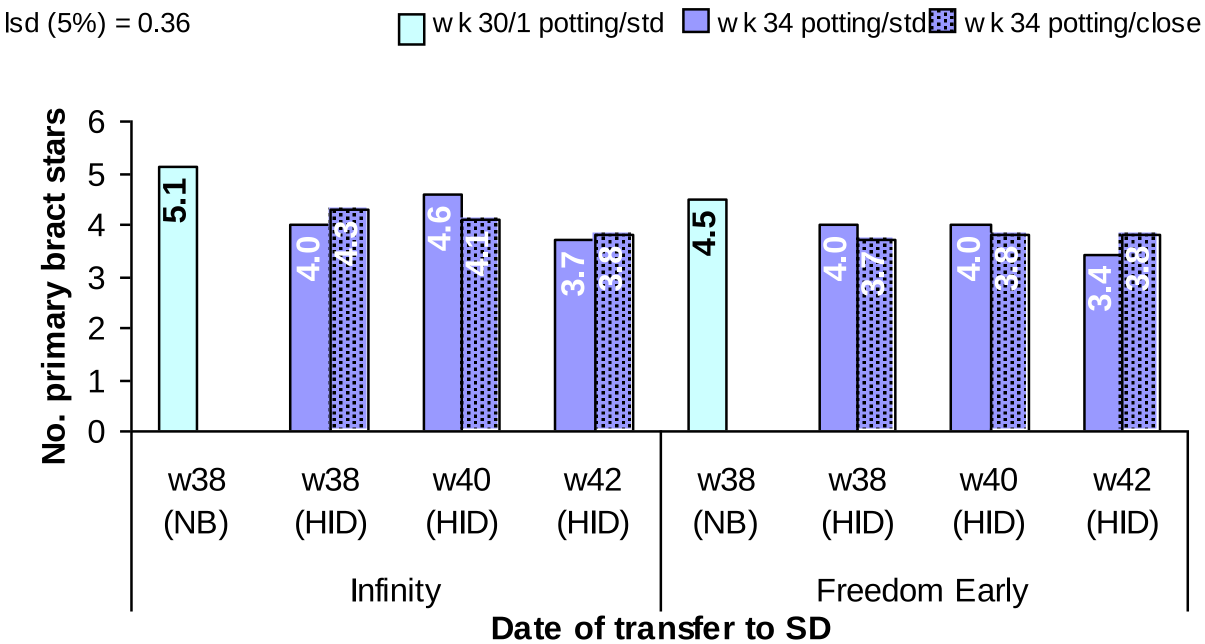


Figure 7. Number of primary bract stars per plant measured at marketing.

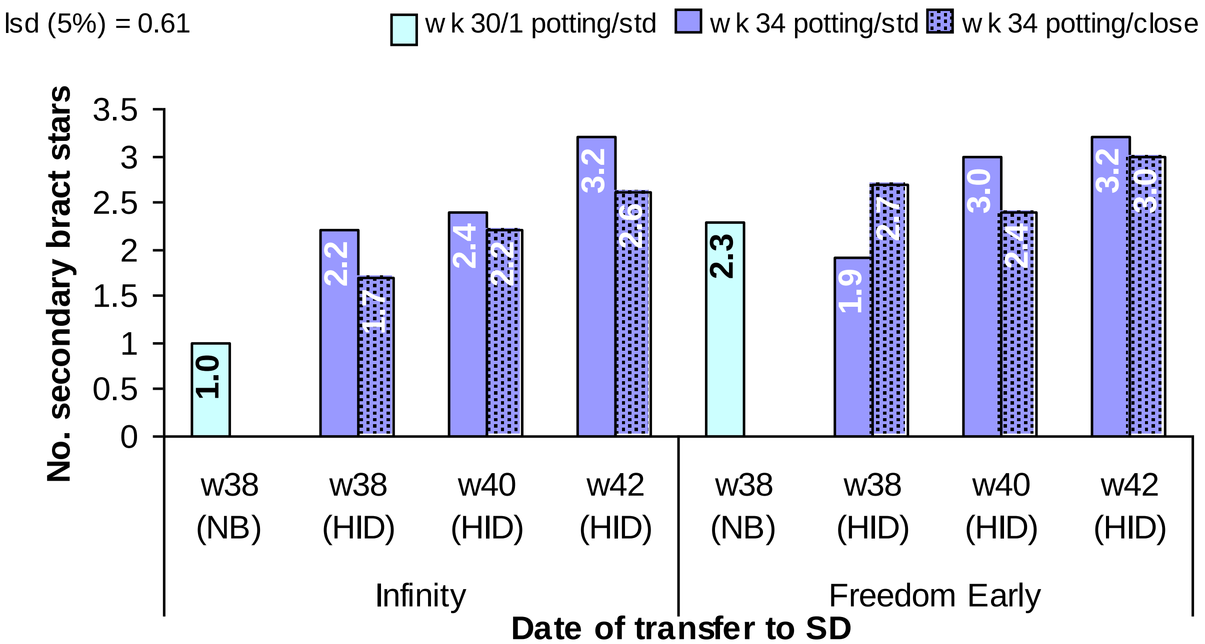


Figure 8. Number of secondary bract stars per plant measured at marketing.

Cyathia size, number and development

In contrast to year 1 (2005), late potting and delaying the start of SD had no significant effects on cyathia. In 2005, the reference crop was grown without night-break lighting and the more advanced cyathia in this treatment may have been due to earlier initiation than the plants receiving HID lighting and therefore greater control over daylength.

Number of green leaves per break

Later potting reduced the average number of green leaves per break by 48% compared with the week 30/31 potted reference crop if moved to SD in week 38. Delaying the start of SD increased the number of green leaves and starting SD in week 42 gave equivalent numbers of green leaves to the reference treatment. Spacing and variety did not interact with the effects of late potting and delayed initiation (figure 9) on number of green leaves per break.

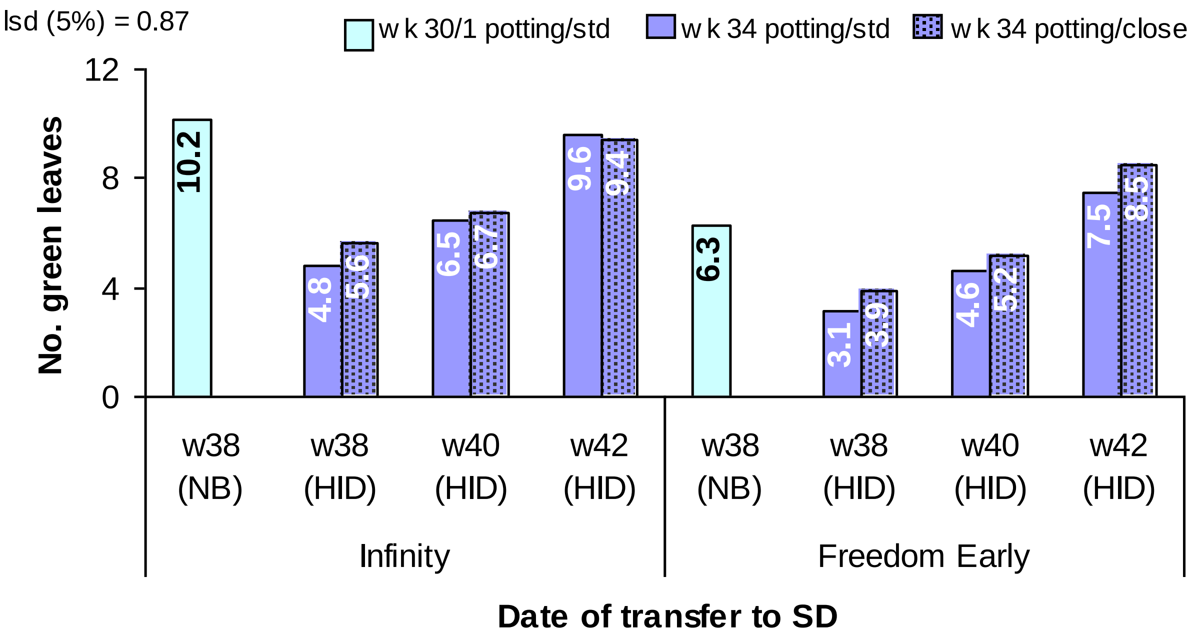


Figure 9. Number of green leaves per break measured at marketing.

Number of red leaves per break

Freedom Early Red had significantly more ($P<0.01$) red leaves per break than Infinity at marketing. Later potting had a smaller effect on number of red leaves per break than it did on green leaves described above. Potting in week 34 and delaying SD to week 42 significantly ($P<0.001$) reduced the average number of red leaves per break by 17% (i.e. 2.2 leaves). There were no significant interactions due to spacing or variety on the main effects described above, although the number of red leaves/bracts per break do appear to be generally higher for Freedom Early Red than Infinity which corresponds with the differences in response group of these two varieties (figure 10).

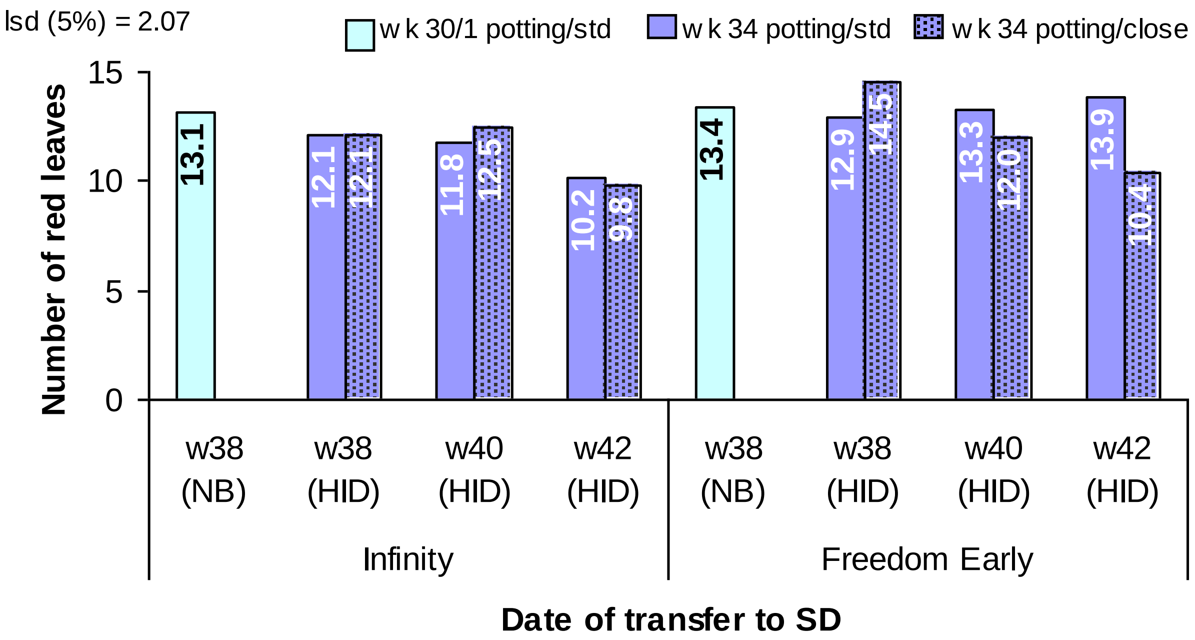


Figure 10. Number of red leaves per break measured at marketing.

<u>Dry weight</u>

Potting in week 34 significantly (P<0.001) reduced plant dry weight compared with the reference plants potted in week 30/31. Average dry weight of week 34 potted plants moved to SD in week 38 was 43% of the average dry weight of week 30/31 potted plants. Delaying the start of SD for week 34 potted plants to week 42 significantly increased dry weight compared with week 34 potted plants moved to SD in week 38, but did not increase the weight sufficiently to be comparable with the reference plants. Spacing and variety did not interact with the effects of late potting and delayed initiation described above (figure 11).

