Project title:	Protected Ornamentals: Investigation into the potential savings available from adopting energy optimisation principals in UK glasshouse production
Project number:	PC 190
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Final Report:	August, 2003 (Poinsettias)
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GROWER SUMMARY

Headline

Temperature Integration used in poinsettia production under experimental conditions showed the potential to save as much as 30% of energy for heating, although the temperature limits and humidity control strategies need further evaluation in order to avoid adverse effects on shelf-life.

Background and expected deliverables

The combination of recent increases in the cost of energy and the introduction of the climate change levy has meant that energy efficient production is an issue for all producers of protected crops. A recent study trip to Denmark and the Netherlands (HDC project PC 172) concluded that the use of advanced climate control methods is an effective way of improving energy efficiency. Climate control regimes that allow a move away from the traditional method of fixed 'set points' for temperature are claimed to allow for significant energy savings. These systems use control methods that allow the environment to change dynamically to meet the needs of the crop in accordance with external weather conditions.

In 2001, a trial was set up at HRI-Efford to evaluate commercially available climate control programmes that allow temperature integration to produce commercially relevant protected ornamentals and concentrated on pot chrysanthemums as a model crop (PC 190). PC 190 demonstrated that temperature integration could be adopted with little change to current commercial pot mum practice. In all aspects the crop from the temperature integration treatments compared favourably to the commercial control. The quality at marketing and shelf life was as good as the control. The schedule of the crop was delayed by no more than 3 days in some varieties, but compared to the energy savings this delay is hardly significant. The energy saved was between 13 and 35 % depending on the period of the trial considered. It would appear that by using 24hr integration over a three day period a saving of 25% of the energy used for heating could be made, compared to the control.

The second year of this trial (PC 190) concentrated on demonstrating that temperature integration could be used successfully in the production of poinsettia. Poinsettias were selected for the second year because they are sensitive to both low humidity levels early in the season and high humidity levels later in the season.

Deliverables

- To evaluate the potential energy savings of a temperature integration regime compared to a commercial control
- To quantify crop speed, quality and shelf life of the poinsettia crops grown under two temperature regimes.

This trial did not aim to produce a blueprint for poinsettia production using temperature integration, but to determine whether temperature integration could be used to produce a poinsettia crop and contribute towards energy savings. Further work will be required to improve confidence in the temperature and humidity limits as well as to continue to develop new and challenging ways to save energy.

Summary of project and main conclusions

Environmental control & energy savings

Eleven varieties of poinsettias were grown in two temperature regimes (See Table A for the environmental set points used during production). The main environmental difference between the temperature integration treatment and the control, was in the last month of production. Both regimes used a heat then vent strategy for humidity control, this meant the temperature integration regime, which had higher vent temperatures, gained more heat and maintained a slightly higher temperature, between weeks 44 to 46.

The high temperatures were a function of how the temperature integration regime was applied and not as a result of temperature integration itself. It is likely that a temperature integration strategy with a vent point close (~1ºC) to the desired average temperature and a lower permitted temperature limit would maintain a considerably lower average temperature than achieved in this trial.

Table A: Compartment heat and vent set points, and deviation settings chosen for the temperature integration treatment on poinsettia (Year 2002)

