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Grower Summary

Headlines

- Poinsettia variety Infinity could be potted in week 34, 4 weeks later than normal, and grown under 4000 lux supplementary SONT lighting. This gave a high yield per m^2 of plants that were of good quality, though smaller than the current specification of five level heads and 25 - 32cm tall. However, they would be suitable for a revised specification that some retailers are now seeking.
- Variety Cortez was not suitable for growing under this regime.
- Using various scenarios, the financial advantage of using this ‘late, lit’ regime, compared with natural-season growing and potting in week 30, varies between £2,950 and £30,910/acre.

Background and expected deliverables

Investment in modern pot-plant nurseries is very high, and facilities have to be used to the maximum to give a commercial return. The summer production of pot-plants could be extended by up to 4 weeks in August if the subsequent poinsettia crop could be grown from later plantings. The use of supplementary lighting to boost growth may allow poinsettias to be planted later, but still in time to market at Christmas, but their quality at marketing and post-harvest would need to be assessed carefully.

This project, carried out on a commercial nursery, addressed the potential of lighting a late-planted poinsettia crop. It monitored the marketing quality and robustness at the point of sale and in shelf-life. If successful, this regime would allow another pot-plant crop (with an additional gross margin of around £10k) to be grown in the poinsettia house in August. Of course a market would need to be achieved for this additional crop.

Summary of the project and main conclusions

Two standard poinsettia varieties, Cortez and Infinity, were grown at a commercial nursery in 2003. There were three main treatments. Plants were potted conventionally at week 30 (without supplementary lighting, referred to as natural season (NS) plants), and others were potted in week 34 and grown under SONT lighting for 20 hours a day up to week 40 then 10 hours a day to harvest, at either 2000 or 4000 lux (referred to as late, lit (LL) plants. In addition, other late-potted plants were grown under incandescent lights or remained under natural lighting only. Plant quality was assessed at the marketing stage and then, after a storage/transport phase, in a standard shelf-life test room for up to 8 weeks.

At marketing, the natural-season crops of varieties Infinity and Cortez were considered to be the only plants that met <u>current</u> supermarket specifications. Infinity, however, produced plants that looked good at marketing when planted late (week 34) and grown under 4000 lux (~9.6Wm^{-2}), though they were smaller than the current market standards for a 13cm crop. But it has been noted that some retailers are now interested in sourcing a smaller product, so a new market for this type of plant could be worth considering. Cortez grown under lights at higher densities suffered from yellowing foliage. It is not known whether other varieties might also respond well to LL growing. Cortez and Infinity plants produced under NS and SONT-LL regimes had a shelf-life of 8 to 9 weeks.

Financial benefits

Glasshouse environment and production figures from this and other HDC-funded poinsettia projects enabled the financial benefits or otherwise of LL production to be compared with conventional NS (week 34) growing. The major additional factors for LL production are those for supplementary lighting (some of which is compensated by glasshouse heating by the waste heat from the lights), and the reduced return due to the lower plant specification. In the LL regime, however, four weeks glasshouse costs are saved compared with NS growing, and the higher pot density (60,000 pots/acre, compared with 32,000 in NS growing) means producing more units per acre. To improve quality pot densities in the LL regime may need to be reduced somewhat.

On this basis, the gross margins (GM) are £39,350/acre for NS growing (allowing £2.00 per pot return), or, for LL growing under 4000 lux, £42,300 and £54,300/acre, based on estimated returns of £1.50 or £1.70, respectively. In these examples, LL production gives a GM advantage over NS production of at least £2,950 and £14,950/acre, respectively, for such returns.

Other savings are possible using the LL regime. Using the whole glasshouse space available in weeks 30 to 34 to produce another crop would yield an additional gross margin of up to £10,000/acre. There is also some glasshouse space to use after week 34, before the LL crop is fully spaced. By turning off the supplementary lighting at times of high natural light in September and October, further savings could be made, of the order of £1,760/acre. While LL growing involves more costs in potting, etc., there is less labour for applying growth retardants and spacing-out, a benefit of perhaps £4,200/acre. These additional factors would increase the GM for LL production to £57,760 and £70,260/acre for returns of £1.50 or £1.70, respectively, a GM advantage over NS production of £18,410 and £30,910/acre, respectively.

Action points for growers

These findings are the result of a single trial, and should be treated with caution until confirmed by further trials supported by the UK poinsettia industry.

Science Section

Introduction

Investment in modern pot-plant nurseries is very high, up to about £350k/acre (4000m^2). These facilities have to be used to the maximum to give a commercial return on such investment. Summer production of pot or bedding plants could be extended by up to 4 weeks in August if there is a market, if the following poinsettia crop could be grown from later plantings. This additional production has the potential to earn up to £10k/acre (allowing for the extra income, less the additional electricity cost, but assuming a lighting installation is present). However, an assessment of the marketing and shelf-life quality and accuracy of scheduling of the poinsettia crop is required to provide growers with a valid cost-benefit analysis. This is important as poinsettia are the largest selling pot plant and the market is worth over £11 million per annum. But, can we produce a poinsettia of acceptable quality in four weeks fewer than normal?

Poinsettias that are lit (using supplementary SONT lighting) in the later stages of growth usually produce high-quality plants, but their bracts are softer and of a lighter colour than natural season (NS) crops. The shelf-life of such plants may be reduced, especially due to softer growth (HDC projects PC 41, 43, 71d, 79 and 127), but, with current economic pressures and new varieties, production with lights should be reconsidered. The bulk of the UK poinsettia market is a 13cm pot size, and, traditionally, poinsettia have been potted early and grown cool to make the best use of natural light in August. If the crop was potted later, in week 34 (late-August) and supplementary lighting used, it may still be possible to produce an acceptable product with good shelf-life, perhaps to a somewhat lower specification than previous considered.

Growers have expressed a wish to revisit this work as market and economic pressures require them to look for improvements in their businesses. In particular, Moermans Ltd were prepared to carry out a trial on their commercial nursery to assess the potential of late-planted, lit poinsettia. The marketing and shelf-life quality of a late-planted, lit (LL) poinsettia crop was evaluated. Two standard varieties were grown under three production regimes (NS, LL and planted late but not lit). After assessment of quality at the marketing stage, plants were transported to Warwick HRI, Kirton for shelf-life assessment. This enabled a judgement to be made whether a LL crop would have the same marketing and shelf-life quality as NS poinsettia grown conventionally from a normal planting date.

If the project confirms that a LL regime is practical, then the four weeks extra available for growing summer pot-plants (i.e., begonia, gerbera and New Guinea impatiens) has the potential to result in a maximum additional income of £10k/acre for the nursery. However, this and other savings would need to cover the additional cost of the electricity for supplementary lighting, as well as the possibly lower specification of the LL plants so produced.

Supplementary lighting has been widely used for chrysanthemums, New Guinea impatiens and begonias to maintain plant quality and speed the crop through the autumn and winter months (HDC projects PC 92, 80 and 146). Work in Germany has demonstrated that supplementary lighting of poinsettia can increase growth. Some UK growers have used lighting for part of their poinsettia production, and, anecdotally, have been pleased with the end product. A grower-based trial was felt an appropriate route for investigation. In this project, two poinsettia varieties, with different response times, were tested, the expectation being that the variety with the shorter response would be better suited to this production method.

This project is an assessment of the value of lighting a late crop of poinsettia to improve throughput, while maintaining the quality and robustness of the product at the point of sale and in shelf-life.

The project has three objectives:

1. Determine if late lit (LL) poinsettia crops have the same or at least acceptable marketing quality as natural season (NS) plants from normal planting dates.
2. Compare the shelf-life quality of NS and LL crops.
3. Compare energy use under NS and LL production.