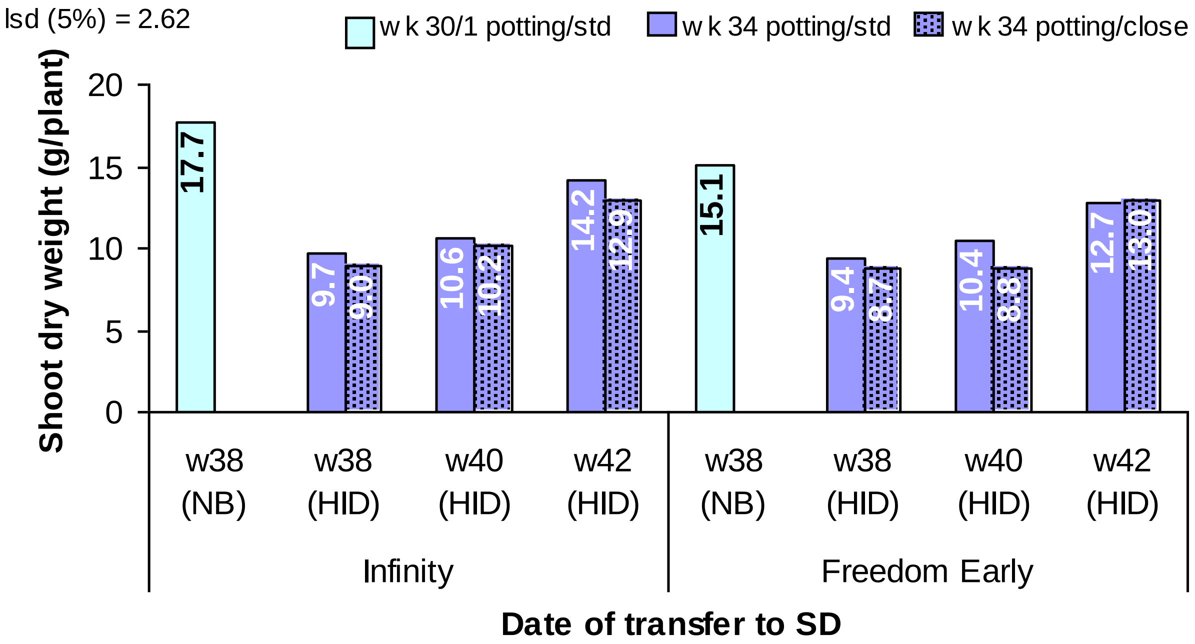


Figure 11. Shoot dry weight measured at marketing.

Plant quality

Later potting significantly (P<0.001) reduced average quality score from 4.0 for week 30/31 potted plants to an average score of 2.9 for all week 34 potted plants. There were no significant interactions on the main effects of potting date due to time of transfer to SD, spacing or variety (figure 12). Previous data for vegetative parameters (e.g. height, spread, number of green leaves, dry weight) have demonstrated that delaying the start of SD may partly compensate for the reduction in growth resulting from potting 4 weeks later, but these were apparently insufficient to improve quality score.

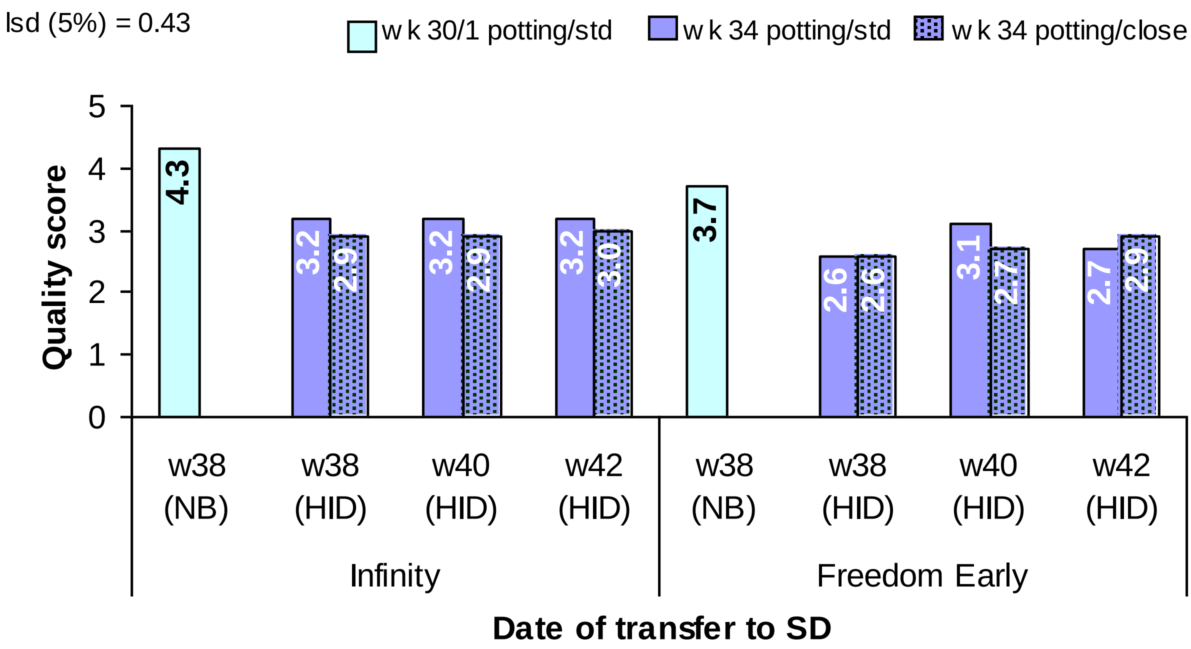


Figure 12. Plant quality assessed at marketing.

Quality scores were limited in 2006 because late potted plants were generally either just at or below the minimum specification for plant height. However late potted plants performed well for parameters such as % bract colour, number of red bracts, number of red bract stars. It was observed that the lack of extension growth for the later potted plants resulted in less space for the bract stars to develop and resulted in uneven bract presentation (especially for the large bracts of Freedom Early Red). To achieve average quality scores at or below 3.0 (i.e. the minimum acceptable for marketing), some pots must be below this minimum score and would hence represent wastage; therefore data has also been presented as percentage of pots achieving a quality score of 3.0 or above to provide an indication of likely grade out (figure 13). The week 30/31 potted reference crops performed best in terms of grade out with 87-100% above score 3 and Infinity performing better than Freedom Early Red. Late potting reduced grade out with Infinity performing better than Freedom Early Red. Closer spacing slightly reduced the percentage of pots above score 3 for Infinity but was more variable with Freedom Early Red. Increasing plant height as discussed previously would be expected to improve grade out of week 34 plants. As with average quality score, there was no apparent overall benefit from delaying the start of SD in terms of % plants meeting market specifications for quality. Quality scores were higher for week 34 potted plants in 2005 with 50-75% of plants above score 3 from starting SD in week 38-40. Furthermore delaying the start of SD increased the percentage of pots achieving a minimum score of 3 to 94%.

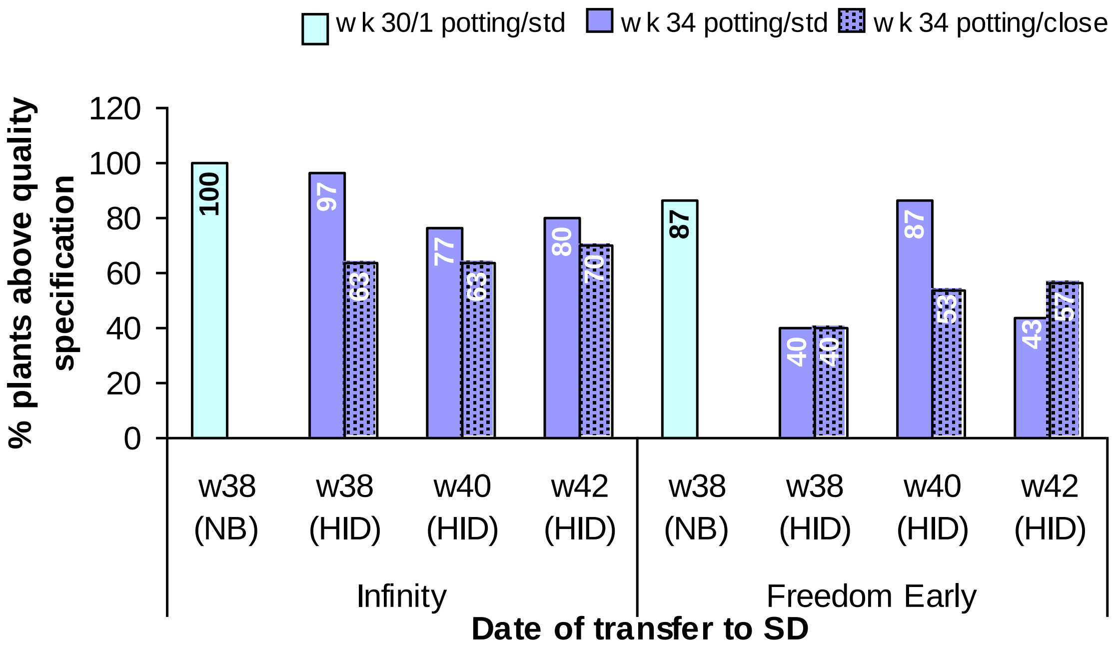
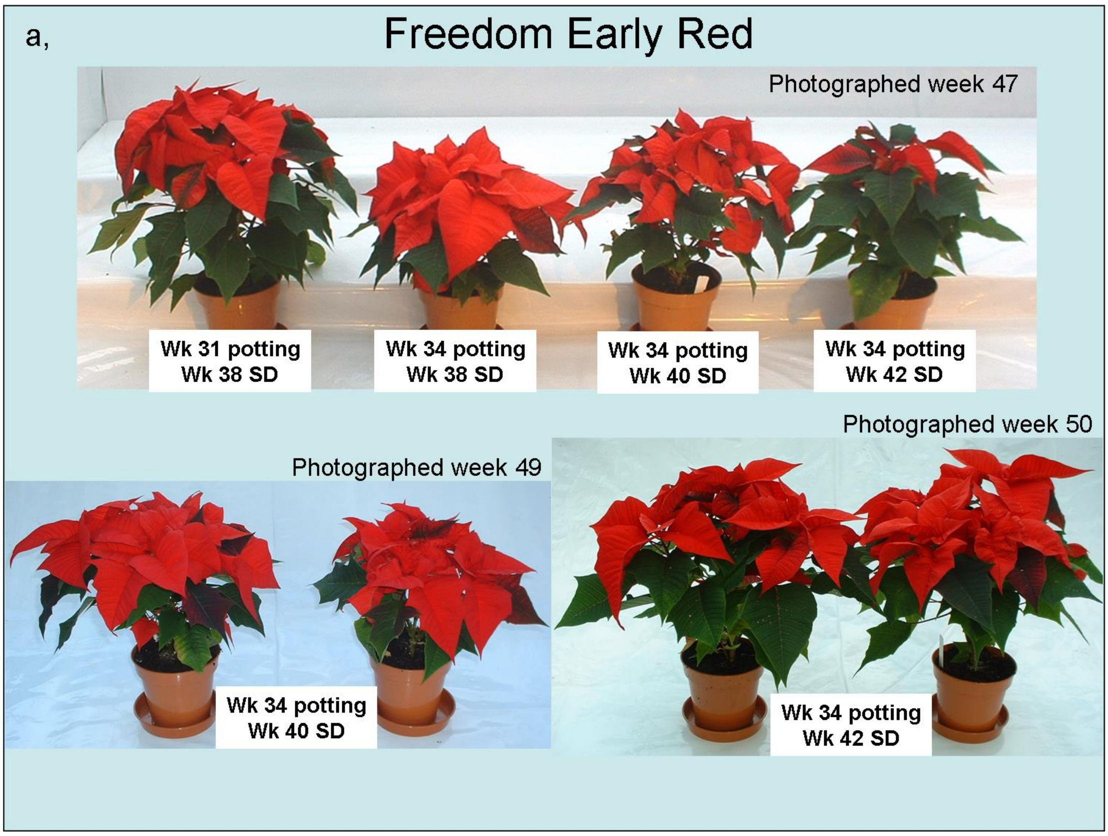


Figure 13. Percentage of plants above quality score 3 at marketing.

Figure 14 below illustrates how the plants compared both in week 47 (i.e. prior to the main marketing week) and also in weeks 49 (for plants moved to SD in week 40) and week 50 (for plants moved to SD in week 42) which illustrates how plants compared when marketing assessments were made.