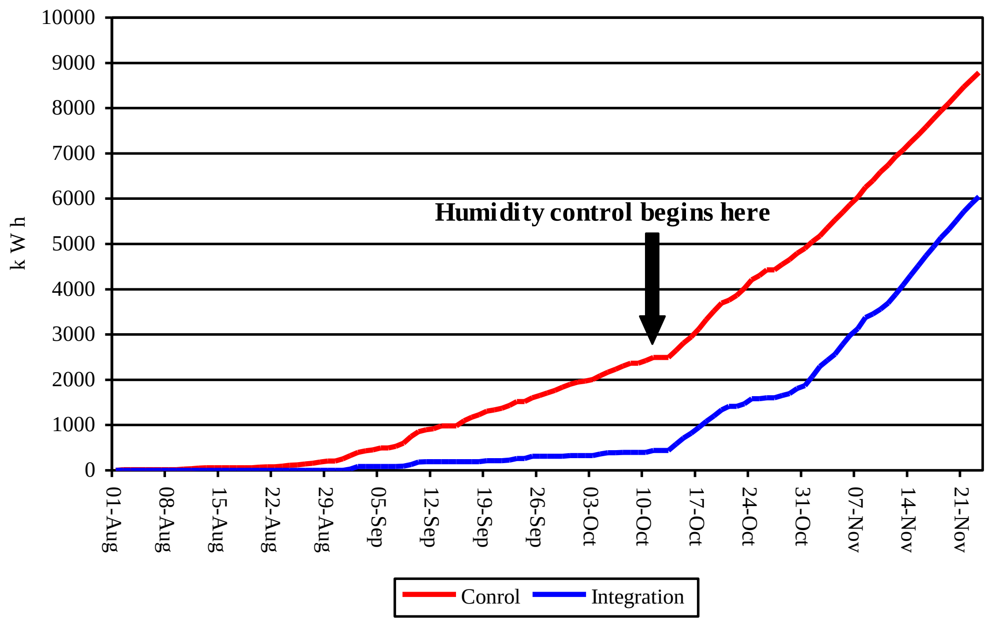
Date	Control (°C)		Integration (°C)		Deviation (*on integration*)
	Heat	Vent	Heat	Vent	Positive/Negative (°C)
01/08/02	20	22	20	24	4/2 = max 24, min 18
11/09/02	20	22	20	24	4/5 = max 24, min 15
16/09/02	19	21	19	23	4/4 = max 23, min 15
11/10/02	18	20	18	23	4/3 = max 22, min 15
25/10/02	18	20	18	23	4/3 = max 22, min 15
29/10/02	17	19	17	23	4/2.5 = max 21, min 14.5
05/11/02	16 (Night 17 / 19)	18	16.5	19*	4/2 = max 20.5, min 14.5
20/11/02	16	18	16	18*	4/2 = max 20, min 14

* The vent temperature increased by an additional 4°C as radiation rose from 100-300 Wm^{-2}.

Switching to a vent then heat humidity strategy might reduce the pipe heat contributing to high average temperatures. Some care would be needed to ensure heating and venting did not occur simultaneously and too often as this would be costly in terms of wasted heat. If growers wanted to use temperature integration but were unsure of maintaining temperatures at the end of production they could simply stop using integration for the last month and return to it for the next crop.

At marketing the energy savings for the total production time were over 30% from the temperature integration treatments. Humidity control was calculated to account for approximately 60% of the total energy use in both compartments (Fig A). It was particularly noticeable that once humidity control began on 11 October 2002, that energy use increased in both compartments and effectively the humidity control process was defining the growing environment.

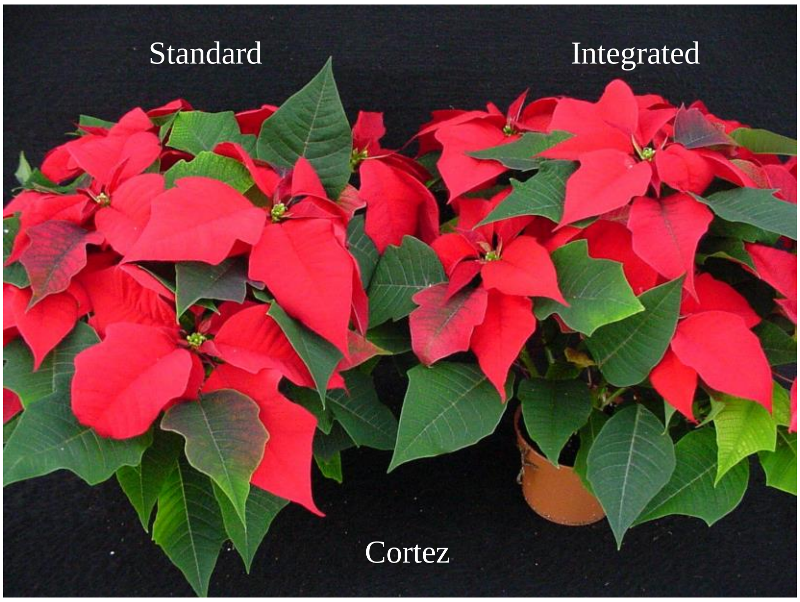
Figure A: The cumulative energy used in the trial. Especially noticeable is the sharp upturn in energy use once humidity control regimes began on 11 October 2002.



Plant quality at marketing and during shelf-life

There were no significant differences at marketing in the quality of poinsettia plants grown with and without temperature integration. All varieties were judged excellent from the temperature integration treatment (Fig B).

Figure B: The variety Cortez from the standard and integrated temperature regimes at marketing.