Materials and Methods

Plant production

Poinsettias of two standard cultivars, Cortez and Infinity (both 7.5-week response group) were grown in 13-cm pots within a commercial crop at P A Moermans' nurseries, Pinchbeck, Spalding. Two blocks of glass, one conventional (for NS production) and one with supplementary lighting (for LL production).

The husbandry (spacing, irrigation, retardant treatments, etc.) of each block of plants was optimised by the grower to suit the requirements of each treatment or variety. Since plants were grown at the normal temperature for the crop at each stage of growth, the LL crop began at a higher temperature than the NS crop, though once short days began the temperatures were approximately the same. Temperatures were lowered for the last three weeks of the crop to improve shelf-life and enhance the intensity of colour. CO_2-enrichment was not used.

The growers provided a crop diary and glasshouse environment records (light levels, temperature, relative humidity, etc.). Key cultural details and glasshouse conditions are given in Tables 1 and 2, respectively.

Table 1. Key cultural details

	NS	***LL regime***	
	(Treatment 1)	***SONT lighting***	***Treatments 4 and 5***
Potting date	Week 30	Week 34	Week 34
Pinching date	Week 33	Week 36	Week 36
Location	On floor	On bench	On bench
Chlormequat applications (46% chlormequat)	Week 36 0.75ml Week 40 1.00ml Week 42 1.00ml Week 43 1.50ml Week 43 1.00ml Week 44 1.00ml	Week 44 1.00ml (for Infinity only)	None
Plant spacing	Week 30 60m^2 Week 37 30m^2 Week 41 15m^2 Week 44 8m^2	Week 34 60m^2 Week 41 30m^2 Week 47 15m^2 -	Pot-thick - - -

Table 2. Light and temperature records at the nursery

Week	*24-hour averages*		
	Light radsum ($W/m^2/day$)		*Temperature (°C)*
	Weekly	*Monthly*	
Week 34 18-24 August	1397	1204	21.9
Week 35 25-31 August	1012		20.9
Week 36 1-7 September	1295	1274	21.5
Week 37 8-14 September	1258		21.4
Week 38 15-21 September	1248		22.5
Week 39 22-28 September	1296		20.7
Week 40 29 September - 5 October	879	760	21.1
Week 41 6-12 October	723		21.0
Week 42 13-19 October	802		21.6
Week 43 20-26 October	636		19.6
Week 44 27 Oct-2 November	414	284	20.0
Week 45 3-9 November	405		20.3
Week 46 10-16 November	297		20.6
Week 47 17-23 November	93		18.2
Week 48 24-30 November	211		17.4
Week 49 1-7 December	No readings available		19.1
Week 50 8-14 December	61	61	20.2

Treatments

There were five treatments:
1. NS production potted week 30
2. LL production potted week 34, with supplementary SONT lighting (4000 lux) used for 20h/day from week 34 to 40 and thereafter for 10h/day
3. As for treatment 2, but using 2000 lux
4. As for treatment 2, but with no lighting (this treatment served as a control to assess the impact of simply potting later without lighting)
5. As for treatment 2, but using low-intensity supplementary lighting from incandescent lamps

Because of the preliminary nature of the investigation, treatments were provided in simple, non-replicated blocks within a large poinsettia unit. Each block consisted of 40 plants, with edge pots used as guard plants. Lighting was given to include the daylight period, but the area was blacked off to avoid affecting the commercial crop. Lights were not turned off when natural lighting was high.

Crop assessments at marketing

At the commercial marketing stage the following assessments were made on 20 pots of each treatment (excluding ‘guards’):
- Plant height (bench to top of foliage)
- Plant diameter across the widest point and at 90°
- Number of primary and secondary breaks on each plant

- Number of breaks in size categories:
  1 <150mm
  2 150-200mm
  3 200-225mm
  4 >225mm
- Average stage of cyathium development on the dominant break:
  1 tight green bud
  2 bud colouring
  3 pollen showing
  4 stigma open
  5 pollen and stigma
  6 abscission
- Average cyathium size in mm, 1 = <2mm.
- Score of grassy growth:
  0 no grassy growth
  1 moderate grassy growth
  2 extensive grassy growth
- Sleevability score:
  1 poor
  3 acceptable
  5 very good
- Leaf colour and yellowing:
  0 good
  1 acceptable
  2 yellow leaf
- Score of overall quality and uniformity:
  0 unmarketable (a few uneven heads)
  1 second grade (3-4 heads above canopy)
  2 first grade (5-6 coloured heads at canopy height)

Energy assessments

This preliminary evaluation of the LL regime for producing poinsettias was not designed to obtain detailed physical data that would allow specific energy calculations comparing the LL and NS regimes. However, a desk study was carried out by Tim Pratt, FEC Services Ltd, to provide energy calculations based on simple thermo-dynamics and empirical data. The data used were collected in other HDC-funded projects (especially PC 207, 'Improved guidelines for humidity control and measurement when using advanced climate control strategies'), with weather and glasshouse data from Warwick HRI's Kirton site and P A Moermans' nursery at Pinchbeck. All calculations were based on an area of 4000m^2 (1 acre) with 100% usage and no wastage; all nurseries will differ in percentage utilised area and wastage. This energy assessment was designed to give a sound indication of whether the other financial aspects associated with growing a LL crop were worthwhile.

Shelf-life testing

After the marketing stage assessment, pots were sleeved and packed as normal by the nursery. The plants were collected by van and taken (at ambient temperatures to Kirton. Here, they remained overnight in the van, parked in a shed, until about 24h after the initial collection, when they were unpacked and removed from their sleeves. The pots were placed on flower-pot saucers on benching in a shelf-life test room, at a pot density of 7/m^2 of bench. There were six replicate pots for each treatment x variety combination, arranged in six randomised blocks. The standard shelf-life conditions were 18°C and 65% RH, with cool white fluorescent tubular lighting providing about 1000 lux at plant height for 14h per day. Temperature and RH were logged throughout. All pots were watered according to individual need using tap water (individual requirements varied, largely because of the different sizes of plants in different treatments).

Plants were recorded weekly, pots being discarded when they were considered to have reached the end of their shelf-life. The test was concluded after 8 weeks, when nearly all pots had been discarded. The records taken weekly were:

- Numbers of leaves dropped per plant per week
- Number of bracts lost per plant per week
- Cyathia number on one tagged break per plant
- Mechanical damage (mainly branch breaks due to sleeving/de-sleeving) on a 0 – 5 scale:

  0 none | 1 slight | 2 moderate | 3 severe
- Leaf yellowing score for upper and lower foliage separately on a 0 – 5 scale:

  0 dark green | 1 slightly pale | 3 moderately pale | 5 severe yellowing
- Bract-edge blackening (BEB) on a scale from 0 (none) to 5 (severe)
- The development of bract colour was scored on a 1 – 5 scale:

  1 bracts not fully coloured | 2 some bracts not fully coloured | 3 all bracts reasonably coloured | 5 fully coloured
- Incidence of *Botrytis* symptoms on leaves and bracts
- Overall plant quality on a scale from 5 (high quality) through 3 (acceptable) to 1 (end of shelf-life), using 0 to denote pots already discarded
- Plant longevity, determined as the time (weeks) up to which a plant was considered fit to remain on display.

Results & Discussion

Plant quality at marketing

For both varieties, conventional NS growing produced the best quality plants, though in the case of Infinity the LL plants grown under SONT-lights (either 2000 or 4000 lux) were considered acceptable for a somewhat different specification. These results are summarised in Table 3, and all data are included in the appendix.