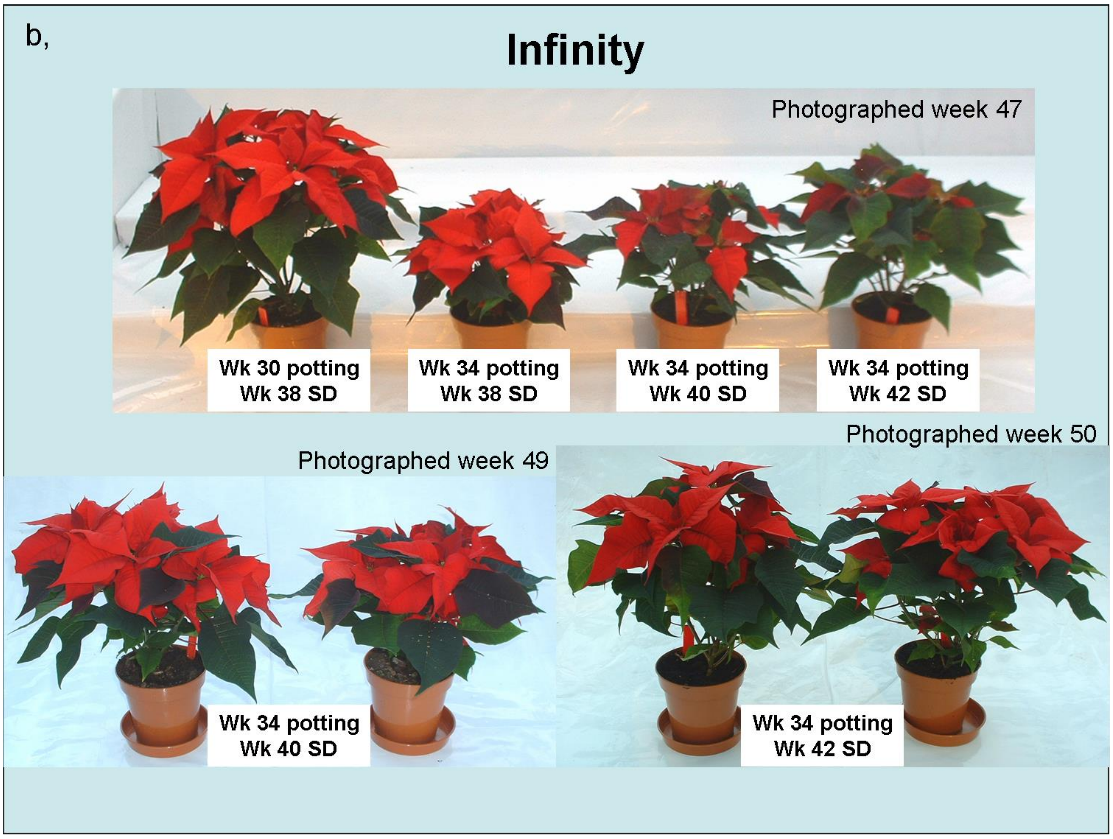


Figure 14. Photographic comparison of late potting and delayed initiation treatments.

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

Mean data and their relevant lsd (least significance difference) figures have been summarised in appendix 2.

Percentage green leaf drop

All treatments lost progressively more green leaves as shelf life progressed (Figure 15). Freedom Early Red lost a higher proportion of green leaves than Infinity during shelf life. The close spacing treatment also had consistently lower green leaf drop during shelf life than the standard treatment. It is not clear why closer space would give such an advantage (close spacing involved keeping plants at pot thick for longer and then moved directly to final (15 pots/m²) spacing, hence the close and standard spacing treatments were at the same densities from week 43 to marketing). There were no significant effects of potting week or date transfer to SD on green leaf drop during shelf life.

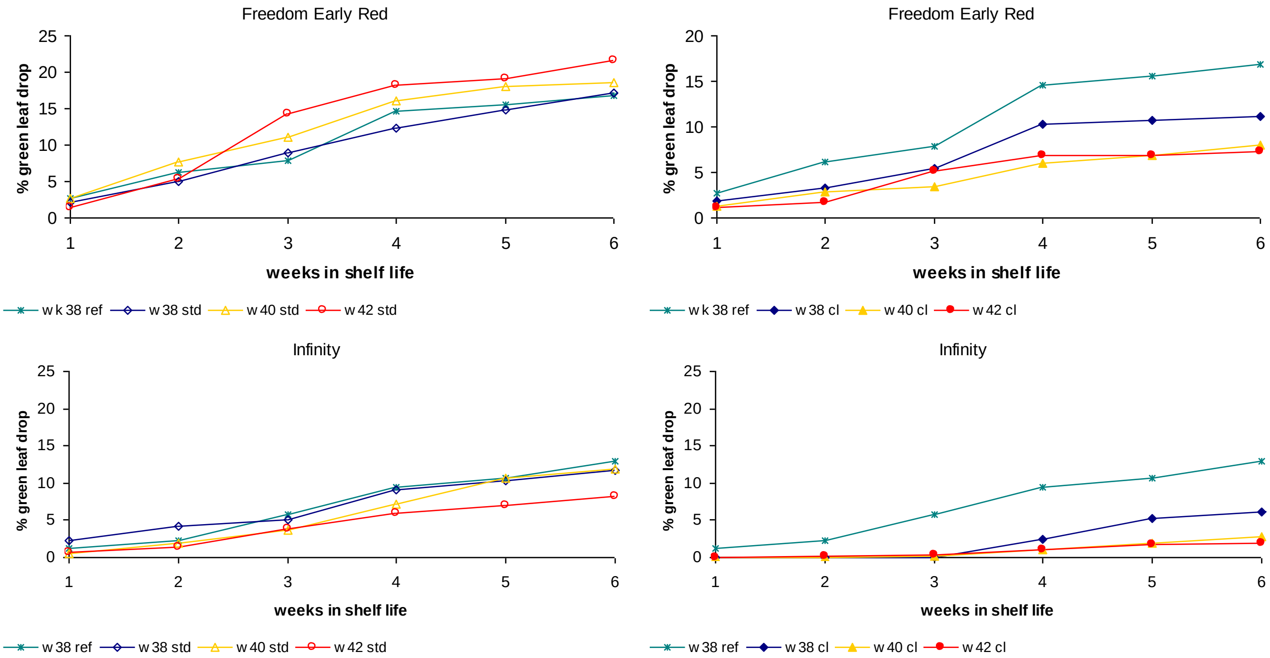


Figure 15. Percentage green leaf loss in shelf life.

Percentage red bract/leaf drop

Freedom Early Red also had a higher proportion of red bract/leaf drop during shelf life than Infinity (Figure 16). In the early stages of shelf life (weeks 1 and 2 from removing sleeves), plants initiated latest had the lowest percentage red leaf/bract drop but there were no significant differences relating to date of transfer to SD from week 3 onwards. As with green leaf drop, red leaf/bract drop was lower for plants grown in close spaced treatments.

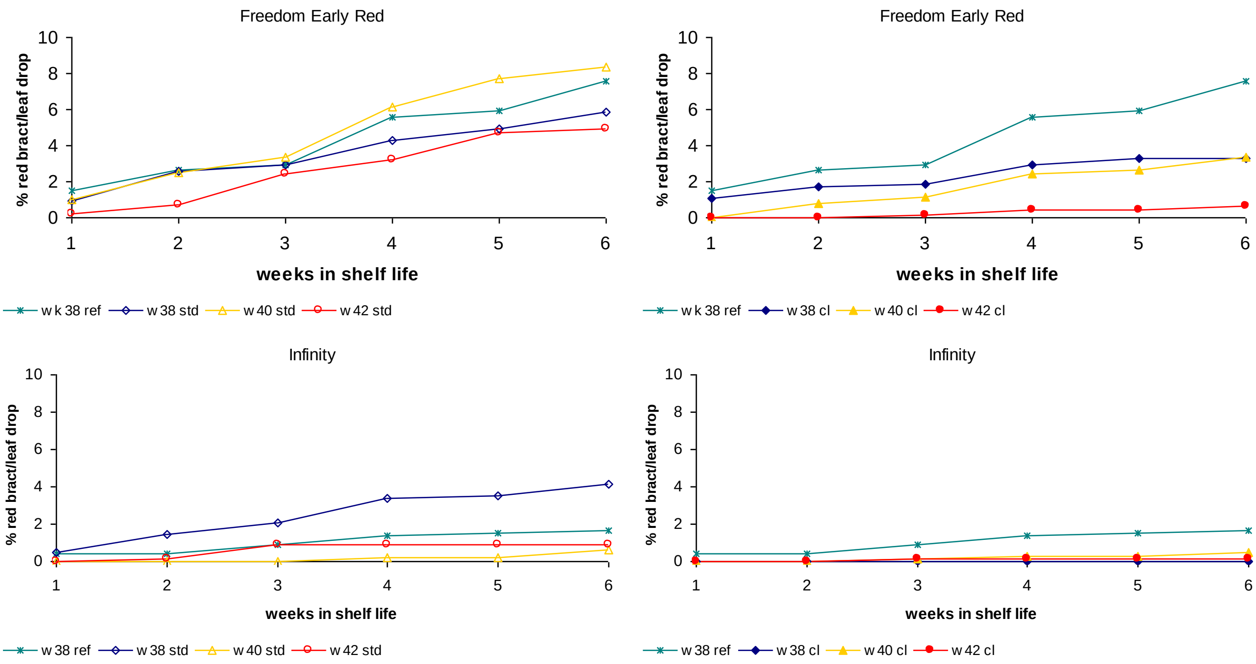


Figure 16. Percentage red bract/leaf loss in shelf life.

<u>Percentage cyathia drop</u>

Despite having comparable numbers of cyathia at marketing to other treatments, Freedom Early Red potted in week 31 had lost all cyathia before the start of shelf life assessments (i.e. they had presumably dropped off during the transport simulation/sleeve removal phases). Hence although this variety has no cyathia drop recorded in shelf life, it had in fact lost 100% of its cyathia before the first assessment (figure 17). The late potted Freedom Early Red treatments had slightly higher cyathia drop associated with the greatest delay in initiation (SD in week 42). Late potted Infinity had the lowest cyathia drop when transfer to SD was delayed to week 42 (i.e. latest initiation) whilst drop from the week 30 reference crop was comparable to that from the late potted plants moved to SD in week 38 or week 40.

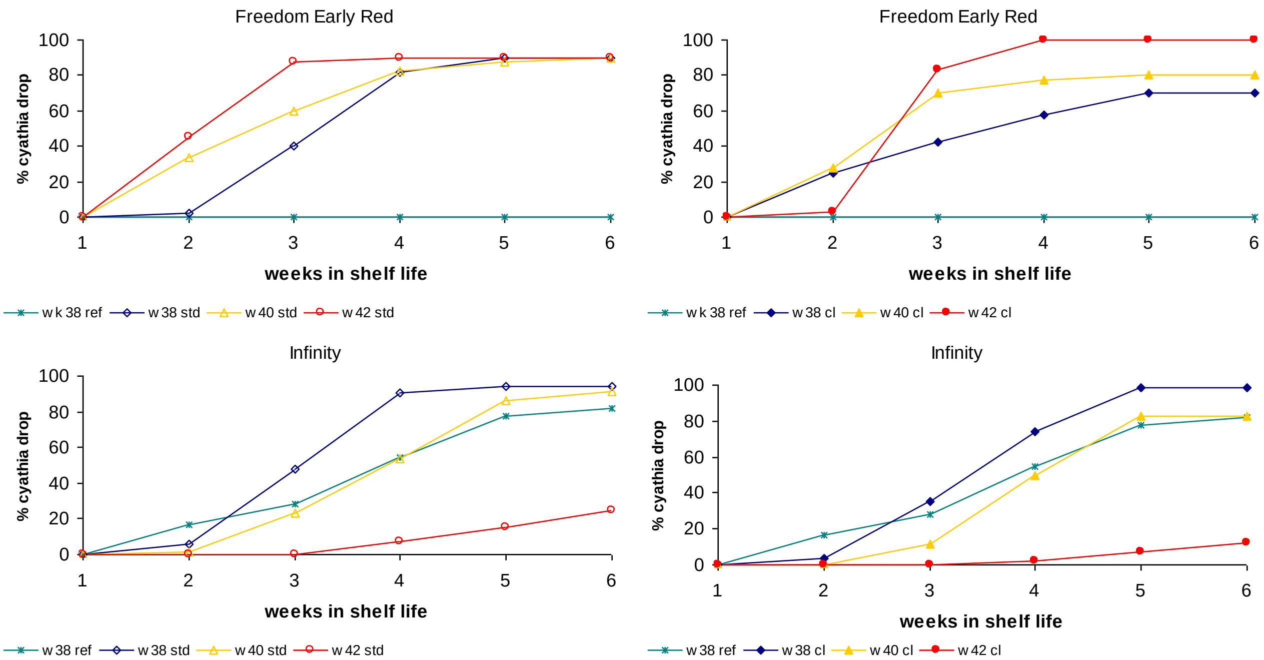


Figure 17. Percentage cyathia drop in shelf life.