Although the marketing quality of the plants was judged excellent, plants from the temperature integration treatment performed poorly in shelf life. They lost more leaves and bracts (Fig C1 and C2) and more plants had to be disposed of before the shelf life period of 6 weeks had passed. Because of the way temperature integration was used in this trial and the use of a heat, then vent humidity control strategy, the average temperature in the temperature integration compartment was 1 to 1.5°C higher during weeks 44-46 compared to the control. It is well known through previous HDC funded work (PC 71c & PC 71d) and grower experience, that finishing a poinsettia crop at temperatures higher than 16-17°C will reduce shelf life quality. This factor may well explain the poorer shelf-life performance of plants grown in the integrated regime.

Figure C1: Mean Cumulative leaf loss/plant throughout shelf life; **** denotes a significant difference***

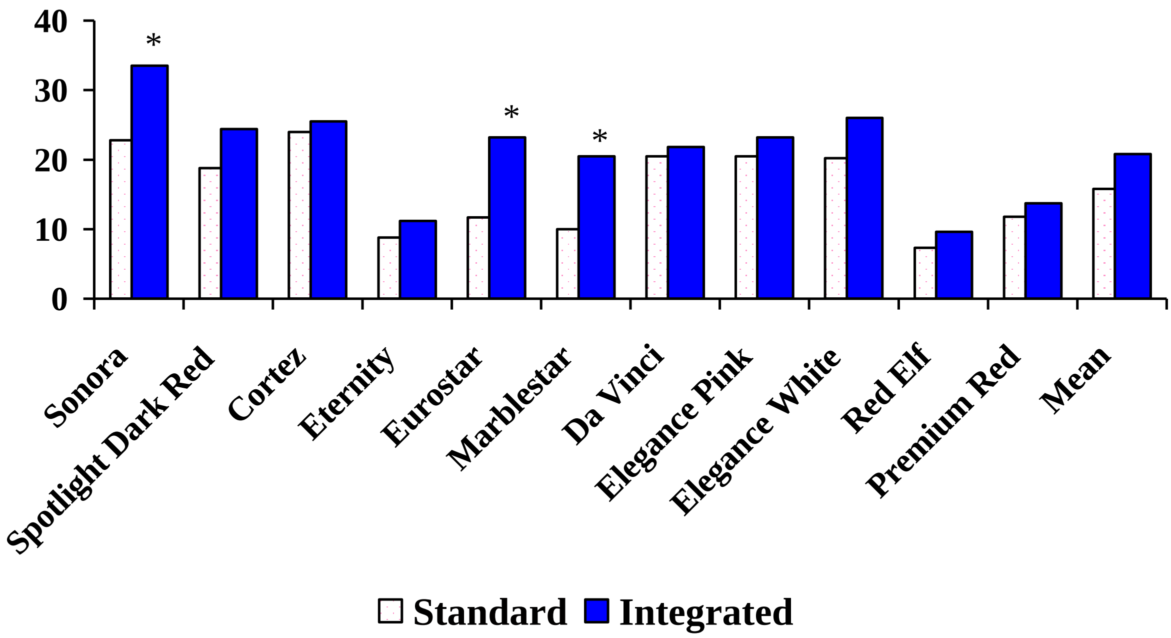
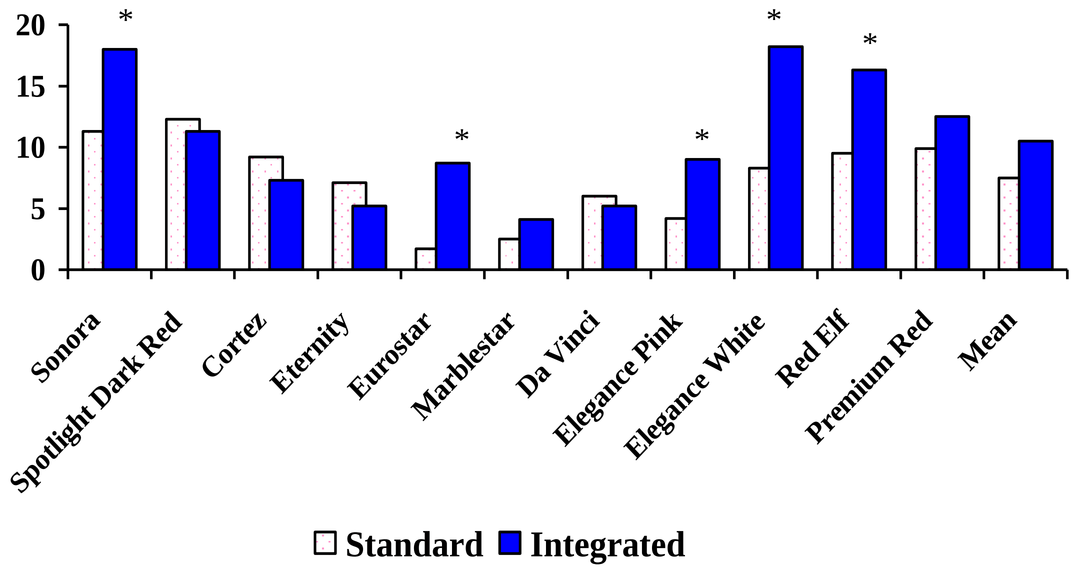