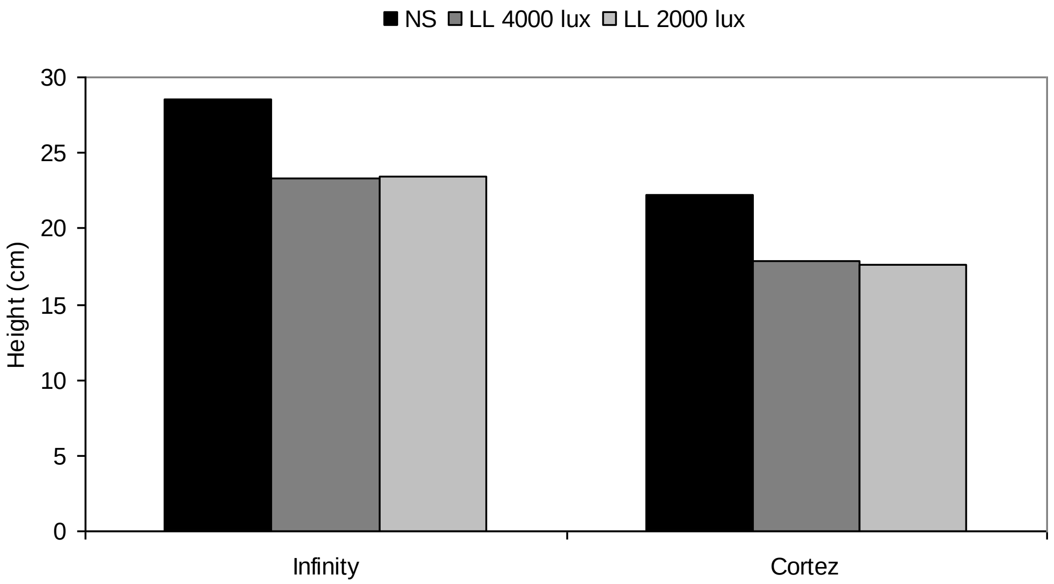
At marketing for Cortez, only the NS regime produced acceptable plants. The SONT-lit LL plants were intermediate in size and late-planted incandescent-lit and non-lit plants were the smallest. NS plants produced five primary breaks, and all other treatments two or three. The number of secondary breaks varied between 1.8 and 2.5, with no clear treatment trends. The size of primary breaks was greatest in NS plants, with 2.9 breaks in the top size category, compared with 1.0 to 1.9 for the SONT-LL plants; in the other two late-planted treatments all primary breaks fell into the two smallest size categories. Leaf yellowing was seen in the NS treatment only. The highest overall quality/uniformity score was for NS plants, 1.5 (out of a maximum of 2.0), the other four treatments produced unmarketable plants.

In Infinity, only standard NS production produced plants considered of an acceptable standard for the highest supermarket specifications. However, the late-lit plants grown at 4000 lux were considered acceptable for sale at a somewhat lower specification. The NS regime produced the largest plants, followed by SONT-LL plants, then late-planted non-lit plants, with the late-planted incandescent-lit plants being the smallest. NS and SONT-LL plants produced between 4.4 and 4.7 primary breaks each, and the remaining late-planted plants 4.1 – 4.4. The number of secondary breaks varied between 1.7 and 2.5 for the five treatments. The number of primary breaks in the top size category was 2.6 – 2.7 in NS and SONT-LL plants (4000 lux), with only 2.2 in the 2000 lux treatment; in the other two late-planted treatments all primary breaks fell into the two smallest size categories. No significant leaf yellowing was seen in the plants of Infinity. The highest overall quality/uniformity scores were 1.6 for NS plants, 1.2 for SONT-LL 4000 lux plants, and 0.7 for 2000 lux plants (out of a maximum score of 2.0); the other two treatments produced unmarketable plants.

For both varieties, mean cyathium stage and size varied, Infinity clearly showed smaller and more immature cyathia depending on age and size, whereas Cortez showed no clear treatment effects. Little grassy growth or mechanical damage was seen in the trial.

The treatment differences for the NS and SONT-LL treatments are summarised in Figure 1. Only NS Infinity would reach a height specification of >25cm, though LL Infinity and NS Cortez would meet a somewhat lower height specification of 20-25cm. Descriptions of plants in the different treatments are given in Appendix 1.

Figure 1. Plant characteristics at marketing for poinsettias under NS and SONT-LL regimes. (a) Plant height.



(b) Overall quality score (0 = unmarketable, to 2 = high).

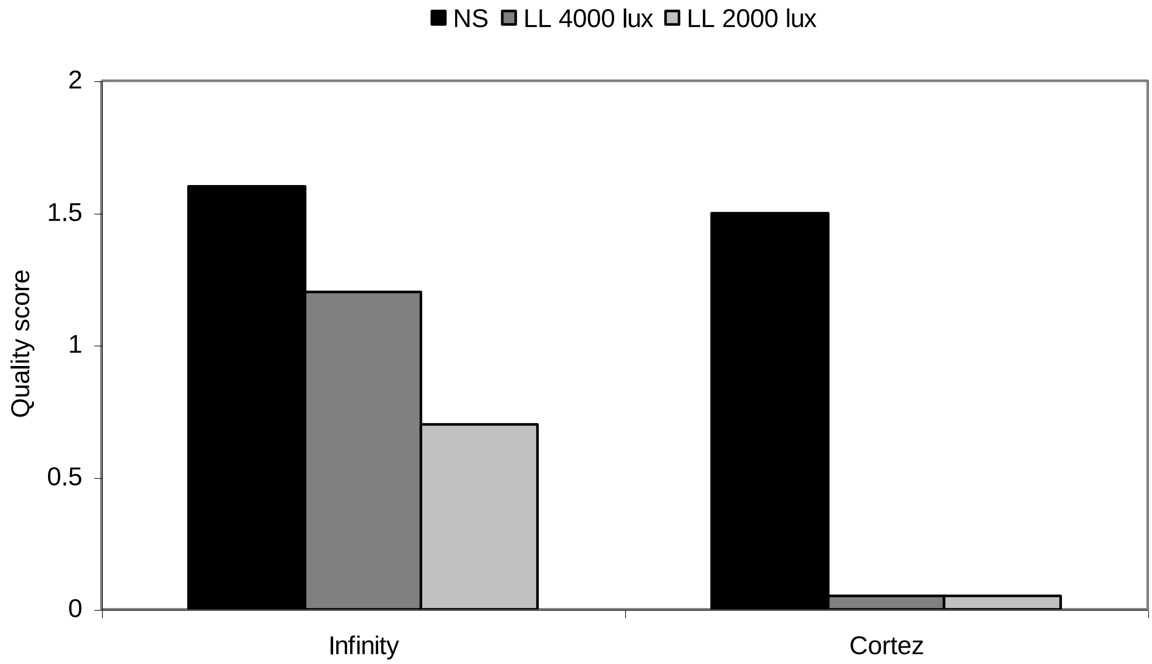


Table 3. Plant quality attributes at marketing following NS and LL growing regimes.