<u>Quality score</u>

Quality score during shelf life was similar for Freedom Early Red in all treatments (Figure 18). Infinity potted in week 30 had higher initial quality but then had a greater subsequent decline in quality until week 3 when it had a comparable score to the week 34 potted treatments. The week 34 potted Infinity transferred to SD in week 42 stands out as having the lowest quality score throughout shelf life. Spacing does not appear to have affected quality score, despite reductions in green leaf drop associated with closer spacing noted previously.

In 2005, the week 30 potted reference treatment also had higher initial quality but faster subsequent decline and it was suggested that this might be related to earlier initiation. Since the week 30/31 reference treatments were given night-break lighting until week 38, initiation of this treatment would be expected to be comparable with the week 34 potted treatments moved to SD in week 38, hence these differences are unlikely to be due to date of initiation but may be related to the use of supplementary lighting.

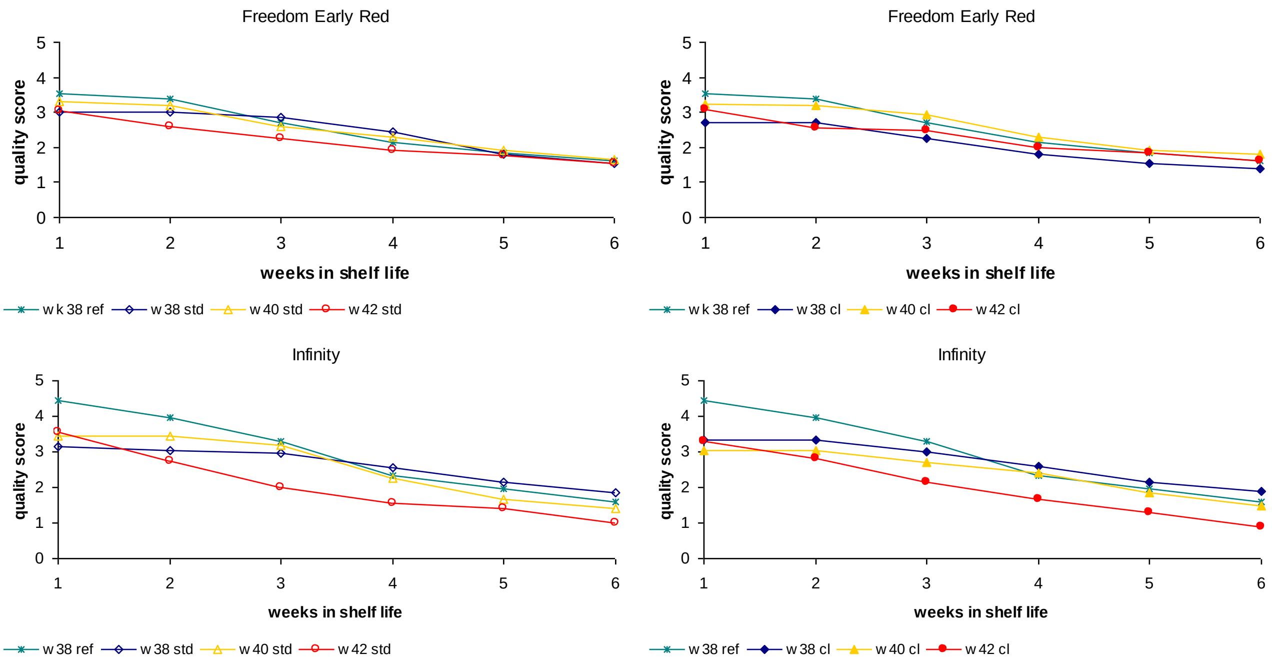


Figure 18. Quality score in shelf life.

2.3.3. Mineral Analysis

The growing medium used in 2006 had a low nitrogen base feed in comparison with 2005 (table 2) which resulted in unexpected low available total nitrogen concentration (around one fifth of the concentration in 2005). The frequency of feeding was modified to increase available N but overall N concentrations as monitored in the growing medium were low throughout production (generally between 20 and 30 mg/l and occasionally rising to 50 mg/l). Phosphorus in 2006 was also around one third of the concentration compared with 2005, whilst calcium and magnesium were around 3 times higher in the base feed in 2006 and 2005 which presumably contributed to the high conductivity in 2006. This low nutrient start may have contributed to the poor vigour in the late potted crops although apparently did not restrict the growth of the week 30 potted crop which was taller in 2006 than 2005 (see section 2.3.1). Irrigation frequency would be greater for the early stages of a week 30 potted crop compared with a week 34 potted crop, affording more opportunity to apply liquid feeding.

Leaf samples analysed at final harvest had comparable nutrient concentrations in 2006 to samples taken at the same stage in 2005, indicating that liquid feeding had supplied sufficient N by this stage but this does not help determine if nutrition was limiting growth early on in production. There were no indications of differences relating to potting date or date of transfer to SD on the nutrient status of the growing medium during production in 2006.

		2005	2006
pH		6.10	5.92
Conductivity	**µS/cm (20°C)**	173	376
Nitrate (as N)	**mg/l**	68.67	24.14
Ammonium (as N)	**mg/l**	36.26	0.15
Total N	**mg/l**	104.93	24.29
Potassium	**mg/l**	80.35	102.90
Calcium	**mg/l**	45.48	143.84
Magnesium	**mg/l**	26.28	79.73
Phosphorus	**mg/l**	26.70	9.78
Iron	**mg/l**	0.96	0.76
Zinc	**mg/l**	0.85	0.31
Manganese	**mg/l**	0.15	0.32
Copper	**mg/l**	0.15	0.06
Boron	**mg/l**	0.14	0.08
Sodium	**mg/l**	49.02	75.92
Chloride	**mg/l**	15.29	23.06
Sulphur	**mg/l**	53.67	67.29

Table 2. Comparison of base nutrition in growing media used in 2005 and 2006 experiments.

2.4. FINANCIAL ANALYSIS

The financial benefits 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)

These benefits need to be balanced against the following;

- 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. Ultrasonic heat meters measured the heat used in the form of hot water delivered to the greenhouse compartments. 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%.

Energy data analysis

The energy use associated with each treatment was calculated according the amount of time spent in each compartment. Figures 19 & 20 show the total gas and electricity consumption per m^2 where a difference occurs.

Cumulative energy use trends (kWh/m²)

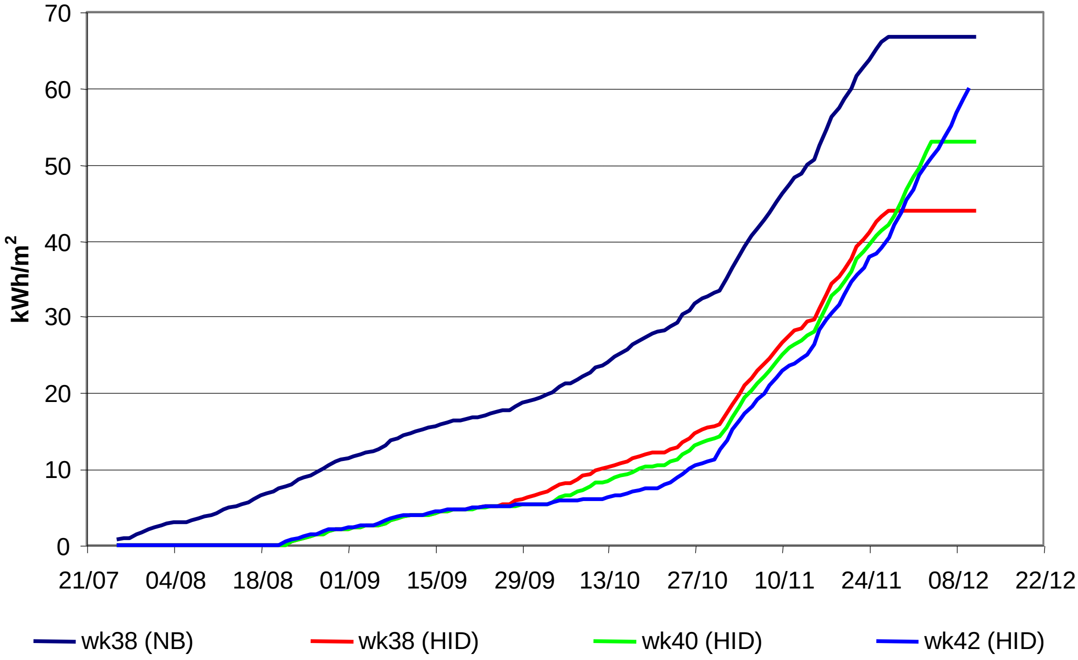


Figure 19. Cumulative gas use (once plants were marketed they ceased to consume further energy and hence cumulative energy use became static)

The late potted treatments grown with HID lighting (wk38-42 (HID)) used less gas for heat than the week 30 potted treatment (wk38 (NB)) due to both the later potting date and the waste heat from the supplementary lighting. Further differences between the HID treatments occurred due to the different lengths of time they spent with LD lighting thereby benefiting from more waste heat from the supplementary lighting.

Later in the season heat demand was high and any delay in the marketing date had a significant impact on the total amount of gas used for heating. This is clearly demonstrated in wk42 (HID) treatment which, although it was the lowest in late October, ended as the highest as it did not reach an acceptable colour until 2 weeks after wk38 (HID) plants.

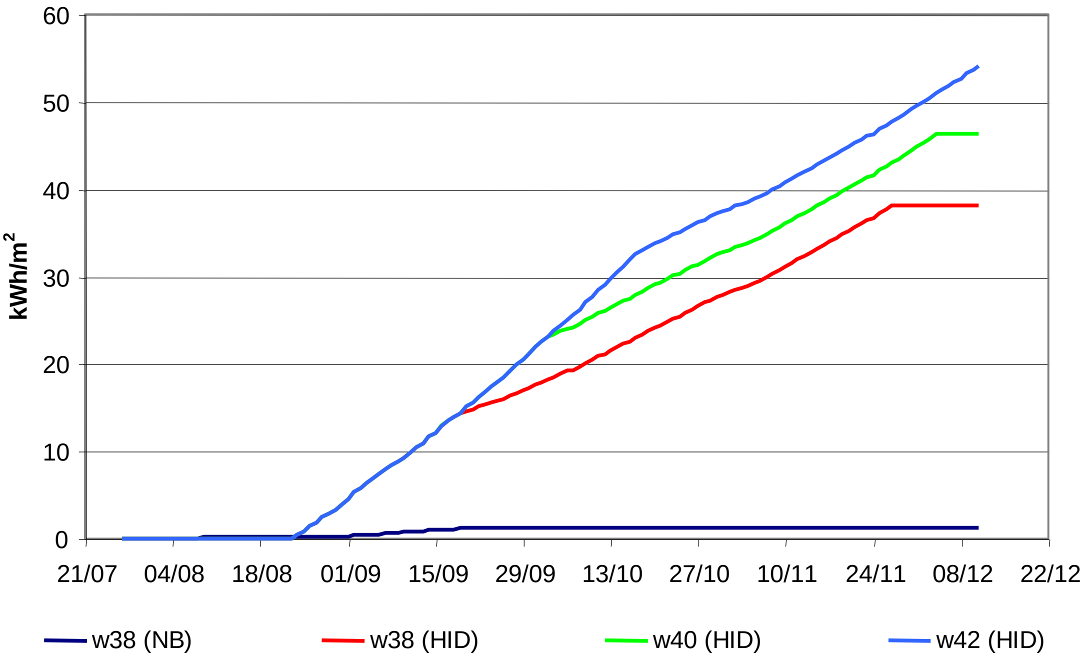


Figure 20. Cumulative electricity use

The wk38 (NB) reference crop used only minor amounts of electricity for night-break lighting compared to the treatments which used supplementary lighting. The HID treatments show the effect of using long day supplementary lighting for progressively longer periods. Plants transferred to SD in week 42 had the highest consumption by virtue of the fact that the switch to short days was 4 weeks later than for transfers in week 38 but also because delaying the start of SD meant it took longer to reach a marketable standard.

Total energy use per plant and per m²

Energy use per plant was calculated using the assumption that space utilisation was 100% at each plant density. This is rarely, if ever, the case especially when the crop is grown on the floor. The plants are grown close together but only occupy as little as 30% of the floor space at the first spacing after rooting. In this situation the energy use per pot is equal to the energy used per m^2 divided by the final plant density.

Energy use has also been presented as:

- Basic (or delivered) kWh i.e. the total of gas & electricity.
- Primary kWh which incorporates a factor of x 2.6 for electricity to reflect the efficiency of electricity generation and therefore its environmental impact.

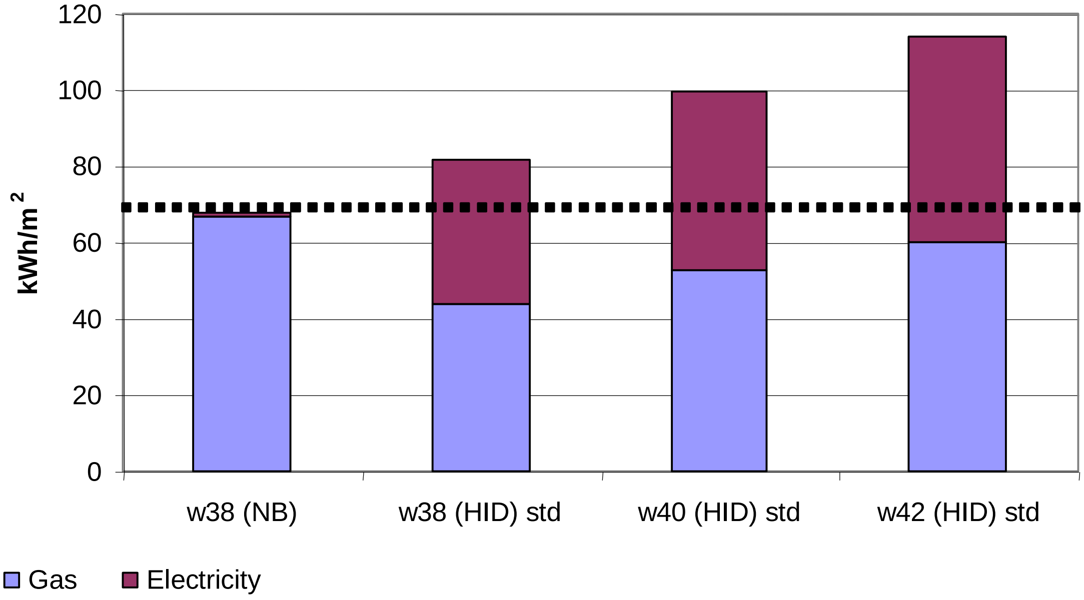


Figure 21. Basic energy use per m^2

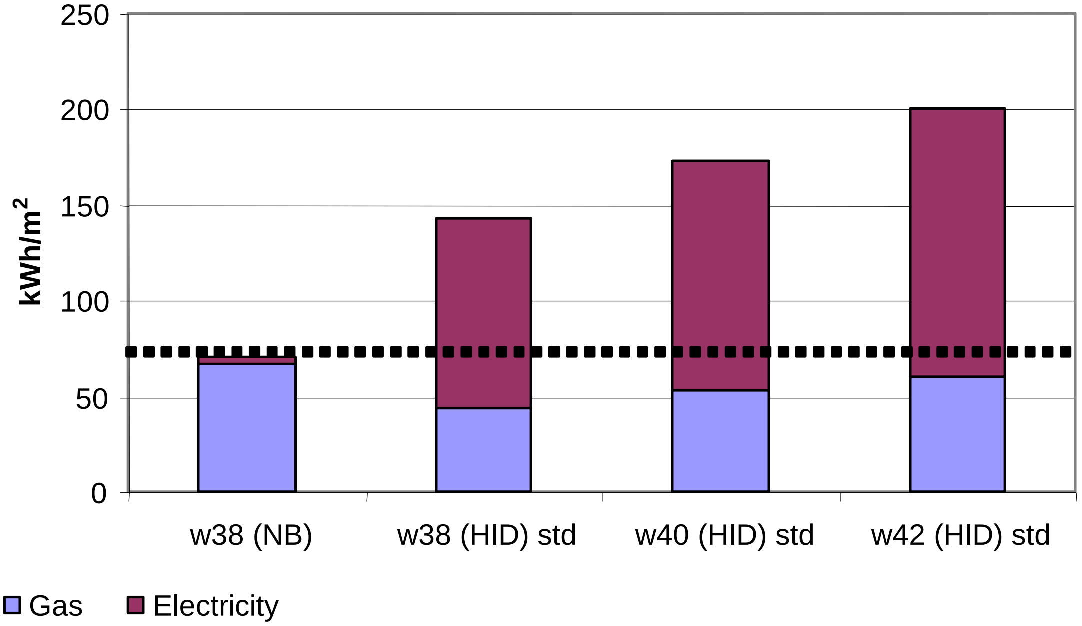


Figure 22. Primary energy use per m^2

Late season potting clearly delivers some saving in gas use. However, the saving is small as it occurs during the summer months when heat demand is low. Further savings in gas use result from the waste heat from the supplementary lighting but this has little impact compared to the much higher electricity requirement. The primary energy use for the wk38 (NB) reference crop averaged 68.7kWh/m^2 compared to the best late potted crop wk38 (HID) at 142.8kWh/m^2 (108% more).

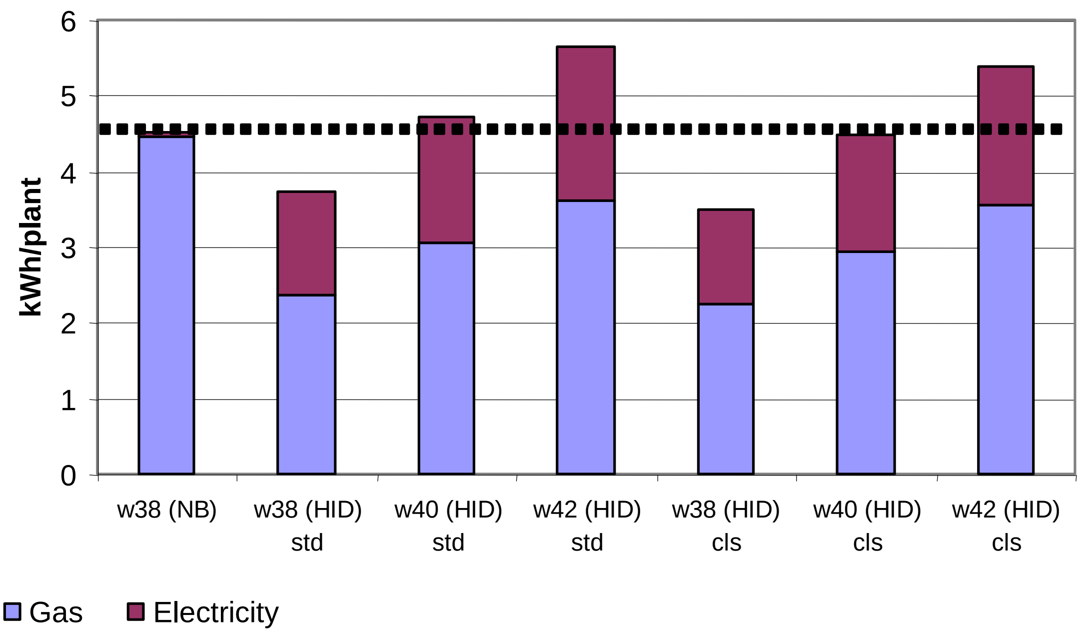


Figure 23. Basic energy use per plant

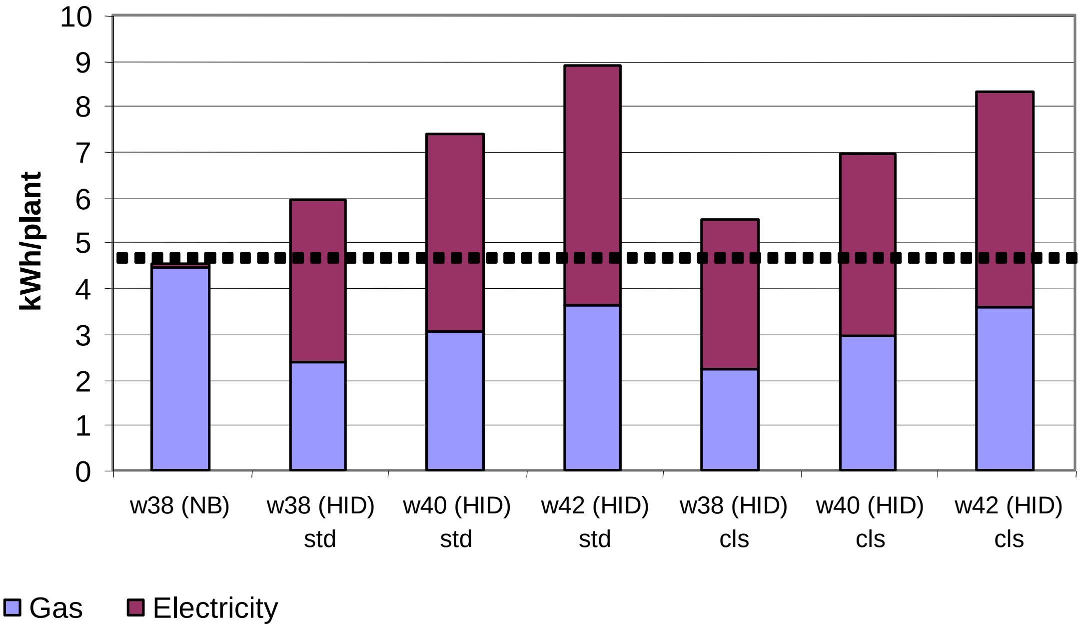


Figure 24. Primary energy use per plant

Calculating the energy use per plant illustrates how spacing impacts on the energy use per pot (Figure 23 & Figure 24). This significantly improves the figures for the late potted crop compared to the kWh/m^2 figure. On this basis, the late potted treatment with the lowest primary energy input wk38 (HID) close only used 19.6% more energy (primary) than the week 30 potted reference crop.

Financial analysis

The energy cost has been calculated based on a gas price of 1.5p/kWh and an electricity price of 6.0p/kWh. These are considered to be typical of energy costs at the time of writing this report.