Ref	*Variety and treatment*	*Plant height (cm)*	*Plant spread (cm)*	*No. of primary breaks*	*No. of secondary breaks*	*No. of breaks in size categories*				*Cyathium size (mm)*	*Cyathium stage (1-6)*	*Grassy growth (0-2)*	*Sleev-ability (1-5)*	*Yellow leaf (0-2)*	*Plant quality (0-2)*
						1	*2*	*3*	*4*						
	Infinity														
1	NS	28.5	39.2	4.6	1.7	1.0	1.0	1.8	2.6	2.2	2.0	0	5.0	0	1.6
2	LL 4000 lux	23.3	36.2	4.7	2.0	1.1	1.7	1.3	2.7	1.9	1.9	0	.5.0	0	1.2
3	LL 2000 lux	23.4	34.8	4.4	1.7	1.0	1.2	1.7	2.2	1.5	1.2	0	5.0	0	0.7
4	Late, not lit	20.4	29.2	4.1	2.5	0.6	1.1	0	0	-	-	-	-	-	0
5	LL, incandescent	14.6	22.6	4.0	2.0	5.2	0.8	0	0	-	-	-	-	-	0
	Cortez														
1	NS	22.2	41.7	4.8	2.4	1.4	1.6	1.6	2.9	1.1	1.2	0	4.6	0.9	1.5
2	LL 4000 lux	17.9	30.8	3.4	2.2	1.5	1.3	1.0	1.7	2.6	3.0	0	5.0	0	0
3	LL 2000 lux	17.6	28.8	3.2	1.8	1.5	1.4	1.2	1.0	2.4	2.9	0.1	5.0	0	0
4	Late, not lit	13.9	23.5	2.9	2.5	0.4	2.2	0	0	-	-	-	-	-	0
5	LL, incandescent	13.0	21.0	2.5	2.1	3.4	1.2	0	0	-	-	-	-	-	0

-, unmarketable, not assessed

Shelf-life assessments

On receipt, for both varieties, the NS plants were the largest; LL plants grown under SONT lighting (both intensities) were intermediate in size, and late-planted plants grown without lights or under incandescent lights were small and unmarketable (Table 3). For variety Infinity only, the SONT-LL plants (both from the 2000 and 4000 lux treatments), though smaller than the usual current specification, were considered of acceptable quality for a new specification.

For both Cortez and Infinity, NS and SONT-LL plants had a shelf-life of 8 to 9 weeks (Figure 2 and Appendix Table A8). The shelf-life of late-planted non- or incandescent-lit plants was poor, though plants of Infinity gave a better shelf-life performance than comparable plants of Cortez.

Figure 3 shows how the overall quality scores changed during shelf-life (see also Appendix Table A8). In the case of Infinity, the quality score of NS and SONT-LL plants all declined gradually over the 8-week shelf-life period. In Cortez, the SONT-LL plants were not as good as NS plants at the start of shelf-life, but their quality score remained at a plateau for several weeks before declining.

Care should be exercised in interpreting the rates of leaf and bract loss from plants, because of the different initial sizes of the plants in different treatments (Appendix Tables A1 and A2). However, plants from the 4000 lux LL regime did appear to have a relatively high rate of leaf and bract loss, compared with other treatments, as demonstrated in some earlier trials. There were no consistent differences between treatments in cyathium numbers (Appendix Table A3).

In Cortez, but not Infinity, the yellowing of the upper foliage was greater in LL than in NS plants, while yellowing of the lower foliage was similar in all treatment combinations (Appendix Tables A4 and A5). This leaf yellowing is likely to be caused by not spacing the plants soon enough.

In both varieties, bract colour was initially, and remained, strongest in NS plants (Appendix Table 6). SONT-LL plants, particularly those raised under 4000 lux, were second-best, while bract coloration was poor in other late-planted treatments. Over the course of shelf-life, the bract colouration score decreased gradually in all treatments.

The extent of BEB was similar in both varieties and in all treatments (Appendix Table A7). Little mechanical damage due to sleeving was seen in this project (data not presented). No symptoms of *Botrytis* infection were observed.

Infinity clearly showed potential for potting in week 34 and growing under appropriate lighting, producing a plant suitable for a somewhat lower specification. Other varieties might be worth screening to see if they offer similar potential.

Figure 2. Shelf-life of NS and LL plants

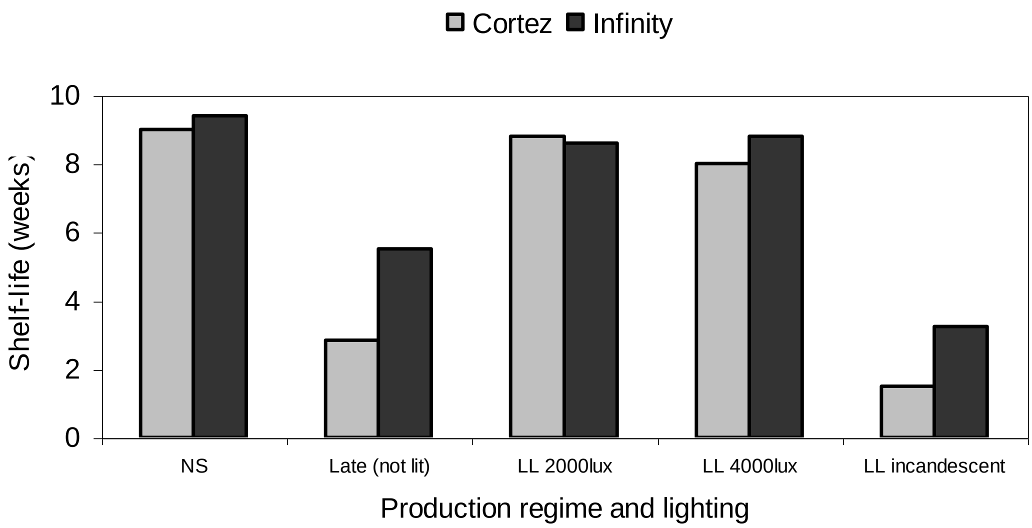


Figure 3(a). Overall quality score in shelf-life: Cortez

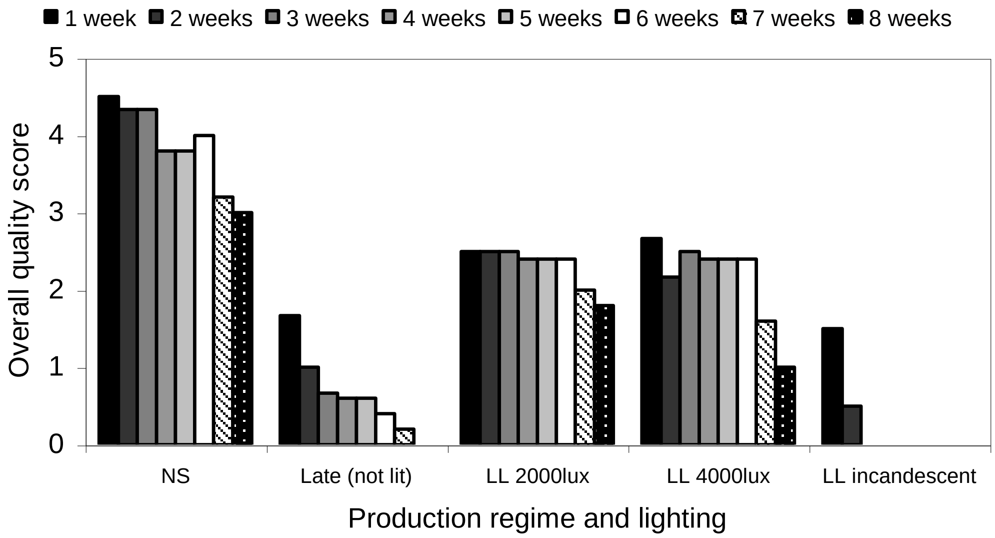
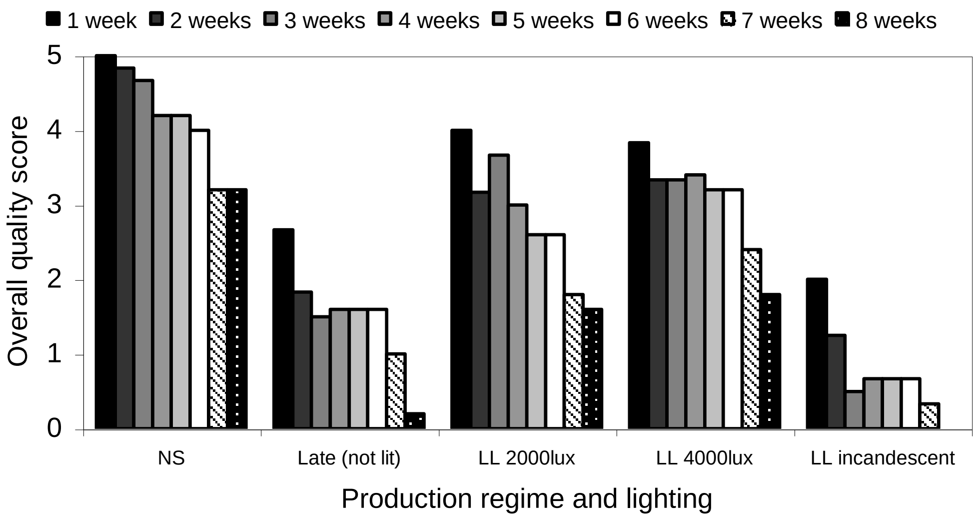