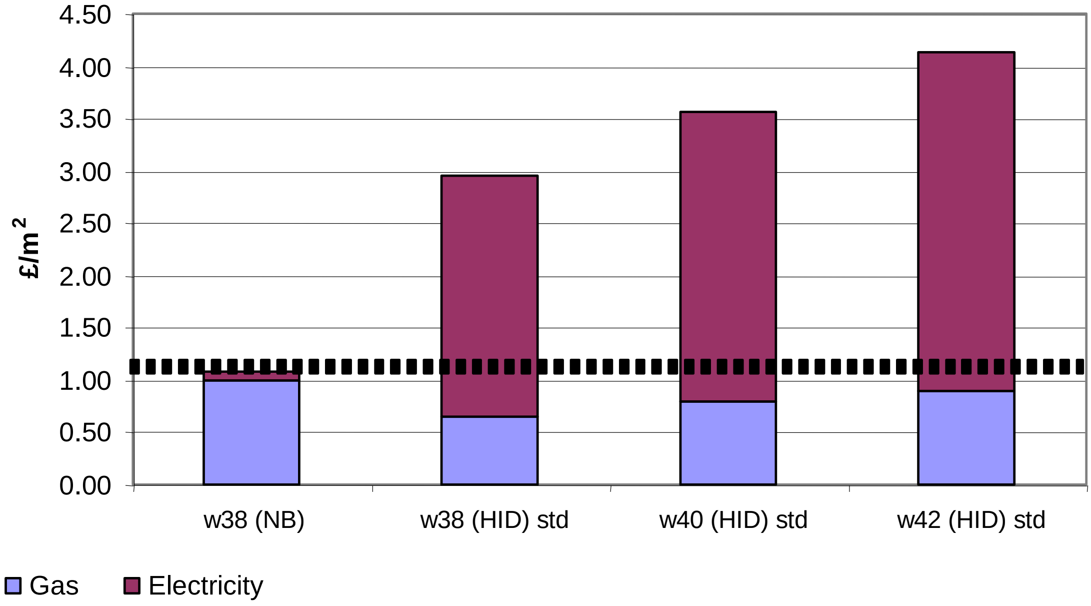


Figure 25. energy cost per m^2

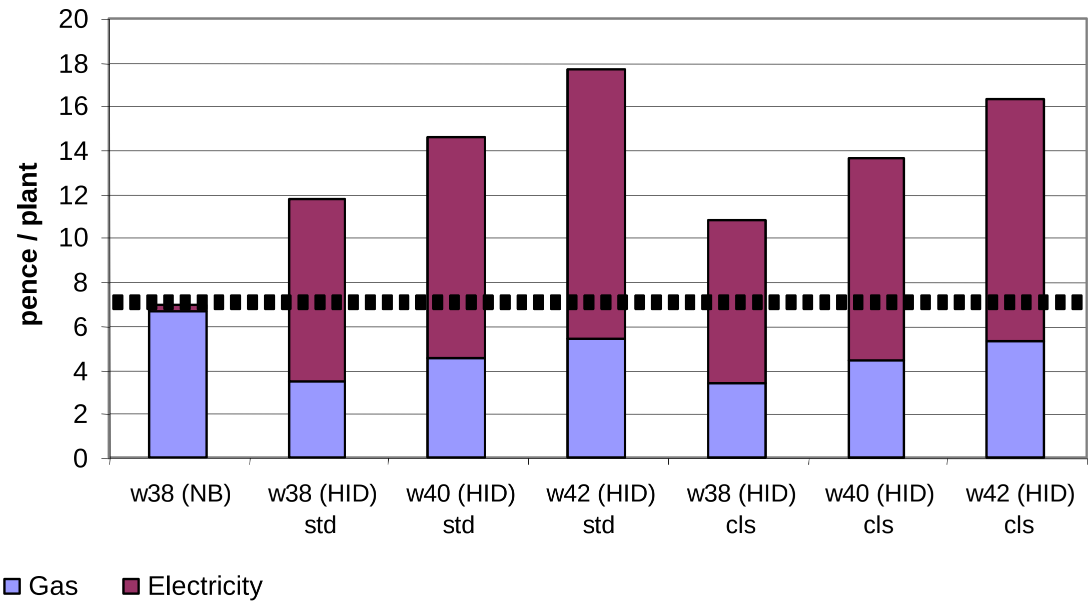


Figure 26. Total energy cost per plant

The average energy cost for the reference crop was 6.9p/plant. The cheapest late potting crop was wk38 (HID) grown at close spacing, which cost 10.8p/plant (+54%). It should be noted that these figures assume perfect space utilisation. As the efficiency of space utilisation reduces, the difference between natural season and late potted plants will increase. Figure 27 compares the total cost per plant assuming ideal space utilisation (as in Fig 26) with:

- Plants are grown pot thick at 100% space utilisation
- Plants are then allocated to a greenhouse depending on their final density and progressively spaced to fill unused area around them

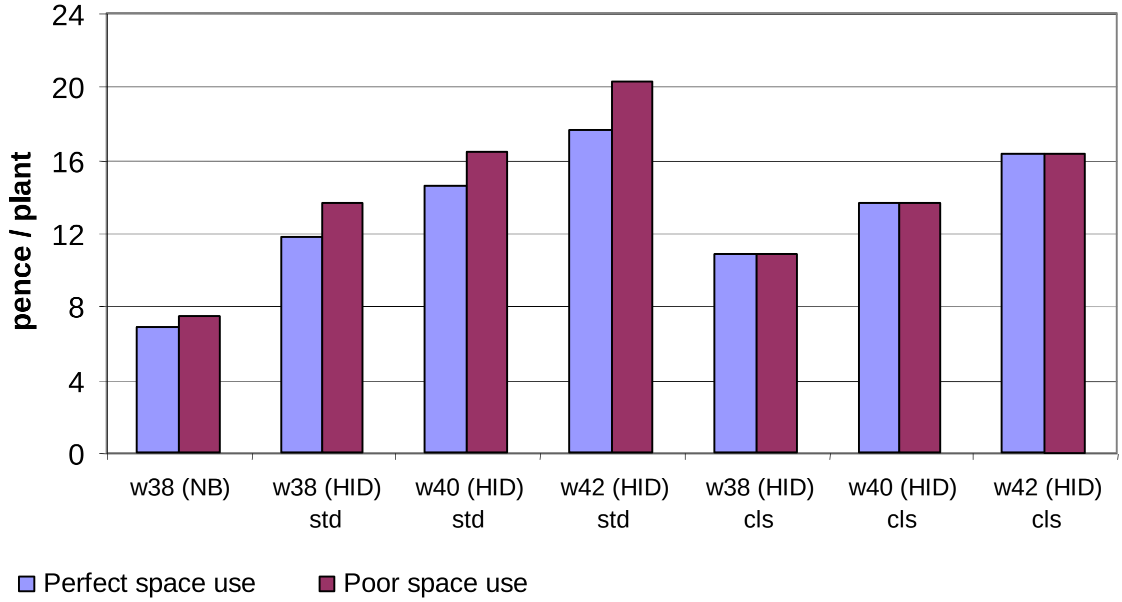


Figure 27. Effect of space use efficiency

As can be seen, poor space utilisation has no effect on the treatments grown at close spacing. This is because they are transferred straight from pot thick to the final density of 15/m^2+ whereas treatments grown at standard spacing incur an increase of 2 – 3p/plant (approx. 15%).

All of the costs presented relate to the direct energy cost and have not taken account of any depreciation or maintenance costs associated with the supplementary lighting installation. It is likely that any grower considering adopting this approach will only do so if there is an existing lighting installation i.e. no capital investment is required. The depreciation and maintenance costs allocated to a specific crop will vary widely depending on the use of the lights throughout the whole year.

Comparison with 2005

Tables 3 & 4 below detail the natural season and late potted treatments in 2005 & 2006 for which the energy data is most directly comparable. The 2005 costs have been recalculated using the energy costs applied to the 2006 data as this more accurately reflects current prices.

	Treatment	**kWh/m²**			**kWh/plant**		
		Gas	Elec.	Total	Gas	Elec.	Total
2005	w38 (NB)	66.0	0.0	66.0	5.8	0.0	5.8
2006	w38 (NB)	66.8	1.2	68.0	4.5	0.0	4.5
2005	w38 (HID) std	46.0	39.0	85.0	2.5	1.5	4.0
2006	w38 (HID) std	43.8	38.1	81.9	2.3	1.4	3.7
2005	w38 (HID) close	46.0	39.0	85.0	2.4	1.4	3.8
2006	w38 (HID) close	43.8	38.1	81.9	2.2	1.2	3.4

Table 3. Comparison of basic energy use of week 30 and week 34 potted crops in 2005 and 2006.

	Treatment	**£/m²**			**pence/plant**		
		Gas	Elec.	Total	Gas	Elec.	Total
2005	NS	0.99	0.00	0.99	9	0	9
2006	w38 (NB)	1.00	0.07	1.07	7	0	7
2005	w38 (HID) std	0.69	2.34	3.03	4	9	13
2006	w38 (HID) std	0.66	2.29	2.95	4	8	12
2005	w38 (HID) close	0.69	2.34	3.03	4	9	13
2006	w38 (HID) close	0.66	2.29	2.95	3	7	11

Table 4. Comparison of energy cost for week 30 and week 34 potted crops in 2005 and 2006.

In 2006, the natural season treatment used 3% more energy per m² but 23% less per plant. This is due to the fact that in 2006 the final density was 12/m² compared to 9/m² in 2005. The remaining two comparisons used on average 4% less per m² and 8% less energy per plant in 2006. Subtle variations in the treatments combined with a relatively mild autumn / winter mean that it is difficult to draw any firm conclusions other than they are broadly similar in each year.

The same pattern is reflected in the cost per plant.

Costs vs Benefits

The estimated increase in gross margin for potting poinsettias 4 weeks later and using the increased available space productively was calculated as part of project PC 208 to be £4.55 to £7.64 /m² (assuming returns of £1.50 to £1.70 per pot). The increased energy costs associated with potting in week 34 have been comparable in 2005 and 2006 at an average of £1.96/m² above the cost of a standard week 30 potted crop. There is also a smaller cost associated with the supply of CO_2 at around £0.16 /m² assuming pure CO_2 is used (see PC 243 annual report 2005). Taking these extra costs from the predicted increased margin from PC 208 gives a margin of £2.44 - £5.53 /m² for week 34 potting. This margin would reduce to £1.71 to £4.80 /m² if the week 34 potted crop was also delayed to week 40 before transferring to SD. This treatment would represent a compromise between the delays in marketing resulting from transferring to SD in week 42 and the smaller plant size as a result of transferring to SD in week 38. As emphasised previously these figures assume fully efficient space use which includes extra cropping in the 4 weeks prior to a week 34 potting as well as using the space available until the week 34 crop is moved from pot thick (around week 40).

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 week 30 potted crop received a total of 21 applications during production whilst the week 34 potted crop received 18 applications (appendix 1, table 6), a saving of 15% on number of applications.

2.5 DISCUSSION

Data collected in 2005/06 (year 1 of this project), indicated that potting in week 32 and growing with supplementary lighting could produce comparable plant quality to natural season production. Potting in week 34 produced plants that were smaller and lower quality but generally deemed suitable for marketing. The focus in 2006/07 therefore moved towards week 34 potted plants as the treatment in greatest need of further verification. Achieving adequate plant height was a challenge for week 34 potted plants in 2006 resulting in a high proportion of plants below minimum height and therefore unacceptable. In a commercial setting, there would be greater flexibility to manipulate temperatures in order to increase plant height if required (although using a higher vent rather than increasing heating set points would be the more cost effective method of doing this if possible). It would also be important to adjust height tracking to account for the different growth curve resulting from later potting and lighting. It is assumed that the delay effect of the night-break lighting contributed to the taller week 30 potted plants in 2006 compared with 2005. It is less obvious why the week 34 potted plants were much shorter in 2006 than in 2005. Slightly lower achieved temperatures and problems with initial plant quality may have contributed to these differences. In particular the week 34 potted Freedom Early Red cuttings were rooted earlier than required for the start of the experiment and hence were given a hard pinch when they arrived which may have reduced the extension growth of the lower shoots in particular. Quality of the Infinity cuttings was also variable but more readily graded out. Low initial total N concentration in the growing medium may also have restricted early plant vigour although the impact was felt on the late potted plants rather than the reference crop (possibly because of the increased opportunity for watering and hence feeding with early potting).

Delaying the start of SD increased production time due to later bract colouring, and also increased vegetative parameters such as plant height and spread. A balance therefore needs to be found between the required plant size and the acceptable level of bract colour visible from the top of the plant. It is widely assumed that the higher the proportion of red colour at the top of the plant the better for customers. On this basis, the reduction of red colour for late potted plants with SD delayed to week 40 or week 42 (at 62-75% for Infinity) may be detrimental. However there is a market for plants with lower % red colour which are often available at the start of the season. It will be interesting to see if new HDC funded work with focus groups will clarify what proportion (or range of proportions) of red colour is (are) preferred by the end customer.

Infinity produced adequate plant quality from week 34 potting in 2005/06 and 2006/07. Freedom Early Red was included in 2006/07 to assess if the delay effect of starting SD later than normal in the season might be minimised by the faster colouring up of a short response group variety. Freedom Early Red did have a higher proportion of % red cover at marketing after having a delayed transfer to SD compared with Infinity. However, this shorter response may have limited the extra vegetative growth resulting from delays in initiation since parameters such as plant height were increased by delayed initiation to a lesser extent for Freedom Early Red than for Infinity.