Figure 3(b). Overall quality score in shelf-life: Infinity



Economic assessment of the LL regime

Gross heat demand

The heat required to maintain a given temperature in a glasshouse is directly related to the difference between the inside and outside temperatures. One means of quantifying this difference is to use the 'degree-days' concept. Consider the following example:

Day 1	Day 2
Average glasshouse temperature 20°C	Average glasshouse temperature 22°C
Average outside temperature 10°C	Average outside temperature 11°C

For day 1 the temperature difference is 10°C, therefore 10°C-days (10 degree-days) of heating were required. For day 2, 11°C-days (11 degree-days) of heating were required. Therefore, one would expect to use 10% more energy on day 2 than on day 1. Analysing the heat demand data from HDC-project PC 207 in this way showed that, on average, for every degree-day of heating required, 0.19kWh/m^2 of heat was delivered to the glasshouse.

Table 4 shows the average temperatures achieved in the current trial at P A Moerman's glasshouse, and the average outside temperature at the Kirton weather station. The next column shows the resultant degree-days of heating required each week, and the final column shows the amount of heat required to achieve it, based on a gross heat demand of 0.19kWh/m^2 per degree-day. This shows that the total amount of heat input required to the glasshouse during the production period of LL plants (weeks 34 – 50) was 212kWh/m^2; this is the amount of heat delivered to the glasshouse, not the amount of gas consumed.

Table 4. Gross heat requirement for poinsettia glasshouse at P A Moermans' nursery.

Week no.	*Average temperature (°C)*		*Heating required weekly (degree-days)*	*Gross heat input weekly (kWh/m²)*
	Glasshouse (Pinchbeck)	*Outside (Kirton)*		
34	21.9	19.2	18.6	3.5
35	20.9	15.5	38.0	7.2
36	21.5	16.6	34.0	6.5
37	21.4	14.9	45.4	8.6
38	22.5	17.9	32.5	6.2
39	20.7	12.8	55.4	10.5
40	21.1	12.5	60.4	11.5
41	21.0	12.4	60.2	11.4
42	21.6	11.7	69.3	13.2
43	19.6	6.1	94.7	18.0
44	20.0	6.9	91.5	17.4
45	20.3	8.9	79.8	15.2
46	20.6	8.6	84.3	16.0
47	18.2	8.2	69.8	13.3
48	17.4	4.2	92.4	17.6
49	19.1	6.7	86.9	16.5
50	20.2	5.6	102.1	19.4
Total	-	-	1115.3	211.9

Waste heat from the lighting installation

The above calculation produces a figure for gross heat demand, and does not account for the waste heat generated by the supplementary lighting installation. Two different light intensities were used, 4000 and 2000 lux. To achieve these light levels with a well designed and maintained lighting installation would require an installed electrical power of 40 and 20W/m^2, respectively, of which 70% is converted into waste heat. The additional lighting for the LL regime was based on 20h/day for weeks 34 to 40 and 10h/day for weeks 40 to 50. Applying these factors to these supplementary lighting regimes (Table 5) gives the amount of waste heat produced by the light installation over weeks 34 to 50. This amounts to 46 and 23kWh/m^2 for the two lighting intensities, respectively.

Table 5. Waste heat produced by the supplementary lighting at Moermans' nursery.

Week no.	*Hours of supplementary lighting*	*Heat produced (kWh/m^2)*	
		At 4000 lux	*At 2000 lux*
34	20	3.8	1.9
35	20	3.8	1.9
36	20	3.8	1.9
37	20	3.8	1.9
38	20	3.8	1.9
39	20	3.8	1.9
40	20	3.8	1.9
41	10	1.9	1.0
42	10	1.9	1.0
43	10	1.9	1.0
44	10	1.9	1.0
45	10	1.9	1.0
46	10	1.9	1.0
47	10	1.9	1.0
48	10	1.9	1.0
49	10	1.9	1.0
50	10	1.9	1.0
Total	-	46.2	23.1

Unfortunately, all the waste heat produced by the lights cannot simply be assumed to replace heat demand from the heating system. During the middle of the day, especially during weeks 34 to 38, when the outside temperature remained high, the vents would be open, with no heat being used; therefore the waste heat produced by the lights would simply be vented. For the purposes of this analysis it has been assumed that the amount of waste heat utilised was:

Weeks 34-38	30%
Weeks 39-40	60%
Weeks 41-50	100%

From Table 5, supplementary lighting of 4000 and 2000 lux supplied 46 and 23 kWh/m^2 of heat, respectively. Applying the above correction, 4000 and 2000 lux of supplementary lighting actually replace 30 and 15kWh/m^2 of the gross heat demand with the two lighting intensities. This reduces the net heat demand of 212kWh/m^2 (Table 4) to 182 and 197kWh/m^2, respectively. Assuming a typical boiler efficiency of 85%, and a gas price of 1.0p/kWh (inclusive of climate change levy of 0.15p/kWh), the cost of heating the glasshouse is:

£1.82/m^2 using 4000 lux and
£1.97/m^2 using 2000 lux,

compared with £2.12/m^2 without supplementary lighting.

Supplementary lighting installation running costs

Table 6 shows the operating hours of the lighting installation. 'Actual' hours of lighting were those actually used in the trial, where the supplementary lights were left on for 20 or 10 hours per day, according to season. However, savings could be made if the supplementary lighting were turned off when natural light levels were high. Although there is little knowledge of the intensity at which poinsettia plants saturate with light, commercial practice with other crops (such as AYR chrysanthemum) is to turn lights on/off at around 200-300W/m^2, depending on crop condition and scheduling. Turning off the supplementary lighting at this level will have a substantial impact on operating hours, particularly during September and October, and would produce a useful saving of perhaps one-third of the full cost, and these figures are given in the 'estimated' column of Table 6. Over the whole period (weeks 34 - 50), the number of day-rate hours would be 1232 (or an estimated 963 if lights were switched off in high natural light), plus 448 night-rate hours. Of course, reducing the hours of supplementary lighting in this way would also reduce the amount of waste heat available from the lights to heat the glasshouse, but as the lights will be turned off only in bright weather, waste heat available at these times would in any case be largely vented, so this factor has been ignored.

Table 6. Hours of supplementary lighting.

Week no.	*Total hours*	*Day-rate hours (actual)*	*Night-rate hours (actual)*
34	20	13.0	7.0
35	20	13.0	7.0
36	20	13.0	7.0
37	20	13.0	7.0
38	20	13.0	7.0
39	20	13.0	7.0
40	20	13.0	7.0
41	10	8.5	1.5
42	10	8.5	1.5
43	10	8.5	1.5
44	10	8.5	1.5
45	10	8.5	1.5
46	10	8.5	1.5
47	10	8.5	1.5
48	10	8.5	1.5
49	10	8.5	1.5
50	10	8.5	1.5
Total hours	-	1232	448

The cost of electricity was taken at 4.5p/kWh (day rate) and 2.0p/kWh (night rate). On this basis the cost of supplementary lighting for the full 20/10 hours light per day would be:

Using 4000 lux, total electricity 66kWh/m^2, costing £2.53/m^2

Using 2000 lux, total electricity 33kWh/m^2, costing £1.26/m^2

Applying the savings in periods of high natural light up to week 44, the costs would be reduced to £2.09 and £1.05/m^2, respectively.

Summary of gas and electricity costs

A summary of costs, with and without supplementary lighting (20 or 10 hours/day) over weeks 34 to 50, is given below. The total costs have also been scaled up to a 4000m^2 (1 acre) block.

Treatment	*Total energy used (kWh/m²)*			*Total costs (£/m²)*			*Total costs*
(lux)	*Gas*	*Electricity*	*Total*	*Gas*	*Electricity*	*Total*	*(£/4000m²)*
LL, 4000	182	66	248	1.82	2.53	4.35	17,400
LL, 2000	197	33	230	1.97	1.26	3.23	12,920
NS	212	0	212	2.12	0	2.12	8,480

Applying the electricity saving by turning off supplementary lighting in high-light periods, the corresponding costs are reduced to:

Treatment	*Total costs (£/m²)*			*Total costs*
(lux)	*Gas*	*Electricity*	*Total*	*(£/4000m²)*
LL, 4000	1.82	2.09	3.91	15,640
LL, 2000	1.97	1.05	3.02	12,080
NS	2.12	0	2.12	8,480

These calculations show that the energy costs to grow a LL crop (20 or 10 hours light per day) exceed those of a natural season (non-lit) crop by £8920/acre using a 4000 lux lighting installation, and by £4440/acre using 2000 lux. From the plant quality measurements, and using appropriate varieties, probably only the higher lighting intensity should be considered as producing plants of sufficient quality. Hence, the LL regime would be profitable only if the extra energy costs of £8920/acre were recouped through additional production in the vacant glasshouse space (especially during weeks 30 to 34), and (or) through other savings consequent on using the LL regime (such as closer pot spacings). Applying the estimated saving by turning off 4000 lux supplementary lights in high-light periods would reduce the figure to be recouped to £7160/acre.

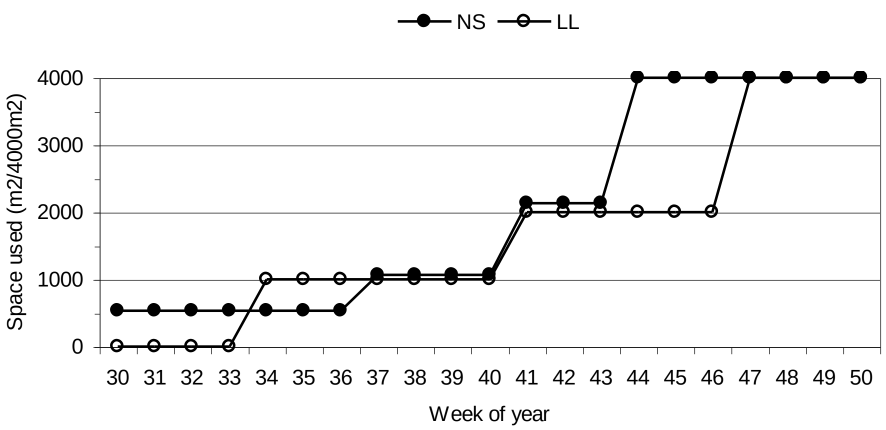
Labour and space implications
In the LL regime:

- Extra labour will be required for potting and stopping, because nearly twice as many plants are grown per acre
- Less labour will be required, compared with the NS programme, for spacing (needed twice instead of three times), PGR applications, and cleaning at marketing.

It is estimated that, using the LL regime, four weeks less staff time would be needed for three staff (12 man-weeks), compared with the NS regime. Using an hourly labour rate of £7.50 for a 40-hour week, plus weekend duties, is equivalent to about £350/man-week, or £4200 savings in total.

The comparison also provides a space utilisation issue (Figure 4). Using LL production, the entire glasshouse is available to grow other crops for 4 weeks, weeks 30 to 34; alternatively this period could be used for maintenance or to cover annual holidays. Growing a crop such as begonia, AYR chrysanthemums or gerbera, for which there is proven demand at this time of year, would provide an additional gross margin of up to £10k. In fact, up to 75% (¾ acre) of the glasshouse space is available for other purposes up to week 40, in either the NS or LL scheme.

Figure 4. Space utilisation for NS and LL poinsettia production



Summary of costs and opportunities
Table 7 compares the costs of production for a NS programme of poinsettia production (potting in week 30) and the LL regime (potting in week 34), using a suitable variety (e.g. Infinity) and 4000 lux of supplementary lighting on for 20/10 hours/day. In this project the NS crop grew normally and met specifications using a final spacing of $8/m^2$, giving 100% glasshouse utilisation with 32,000 plants selling at £2.00 each, yielding a gross margin of £39,350/acre. The calculations for LL production are based on achieving **a different type of product and specification** – a smaller but otherwise high-quality poinsettia – for which there is increasing demand from the multiple retail sector. In these calculations, it has been assumed that the plants produced in the LL scheme would fetch £1.50 each rather than the £2.00 for the NS specification, giving a gross margin of £42,300/acre. However, if a better small plant could be produced, the returns might approach those of the NS product: figures based on a return of £1.70 are therefore also included in Table 7, resulting in a gross margin of £54,300/acre. In these examples, LL production gives an advantage over

NS production of at least £2,950 and £14,950/acre for returns of £1.50 and £1.70, respectively.

Other savings are possible using the LL regime. Using the whole glasshouse space available in weeks 30 to 34 to produce another crop would yield an additional gross margin of up to £10,000/acre. There could also be savings in labour and electricity costs, as described above, totalling £5,960/acre. These additional savings result in gross margins of £57,760 (for the £1.50 product) and £70,206/acre (for the £1.70 product), advantages of £18,410 and £30,910/acre, respectively.

Table 7. Poinsettia production costs in NS and LL regimes.

Item	*Production costs (£/acre)*		
	*NS regime**	*LL regime**	
Plants @ 27p each	8640	16200	
Compost @ 3p/ litre	960	1800	
Pots @ 3p each	960	1800	
Labels @ 2p each	640	1200	
Sleeves @ 3p each	960	1800	
Trays (6's) @ 25p each	1340	2500	
Boxes @ 50p each	2670	5000	
Sub-total	16170	30300	
Electricity lighting	0	10120	
Gas heating	8480	7280	
Energy sub-total	8480	17400	
Total	24650	47700	
Return	64000 (32,000 @ £2.00)	90000 (60,000 @ £1.50)	102000 (60,000 @ £1.70)
Gross margin (minimum)	39350	42300	54300
Advantage over NS regime	-	*2950*	*14950*
Estimated labour saving	-	4200	4200
Possible electricity saving	-	1760	1760
GM from weeks 30-34	-	10000	10000
Gross margin (maximum)	-	57760	70260
Advantage over NS regime	-	*18410*	*30910*

*NS regime: 32,000 plants/acre (8 plants/m^2); LL regime, 60,000 plants/acre (15 plants/m^2)

Conclusions

The late lie (LL) concept appears to be a cost-effective one, provided there is sufficient demand for poinsettia of a somewhat different specification than is current. In this preliminary investigation, one variety, Infinity, proved suitable for LL production, while the other, Cortez, did not.