Overall quality at marketing reflected initial quality scores in shelf life, and hence the higher quality week 30 potted plants had higher initial scores in shelf life than the week 34 potted plants. However initial decline in quality score of the week 30 potted Infinity from week 1 to week 3 after removing sleeves was greater than for Infinity potted in week 34 and hence quality was comparable for all treatments during the latter stages of shelf life. Freedom Early Red had higher green leaf and red leaf/bract drop than Infinity but had no significant differences relating to late potting or overall quality during shelf life.

Overall potting in week 34 and growing with supplementary lighting of around 10 W/m² PAR and CO_2 enrichment with a 1000 ppm set point, can be expected to produce a shorter plant with fewer bract stars than potting in week 30. The light intensity chosen would need to account for background light levels (i.e. geographical location) and increasing the intensity of lighting would be expected to improve the quality of late potted plants, although this would of course also increase energy consumption and therefore cost. The suitability of this type of production will therefore depend on markets supplied, it may be that a minimum specification is all that is required and there is no achievable price increase for exceeding this level. In this case, it would be possible to improve returns by increasing throughput per m² (e.g. by late potting which can be grown closer and also making use of the space made available by extra summer production). Financial analysis suggests this approach might be viable, assuming fully efficient space use and that the nursery already has supplementary lighting available. It is clear that with late potting, any attempts to maximise quality will increase production costs. For example, delaying SD to week 42 resulted in the greatest increase in vegetative growth (height, spread) but delayed marketing and hence increased production costs to cover heating and lighting; furthermore the increases in vegetative growth measures were insufficient to impact on overall quality score at marketing.

2.6 CONCLUSIONS

Potting in weeks 32 and 34 and growing with 10W/m² PAR supplementary lighting and CO_2 enrichment with a 1000 ppm set point has produced marketable plants in 2005 and 2006, with the best quality resulting from a week 32 potting.

Week 34 plants were generally below the minimum specification for height in 2006 and just above the minimum specification in 2005. Careful height management tracking will therefore be essential in order to maximise the percentage grade out of a week 34 potted crop. In 2005, potting in week 32 and lighting produced plants well within specifications.

Late potting may be combined with delayed initiation in order to maximise plant height but this may increase production costs if delays also result in delayed marketing.

The energy costs associated with late potting and lighting have been comparable in 2005 and 2006 and suggest the approach may be viable assuming efficient use of the space made available and returns of at least £1.50 per pot for the late potted product.

2.7 TECHNOLOGY TRANSFER

HDC Poinsettia and Cyclamen Open Day at Warwick HRI Wellesbourne 21st November 2006.

HDC Poinsettia and Cyclamen Open Day at Warwick HRI Kirton 18th January 2007.

Shaddick, C. (2007). Later potting, faster production. HDC News: 130, p30.

Fuller, D.P. (2007). Making late potting pay. HDC News: 135, p30.

2.8 REFERENCES

PC 13c. Chrysanthemum: The influence of Supplementary lighting on winter quality and shelf life of American bred varieties of pot ‘mums. Final report (1994).

PC 208. Poinsettia: assessment of the value of lighting a late crop to improve throughput. Final Report (2004).

PC 243. Poinsettia: Assessment of strategies for efficient utilisation of nursery resources. Annual Report (2006).

Appendix 1. Summary of key agronomic treatments

Table 5. General agronomy:

Wk 30 plants:

26/07/06	Potted Infinity
02/08/06	Potted Freedom Early Red
10/08/06	Pinched Infinity and Freedom Early Red to 6-7 leaves
18/08/06	Graded Infinity
22/08/06	Graded Freedom Early Red
29/08/06	Cycocel started as a light spray to even up shoot extension (see table 10 for details of applications)
07/09/06	Plants spaced to 30 pots/m²
15/09/06	Spaced Infinity to15 pots/m²
21/09/06	Spaced Freedom Early Red to 15 pots/m²
10/10/06	Spaced Infinity to12 pots/m²
17/10/06	Spaced Freedom Early Red to 12 pot/m²
28/11/06	Marketing records started
04/12/06	Plants sleeved and boxed for transport to shelf life at Kirton.

Wk 34 plants:

24-25/08/06	Potted Freedom Early Red and Infinity
07-08/09/06	Pinched and graded Freedom Early Red
11-12/09/06	Pinched and graded Infinity
01/09/06	Cycocel started as a light spray to even up shoot extension (see table 10 for details of applications)
04/10/06	Spaced standard treatment plants to 30 pots/m²
26/10/06	Spaced all plants to 15 pots/m²
28/11/06	Marketing records started
04/12/06	Plants from week 40 transfers sleeved and boxed for transport to shelf life at Kirton.
11/12/06	Plants from week 42 transfers sleeved and boxed for transport to shelf life at Kirton.

Table 6. Cycocel use (ml/litre):

Date	Week 30/1 potting		Week 34 potting	
	Freedom Early Red	Infinity	Freedom Early Red	Infinity
28/08/2006		1.00		
01/09/2006		1.00		
06/09/2006	1.00	1.00		
12/09/2006	1.00	1.00		
15/09/2006	1.00	1.00	1.00	1.00
19/09/2006	1.00	1.00	1.00	1.00
26/09/2006	1.00	1.00	1.00	1.00
29/09/2005	1.00	1.00	1.00	1.00
03/10/2006	1.00	1.00	1.00	1.00
06/10/2006	1.00	1.00	1.00	1.00
09/10/2006	1.00	1.00	1.00	1.00
13/10/2006	1.00	1.00	1.00	1.00
17/10/2006	1.00	1.00	1.00	1.00
20/10/2006	0.50	0.50	0.50	0.50
21/10/2006	0.50	0.50		
24/10/2006	0.50	0.50	0.50	0.50
27/10/2006	0.50	0.50	0.50	0.50
31/10/2006			0.50	0.50
03/11/2006	0.50	0.50	0.50	0.50
07/11/2006	0.50	0.50	0.50	0.50
10/11/2006	0.50	0.50	0.50	0.50
14/11/2006	0.50	0.50	0.50	0.50
17/11/2006			0.50	0.50
Total no. applications	***19***	***21***	***18***	***18***
Sum of rates applied	***15.00***	***17.00***	***13.50***	***13.50***

IPM Details:
Steinernema drench for *Sciarid* control – 5 applications from 16/08/06 to 17/10/06.

Amblyseius cucumeris for thrips control – monthly from 16/08/06.

Phytoseiulus for red spider mite control – monthly from 16/08/06.

Encarsia and *Eretmocerus* for whitefly control – weekly from 16/08/06.

Sprayed with Oberon at 0.5 ml/l for *Bemisia* prevention 09/08/06, 23/08/06 and 04/09/06.

Sprayed with Sythane 20 EW at 0.45 ml/l 29/10/06 as a preventative against powdery mildew.

Drenched with Subdue at 1ml/l for prevention of *Phytophthora* 10/11/06.

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

Environmental control:
Where B7 = week 30 potted crop (no HID lighting_
B6 = week 34 potted crop using HID lighting for 20 hours per day
B5 = week 34 potted crop with HID lighting for 11 hours per day

25/07/06
Heating set to 21°C day and 19°C night with venting +2°C.
Shade screen set to close at 350 W/m².
CO_2 enrichment to 1000 ppm during day* time when vents closed, ramping down to 350 ppm 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.*

01/08/06
Blackouts turned on for energy saving in B5-B7 (i.e. close at dusk, open at dawn with temperature gapping when temp is 4°C above set point to a maximum gap of 4% at 8°C above set point and gapping for RH above 83% to max gap of 4% at 93% RH) in B5-B7.

14/08/06
Screen threshold B7 up to 500 W/m².

10/08/06
Started HID lighting in B6 on 01:00 - 21:00 at 10 W/m² on a threshold of 200 W/m².

31/08/06
Shade screen threshold to 550 W/m² in B6 (1 week from potting). Set cyclic lighting to come on in B7 (22:00 to 02:14; 15 mins on per 30 mins), using tungsten lights – to be changed over to fluorescent bulbs as soon as possible.

04/09/06
B7 - Change tungsten bulbs for 23W fluorescent bulbs and changed night-break lighting setting to keep lights on constantly from 22:30 to 2:30.

06/09/06
Increased shade threshold to 850 W/m².

11/09/06
Temperature integration started in B5-B7. Set for 21°C day, 19° night with 15°C as a minimum temperature and 3 day integration period.

20/09/06
Started HID lighting in B5 on 06:30 - 17:30 at 10 W/m² on a threshold of 200 W/m². Switched off day extension lighting in B7 to return to ambient day-length..

Appendix 2 Shelf life data

Quality Score			No. weeks from removing sleeves					
Potting week	Date moved to SD	Spacing	1	2	3	4	5	6
Freedom Early Red								
30	wk 38	std	3.6	3.4	2.7	2.2	1.9	1.6
34	wk 38	close	2.7	2.7	2.3	1.8	1.6	1.4
34	wk 38	std	3.0	3.0	2.9	2.5	1.8	1.6
34	wk 40	close	3.3	3.2	3.0	2.3	1.9	1.8
34	wk 40	std	3.3	3.2	2.6	2.3	1.9	1.7
34	wk 42	close	3.1	2.6	2.5	2.0	1.9	1.6
34	wk 42	std	3.1	2.6	2.3	1.9	1.8	1.6
Infinity								
30	wk 38	std	4.5	4.0	3.3	2.4	2.0	1.6
34	wk 38	close	3.4	3.4	3.0	2.6	2.2	1.9
34	wk 38	std	3.2	3.1	3.0	2.6	2.2	1.9
34	wk 40	close	3.1	3.1	2.7	2.4	1.9	1.5
34	wk 40	std	3.5	3.5	3.2	2.3	1.7	1.4
34	wk 42	close	3.3	2.8	2.2	1.7	1.3	0.9
34	wk 42	std	3.6	2.8	2.0	1.6	1.4	1.0
L.S.D. (5%)			0.6	0.7	NS	NS	NS	NS

% Green Leaf Drop			No. weeks from removing sleeves					
Potting week	Date moved to SD	Spacing	1	2	3	4	5	6
Freedom Early Red								
30	wk 38	std	2.7	6.2	7.9	14.6	15.5	16.8
34	wk 38	close	1.9	3.2	5.5	10.4	10.7	11.1
34	wk 38	std	2.1	5.1	8.9	12.4	14.8	17.1
34	wk 40	close	1.3	2.9	3.5	5.9	6.9	7.9
34	wk 40	std	2.6	7.7	11.1	16.1	17.9	18.6
34	wk 42	close	1.1	1.7	5.2	6.8	6.8	7.2
34	wk 42	std	1.4	5.3	14.2	18.3	19.0	21.6
Infinity								
30	wk 38	std	1.3	2.4	5.8	9.5	10.6	13.0
34	wk 38	close	0.0	0.0	2.5	5.2	6.0	7.2
34	wk 38	std	2.3	4.2	5.0	9.1	10.4	11.8
34	wk 40	close	0.0	0.0	0.2	1.0	1.9	2.8
34	wk 40	std	0.6	1.8	3.7	7.1	10.6	12.0
34	wk 42	close	0.0	0.2	0.3	1.0	1.7	2.0
34	wk 42	std	0.7	1.5	3.9	5.9	7.0	8.3
L.S.D. (5%)			2.1	3.8	7.1	8.6	8.7	9.0

% Red Leaf/Bract Drop			No. weeks from removing sleeves					
Potting week	Date moved to SD	Spacing	1	2	3	4	5	6
Freedom Early Red								
30	wk 38	std	1.5	2.6	2.9	5.6	5.9	7.6
34	wk 38	close	1.1	1.7	1.9	2.9	3.3	3.3
34	wk 38	std	0.9	2.6	2.9	4.3	4.9	5.8
34	wk 40	close	0.0	0.8	1.2	2.5	2.7	3.4
34	wk 40	std	1.0	2.5	3.3	6.1	7.7	8.4
34	wk 42	close	0.0	0.0	0.1	0.5	0.5	0.6
34	wk 42	std	0.2	0.7	2.4	3.2	4.7	4.9
Infinity								
30	wk 38	std	0.4	0.4	0.9	1.4	1.5	1.6
34	wk 38	close	0.0	0.0	0.0	0.0	0.0	0.0
34	wk 38	std	0.5	1.4	2.1	3.4	3.5	4.1
34	wk 40	close	0.0	0.0	0.2	0.3	0.3	0.5
34	wk 40	std	0.0	0.0	0.0	0.2	0.2	0.6
34	wk 42	close	0.0	0.0	0.1	0.1	0.1	0.1
34	wk 42	std	0.0	0.1	0.9	0.9	0.9	0.9
L.S.D. (5%)			0.8	1.6	2.3	3.3	3.9	4.0