Cortez plants from all treatments except conventional natural season (NS) production were rated as either very poor or unmarketable, while SONT-LL plants of Infinity, especially those grown under 4000 lux lighting, were smaller than NS plants but were marketable. The NS plants had similar numbers of breaks, rates of leaf and bract loss, and reasonable overall quality and shelf-life.

It has previously been observed that poinsettia growing under supplementary lighting may possess less well-developed coloration of the bracts, though in the present study the bracts of Infinity were a satisfactory plum-red, with contrasting veins, under both regimes. Hence there is potential in further work to compare NS and LL plants of a selection of cultivars, to determine whether others are amenable to LL production.

A full financial analysis based on average costs and potential markets from a number of nurseries needs to be included in future work.

A number of factors might be used to increase poinsettia quality generally, and would benefit LL production. These include optimising supplementary lighting across the whole glasshouse block in order to maximise benefits, and utilising CO_2-enrichment and reflective mulches to promote growth. For this work to be relevant and successful it is likely to be required to take place on a research site, along with a fuller financial analysis based on average costs and potentials markets from a number of growers.

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APPENDIX

Descriptions of plants in the different treatments are given below.

NS regime (week 30, natural season lighting)

Cortez: Bracts normal size, oak-leafed, deep velvet rose-red, veins darker than bract margin. Cyathia normal but small. Large plant canopy, shoots strong with some angle-shaped shoots, height 22cm, nearly five shoots per plant. Some yellow leaf. Quality score 1.5 (out of a maximum of 2.0).
Infinity: Bracts oval to lanceolate, plum-red, main veins darker in colour. Cyathia small, not prominent. Large plant canopy, upright, strong, with no yellow leaf, height 28cm, shoots strong but some 'double decking'. Quality score 1.6 (out of 2.0).

LL regime, SONT lighting at 2000 lux

Cortez: Bracts normal, fewer and larger than Infinity. Cyathia large. Plant height 17.5cm. Number of stems less than in NS regime (3.2 compared with 4.8). Plants unmarketable.
Infinity: Bracts normal, smaller than 4000 lux LL or NS. Cyathia smaller. Plants less even than 4000 lux treatment. Plant quality 0.7 (out of 2.0).

LL regime, SONT lighting at 4000 lux

Cortez: Bracts large, two per plant, bright red with highlighted veins. Cyathia large, prominent. Some pinpointing after two nights in the sleeve. Plants short, 18cm, with fewer shoots than NS. Plant quality 0.1, very poor.
Infinity: Bracts full, dark plum-red, main veins highlighted darker, oval in shape. Cyathia prominent, yellow with red stamens. Habit upright, all but one shoot good, height 23cm. Nearly 5 primary shoots per plant. Plant quality 1.2 (out of 2.0).

Late planting (week 34), natural season lighting

Cortez: A few large bracts of good colour, but with indeterminate structures (half leaf and half bract). Cyathia very small. Shoots weak, many not reaching the required size, height 14cm, with three primary breaks. Plants very poor with a lot of yellow leaf under a big canopy. Unmarketable.
Infinity: Bracts pale red in colour, but some indeterminate structures with white margins. Cyathia small to insignificant. Shoots well formed, upright, but heads not flat, four per plant, no yellow leaf. Plants unmarketable.

Late planting (week 34), incandescent lighting

Cortez: Bracts normal colour. Small plants with one or two apical dominant shoots. Cyathia larger than in late-planted, non-lit plants. Some bracts indeterminate. Growth poor, 13cm high, primary breaks 2.5 on average. Unmarketable.
Infinity: Bracts normal colour and shape. Cyathia small but visible. Shoots small but developed, internodes close together. Primary shoots four, height 14cm. Unmarketable.

Full results from shelf-life testing

Table A1. Shelf-life performance of NS and LL poinsettias Cortez and Infinity: leaf loss.

Variety	*Regime and lighting*	*Cumulative number of leaves lost per plant*							
		1 week	*2 weeks*	*3 weeks*	*4 weeks*	*5 weeks*	*6 weeks*	*7 weeks*	*8 weeks*
Cortez	NS	6.7	8.8	9.0	9.8	9.8	9.8	9.8	9.8
	Late (not lit)	3.7	4.2	4.3	4.3	4.7	4.7	4.7	4.7
	LL 2000lux	3.3	3.8	3.8	4.0	4.4	4.8	5.2	5.2
	LL 4000lux	2.2	5.0	5.5	6.7	7.5	7.5	8.5	8.5
	LL incandescent	3.5	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Infinity	NS	2.3	2.7	3.0	3.4	3.4	3.6	3.6	3.6
	Late (not lit)	2.7	3.2	3.2	3.2	3.2	3.2	3.6	3.6
	LL 2000lux	1.5	2.0	2.2	2.2	2.2	2.4	2.4	2.4
	LL 4000lux	3.0	4.5	4.5	4.5	4.5	4.7	5.9	6.7
	LL incandescent	1.0	1.8	1.8	2.8	2.8	2.8	3.1	3.1

Table A2. Shelf-life performance of NS and LL poinsettias Cortez and Infinity: bract loss.

Variety	*Regime and lighting*	*Cumulative number of bracts lost per plant*							
		1 week	*2 weeks*	*3 weeks*	*4 weeks*	*5 weeks*	*6 weeks*	*7 weeks*	*8 weeks*
Cortez	NS	0.0	0.7	0.7	0.7	0.7	0.7	0.7	0.7
	Late (not lit)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	LL 2000lux	0.0	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	LL 4000lux	0.0	0.5	1.8	1.8	1.8	1.8	2.0	2.2
	LL incandescent	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Infinity	NS	0.0	0.2	0.3	0.5	0.5	0.5	0.5	0.5
	Late (not lit)	0.0	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	LL 2000lux	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2
	LL 4000lux	0.0	0.8	1.0	1.4	1.4	1.4	2.2	2.4
	LL incandescent	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table A3. Shelf-life performance of NS and LL poinsettias Cortez and Infinity: cyathia numbers.

Variety	*Regime and lighting*	*Number of cyathia present (on one tagged break per plant)*							
		1 week	*2 weeks*	*3 weeks*	*4 weeks*	*5 weeks*	*6 weeks*	*7 weeks*	*8 weeks*
Cortez	NS	5.7	4.0	1.3	3.0	3.0	3.2	4.0	4.4
	Late (not lit)	0.7	1.2	1.5	1.0	1.2	2.0	1.8	2.0
	LL 2000lux	6.5	6.3	3.8	4.2	5.6	6.0	5.8	7.2
	LL 4000lux	4.5	4.5	3.5	3.2	3.4	3.4	4.2	4.0
	LL incandescent	2.0	2.0	1.5	3.0	3.0	5.0	6.0	3.0
Infinity	NS	6.5	4.8	3.5	4.6	4.8	4.8	5.6	5.4
	Late (not lit)	0.8	0.7	1.5	2.2	1.8	2.6	4.8	4.6
	LL 2000lux	4.2	2.8	1.8	2.0	2.6	2.4	2.6	2.8
	LL 4000lux	3.8	3.2	0.7	2.6	2.8	2.8	3.4	2.6
	LL incandescent	0.0	0.0	2.3	1.0	1.0	1.7	2.7	4.3

Table A4. Shelf-life performance of NS and LL poinsettias Cortez and Infinity: yellowing score, upper foliage[1].