% Cyathia Drop			No. weeks from removing sleeves					
Potting week	Date moved to SD	Spacing	1	2	3	4	5	6
Freedom Early Red								
30	wk 38	std	0.0	0.0	0.0	0.0	0.0	0.0
34	wk 38	close	0.0	25.0	42.5	57.5	70.0	70.0
34	wk 38	std	0.0	2.5	40.3	82.0	90.0	90.0
34	wk 40	close	0.0	27.5	70.0	77.5	80.0	80.0
34	wk 40	std	0.0	33.3	60.0	82.5	87.5	90.0
34	wk 42	close	0.0	2.8	83.3	100.0	100.0	100.0
34	wk 42	std	0.0	45.0	87.5	90.0	90.0	90.0
Infinity								
30	wk 38	std	0.0	16.4	28.3	54.4	77.5	81.8
34	wk 38	close	0.0	3.9	35.4	74.1	98.3	98.3
34	wk 38	std	0.0	5.8	48.1	90.7	94.1	94.1
34	wk 40	close	0.0	0.0	11.7	50.0	82.5	82.5
34	wk 40	std	0.0	1.4	23.1	53.9	86.0	91.0
34	wk 42	close	0.0	0.0	0.0	2.5	7.5	12.5
34	wk 42	std	0.0	0.0	0.0	7.5	15.0	25.0
L.S.D. (5%)			NS	14.4	26.2	25.7	33.4	31.1

Bract Edge Blackening Score			No. weeks from removing sleeves					
Potting week	Date moved to SD	Spacing	1	2	3	4	5	6
Freedom Early Red								
30	wk 38	std	0.4	0.0	0.0	0.0	0.1	0.1
34	wk 38	close	0.4	0.1	0.0	0.0	0.0	0.0
34	wk 38	std	0.3	0.1	0.1	0.0	0.1	0.2
34	wk 40	close	0.2	0.1	0.1	0.2	0.3	0.3
34	wk 40	std	0.1	0.1	0.5	0.6	0.4	0.4
34	wk 42	close	0.0	0.0	0.0	0.0	0.0	0.0
34	wk 42	std	0.2	0.1	0.0	0.1	0.1	0.0
Infinity								
30	wk 38	std	0.0	0.1	0.1	0.1	0.1	0.1
34	wk 38	close	0.0	0.0	0.0	0.0	0.0	0.0
34	wk 38	std	0.0	0.1	0.1	0.1	0.1	0.2
34	wk 40	close	0.0	0.0	0.0	0.0	0.0	0.0
34	wk 40	std	0.0	0.0	0.0	0.0	0.0	0.0
34	wk 42	close	0.0	0.0	0.0	0.0	0.2	0.2
34	wk 42	std	0.0	0.0	0.1	0.1	0.1	0.1
L.S.D. (5%)			0.4	NS	0.2	0.2	NS	NS

Upper Green Leaf Score			No. weeks from removing sleeves					
Potting week	Date moved to SD	Spacing	1	2	3	4	5	6
Freedom Early Red								
30	wk 38	std	5.0	5.0	5.0	5.0	5.0	4.9
34	wk 38	close	5.0	5.0	5.0	5.0	5.0	5.0
34	wk 38	std	5.0	5.0	5.0	5.0	5.0	5.0
34	wk 40	close	5.0	5.0	5.0	5.0	5.0	5.0
34	wk 40	std	5.0	5.0	5.0	5.0	5.0	5.0
34	wk 42	close	5.0	5.0	5.0	5.0	5.0	5.0
34	wk 42	std	5.0	5.0	4.9	4.9	4.7	4.7
Infinity								
30	wk 38	std	5.0	5.0	5.0	5.0	5.0	5.0
34	wk 38	close	5.0	5.0	5.0	5.0	5.0	5.0
34	wk 38	std	5.0	5.0	5.0	5.0	5.0	5.0
34	wk 40	close	5.0	5.0	5.0	5.0	5.0	5.0
34	wk 40	std	5.0	5.0	5.0	5.0	5.0	4.9
34	wk 42	close	5.0	5.0	5.0	5.0	4.9	4.8
34	wk 42	std	5.0	5.0	4.8	4.8	4.8	4.7
L.S.D. (5%)			NS	NS	NS	NS	NS	NS

Lower Green Leaf Score			No. weeks from removing sleeves					
Potting week	Date moved to SD	Spacing	1	2	3	4	5	6
Freedom Early Red								
30	wk 38	std	5.0	4.9	4.9	4.6	4.4	4.0
34	wk 38	close	5.0	4.9	4.8	4.6	4.7	4.6
34	wk 38	std	5.0	5.0	4.8	4.9	4.6	4.4
34	wk 40	close	5.0	5.0	5.0	4.9	4.9	4.6
34	wk 40	std	5.0	4.9	4.9	4.7	4.3	4.3
34	wk 42	close	5.0	4.8	4.5	4.2	4.0	3.5
34	wk 42	std	4.9	4.6	4.3	3.9	3.9	3.5
Infinity								
30	wk 38	std	5.0	4.8	4.5	4.5	4.2	3.8
34	wk 38	close	5.0	5.0	4.9	4.9	4.8	4.7
34	wk 38	std	5.0	4.9	5.0	4.9	4.8	4.7
34	wk 40	close	5.0	5.0	5.0	4.9	4.6	4.6
34	wk 40	std	5.0	5.0	5.0	4.8	4.6	4.5
34	wk 42	close	5.0	5.0	5.0	4.8	4.6	4.5
34	wk 42	std	5.0	5.0	4.7	4.6	4.3	3.9
L.S.D. (5%)			NS	NS	NS	NS	NS	NS

Red Bract Score			No. weeks from removing sleeves					
Potting week	Date moved to SD	Spacing	1	2	3	4	5	6
Freedom Early Red								
30	wk 38	std	5.0	4.9	4.5	4.3	4.3	3.8
34	wk 38	close	5.0	4.9	4.6	4.5	4.2	4.0
34	wk 38	std	5.0	5.0	4.8	4.5	4.1	3.8
34	wk 40	close	5.0	5.0	4.8	4.5	4.2	4.0
34	wk 40	std	5.0	5.0	4.7	4.5	4.2	3.8
34	wk 42	close	5.0	4.9	4.5	4.3	4.2	3.8
34	wk 42	std	5.0	4.7	4.4	4.1	4.0	3.6
Infinity								
30	wk 38	std	5.0	5.0	4.7	4.4	4.1	3.5
34	wk 38	close	5.0	5.0	4.7	4.5	4.2	3.7
34	wk 38	std	5.0	5.0	4.9	4.6	4.1	3.8
34	wk 40	close	5.0	4.8	4.3	4.1	3.5	3.0
34	wk 40	std	5.0	5.0	4.8	4.3	4.0	3.7
34	wk 42	close	5.0	4.5	3.7	3.3	2.5	2.0
34	wk 42	std	4.9	4.4	3.8	3.2	2.9	2.2
L.S.D. (5%)			NS	0.3	0.39	0.44	0.53	0.86

Appendix 3. Tables to supplement energy analysis figures

Table 7. Treatment descriptions for energy analysis

						Plant spacing (pots/m²)			
Ref.	**Variety**	**Spacing**	**Potting date**	**LD start**	**Move to SD**	**30/m²**	**15/m²**	**12/m²**	**Date of marketing**
Week 30 potted reference crop (with night-break)									
w38 (NS)	Infinity	Standard	26/07/06	31/08/06	20/09/06	07/09/06	15/09/06	10/10/06	27/11/06
w38 (NS)	Freedom Early	Standard	02/08/06	31/08/06	20/09/06	07/09/06	21/09/06	17/10/06	27/11/06
Week 34 potted with supplementary lighting									
w38 (HID) std	Infinity/Freedom Early	Standard	23/08/06	23/08/06	20/09/06	04/10/06	26/10/06	n.a.	27/11/06
w40 (HID) std	Infinity/Freedom Early	Standard	23/08/06	23/08/06	04/10/06	04/10/06	26/10/06	n.a.	04/12/06
w42 (HID) std	Infinity/Freedom Early	Standard	23/08/06	23/08/06	18/10/06	04/10/06	26/10/06	n.a.	11/12/06
w38 (HID) close	Infinity/Freedom Early	Close	23/08/06	23/08/06	20/09/06	→	26/10/06	n.a.	27/11/06
w40 (HID) close	Infinity/Freedom Early	Close	23/08/06	23/08/06	04/10/06	→	26/10/06	n.a.	04/12/06
w42 (HID) close	Infinity/Freedom Early	Close	23/08/06	23/08/06	18/10/06	→	26/10/06	n.a.	11/12/06

Table 8 – Total energy use per m^2

Ref. No.	Variety	Gas	Electricity	*Total primary
Natural season (with night-break)				
w38 (NS)	Infinity	66.8	1.2	69.9
w38 (NS)	Freedom Early	64.5	1.2	67.5
With supplementary lighting				
w38 (HID) std	Infinity/Freedom Early	43.8	38.1	142.8
w40 (HID) std	Infinity/Freedom Early	53.0	46.2	173.1
w42 (HID) std	Infinity/Freedom Early	59.9	54.1	200.5
w38 (HID) close	Infinity/Freedom Early	43.8	38.1	142.8
w40 (HID) close	Infinity/Freedom Early	53.0	46.2	173.1
w42 (HID) close	Infinity/Freedom Early	59.9	54.1	200.5

Table 9 – Total energy use per plant

Ref. No.	Variety	Gas	Electricity	*Total primary
Natural season (with night-break)				
w38 (NS)	Infinity	4.5	0.04	4.6
w38 (NS)	Freedom Early	4.4	0.04	4.5
With supplementary lighting				
w38 (HID) std	Infinity/Freedom Early	2.3	1.4	5.9
w40 (HID) std	Infinity/Freedom Early	3.1	1.7	7.4
w42 (HID) std	Infinity/Freedom Early	3.6	2.0	8.9
w38 (HID) close	Infinity/Freedom Early	2.2	1.2	5.5
w40 (HID) close	Infinity/Freedom Early	2.9	1.5	6.9
w42 (HID) close	Infinity/Freedom Early	3.6	1.8	8.3

* Primary kWh incorporates a factor of x 2.6 for electricity to reflect the efficiency of electricity generation and therefore its environmental impact

Table 10 – Total energy cost per m^2

Ref. No.	Variety	Gas	Electricity	Total
Natural season (with night-break)				
w38 (NS)	Infinity	1.00	0.07	1.07
w38 (NS)	Freedom Early	0.97	0.07	1.04
With supplementary lighting				
w38 (HID) std	Infinity/Freedom Early	0.66	2.29	2.95
w40 (HID) std	Infinity/Freedom Early	0.80	2.77	3.57
w42 (HID) std	Infinity/Freedom Early	0.90	3.24	4.14
w38 (HID) close	Infinity/Freedom Early	0.66	2.29	2.95
w40 (HID) close	Infinity/Freedom Early	0.80	2.77	3.57
w42 (HID) close	Infinity/Freedom Early	0.90	3.24	4.14

Based on 1.5p/kWh gas, 6.0p/kWh electricity

Table 11 – Total energy cost per plant

Ref. No.	Variety	Gas	Electricity	Total
Natural season (with night-break)				
w38 (NS)	Infinity	6.7	0.2	6.9
w38 (NS)	Freedom Early	6.7	0.2	6.9
With supplementary lighting				
w38 (HID) std	Infinity/Freedom Early	3.5	8.3	11.8
w40 (HID) std	Infinity/Freedom Early	4.6	10.0	14.6
w42 (HID) std	Infinity/Freedom Early	5.4	12.2	17.6
w38 (HID) close	Infinity/Freedom Early	3.4	7.5	10.9
w40 (HID) close	Infinity/Freedom Early	4.4	9.3	13.7
w42 (HID) close	Infinity/Freedom Early	5.3	11.0	16.3