Variety	*Regime and lighting*	*Yellowing score, upper foliage*							
		1 week	*2 weeks*	*3 weeks*	*4 weeks*	*5 weeks*	*6 weeks*	*7 weeks*	*8 weeks*
Cortez	NS	0.0	0.0	0.3	1.2	1.8	1.2	1.2	1.2
	Late (not lit)	0.5	0.8	1.0	1.4	2.0	2.0	2.4	2.4
	LL 2000lux	0.0	0.2	0.7	1.4	1.8	1.8	1.8	1.8
	LL 4000lux	0.7	1.2	1.0	2.4	3.0	3.0	3.0	3.0
	LL incandescent	0.5	0.5	1.0	2.0	3.0	3.0	3.0	3.0
Infinity	NS	0.0	0.0	0.0	0.4	0.8	1.2	1.2	1.2
	Late (not lit)	0.3	0.3	0.5	1.0	1.4	1.4	1.6	1.8
	LL 2000lux	0.0	0.2	0.2	1.0	1.4	1.0	1.0	1.0
	LL 4000lux	0.0	0.0	0.3	1.2	1.4	1.8	1.4	1.4
	LL incandescent	0.5	1.0	1.3	2.3	3.0	3.0	3.0	3.0

[1] Damage scores from 0 (dark green) to 5 (severe yellowing)

Table A5. Shelf-life performance of NS and LL poinsettias Cortez and Infinity: yellowing score, lower foliage[1].

Variety	*Regime and lighting*	*Yellowing score, lower foliage*							
		1 week	*2 weeks*	*3 weeks*	*4 weeks*	*5 weeks*	*6 weeks*	*7 weeks*	*8 weeks*
Cortez	NS	1.0	1.5	1.7	2.8	2.8	2.4	2.8	3.0
	Late (not lit)	1.7	2.0	2.0	2.6	3.2	3.6	3.8	3.8
	LL 2000lux	1.0	1.7	2.2	3.0	3.2	3.6	3.6	3.6
	LL 4000lux	1.7	2.2	2.5	3.4	4.0	4.0	4.0	4.0
	LL incandescent	1.5	1.5	2.0	3.0	4.0	4.0	4.0	4.0
Infinity	NS	1.0	1.0	1.2	1.8	2.0	2.0	2.2	2.2
	Late (not lit)	1.0	1.2	1.2	2.2	2.6	2.8	3.2	3.2
	LL 2000lux	1.0	1.2	1.5	2.0	2.8	2.8	2.8	2.8
	LL 4000lux	1.0	1.3	2.0	2.8	3.0	3.2	3.0	3.0
	LL incandescent	1.0	2.0	1.8	3.0	4.0	3.7	4.0	4.0

[1] Damage scores from 0 (dark green) to 5 (severe yellowing)

Table A6. Shelf-life performance of NS and LL poinsettias Cortez and Infinity: bract colouration score[1].

Variety	*Regime and lighting*	*BEB score*							
		1 week	*2 weeks*	*3 weeks*	*4 weeks*	*5 weeks*	*6 weeks*	*7 weeks*	*8 weeks*
Cortez	NS	4.7	4.7	4.3	4.4	3.6	3.6	3.4	3.2
	Late (not lit)	2.8	3.2	2.7	2.6	2.6	2.2	2.2	2.0
	LL 2000lux	4.3	4.2	4.2	4.0	3.2	2.8	2.4	2.0
	LL 4000lux	4.3	4.0	3.7	3.2	3.0	2.6	2.2	1.8
	LL incandescent	3.0	4.0	3.0	3.0	3.0	3.0	3.0	3.0
Infinity	NS	5.0	5.0	5.0	4.2	3.6	3.6	2.6	2.4
	Late (not lit)	3.3	3.2	2.8	2.6	2.0	2.0	2.0	1.4
	LL 2000lux	4.8	4.2	4.3	3.4	3.0	2.4	2.0	1.8
	LL 4000lux	4.8	4.2	4.3	4.0	3.4	2.8	2.4	2.0
	LL incandescent	3.5	3.0	3.0	3.0	3.0	2.7	2.3	2.0

[1] Colouration scores from 1 (poorly developed) to 5 (fully developed)

Table A7. Shelf-life performance of NS and LL poinsettias Cortez and Infinity: score for bract-edge blackening (BEB)[1].

Variety	*Regime and lighting*	*BEB score*							
		1 week	*2 weeks*	*3 weeks*	*4 weeks*	*5 weeks*	*6 weeks*	*7 weeks*	*8 weeks*
Cortez	NS	4.7	4.7	4.3	4.4	3.8	3.4	3.2	3.0
	Late (not lit)	4.7	4.5	4.3	4.4	3.8	3.8	3.8	3.4
	LL 2000lux	4.7	4.3	4.2	4.2	3.6	3.2	3.0	3.0
	LL 4000lux	4.2	4.0	4.0	3.8	3.4	3.2	3.2	3.2
	LL incandescent	5.0	4.5	4.0	4.0	4.0	4.0	4.0	4.0
Infinity	NS	5.0	4.8	4.3	4.4	4.0	3.6	3.6	3.4
	Late (not lit)	4.0	4.2	3.8	3.8	3.0	3.0	3.0	2.2
	LL 2000lux	4.2	4.0	4.0	3.8	3.2	3.0	2.8	2.6
	LL 4000lux	4.3	4.3	4.2	4.0	3.0	3.0	2.8	2.6
	LL incandescent	4.3	4.0	4.0	4.0	3.0	3.0	3.0	3.0

[1] Damage scores from 0 (no BEB) to 5 (severe BEB)

Table A8. Shelf-life performance of NS and LL poinsettias Cortez and Infinity: overall quality score[1] and (in bold) length of shelf-life.

Variety	*Regime and lighting*	*Overall quality score*								***Shelf-life (weeks)***
		1 week	*2 weeks*	*3 weeks*	*4 weeks*	*5 weeks*	*6 weeks*	*7 weeks*	*8 weeks*	
Cortez	NS	4.5	4.3	4.3	3.8	3.8	4.0	3.2	3.0	**9.0**
	Late (not lit)	1.7	1.0	0.7	0.6	0.6	0.4	0.2	0.0	**2.8**
	LL 2000lux	2.5	2.5	2.5	2.4	2.4	2.4	2.0	1.8	**8.8**
	LL 4000lux	2.7	2.2	2.5	2.4	2.4	2.4	1.6	1.0	**8.0**
	LL incandescent	1.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	**1.5**
Infinity	NS	5.0	4.8	4.7	4.2	4.2	4.0	3.2	3.2	**9.4**
	Late (not lit)	2.7	1.8	1.5	1.6	1.6	1.6	1.0	0.2	**5.5**
	LL 2000lux	4.0	3.2	3.7	3.0	2.6	2.6	1.8	1.6	**8.6**
	LL 4000lux	3.8	3.3	3.3	3.4	3.2	3.2	2.4	1.8	**8.8**
	LL incandescent	2.0	1.3	0.5	0.7	0.7	0.7	0.3	0.0	**3.3**

[1] Quality scores from 5 (very good) to 1 (end of shelf-life); 0 = shelf-life already over