Figure C2: Mean cumulative number of bract leaves/plant lost during shelf life; * denotes a significant difference



Conclusions

- Temperature integration was used and demonstrated the potential to save 30% of the energy used for heating a poinsettia crop; £221,000 per annum for the UK production area.
- 11 varieties were evaluated and no variety was delayed more than 1½ days to show colour or visible cyathia. No variety was delayed at marketing and the expert assessment was that all plants were of excellent quality.
- Both the fresh and dry weights of all varieties were increased in the integrated compartment, confirming a similar result in pot mums in 2001.
- <u>Some</u> varieties, including Sonora, Eurostar, Marblestar, Elegance Pink, Elegance White and Red Elf, grown under temperature integration lost more leaves and bracts in shelf life than the control plants.
- The reduced shelf life quality for some varieties and increased plant losses suggest that the method of temperature integration used was not optimum for these varieties. Either not using temperature integration for the last month of production or trying an alternative humidity control strategy should be evaluated.

Financial benefits

Temperature integration will reduce heat demand and therefore fuel bills. However, the precise savings will depend on the individual grower's existing culture, crop and willingness to extend the set point boundaries. Clearly the poinsettia crop is sensitive to changes in production and the shelf life results would council some caution when adopting temperature integration. Much of the energy expended in the trial was in humidity control, and the strategies for the most energy efficient humidity control have clearly not yet been defined. However the potential benefits make it worth pursuing.

The potential cost saving of using less energy in poinsettia production can be calculated to be as much as £221, 000 per annum. This is based on the following estimations supplied by poinsettia producers; There are some 44.4 hectares of poinsettia production in the UK, and the average cost of heating this area would be £737, 000 nationally. A reduction in this between 10 and 30% would save between £73, 000 and £221, 000 per annum.

Action points for growers

- Begin to use temperature integration, taking advice from your climate control computer supplier on the best approach to integrating temperatures with the make and model of the computer that you have available.
- Begin with an average temperature close to your current standard set point and just vary 1°C either side of this.
- Consider increasing your ventilation set point temperature in the winter period to make use of additional thermal gains.
- Rethink your use of minimum pipe temperature to reduce unnecessary energy use.
- Consider only lowering your night temperatures to make use of thermal gains on bright days but be cautious of increasing the vent temperature, especially on poinsettia.
- With poinsettia it may be advisable to only use integration during the growth phase and not for the final month, this may enable lower temperatures to be maintained to finish the crop.

- If using integration to finish the poinsettia crop narrow the integration boundaries, lower the vent point to near the desired temperature and use a vent then heat strategy for humidity control. This will keep the lower temperature of 16ºC that has been shown to improve shelf life.
- Keep looking at where your heat peaks are, slight alterations to settings could save money.
- Keep thinking and challenging humidity control, this is the most costly energy use, but be cautious of adverse effects on crop quality and disease control.

SCIENCE SECTION

2.1 Introduction

The combination of recent increases in the cost of energy and the introduction of the climate change levy has meant that energy efficient production is an issue for all producers of protected crops. A recent study trip to Denmark and the Netherlands (HDC project PC 172) concluded that the use of advanced climate control methods is an effective way of improving energy efficiency. Climate control regimes that allow a move away from the traditional method of fixed 'set points' for temperature are claimed to allow for significant energy savings. These systems use control methods that allow the environment to change dynamically to meet the needs of the crop in accordance with external weather conditions. It was felt that a trial of commercially available systems was required to increase adoption by UK growers to demonstrate the principles available to protected ornamental growers.

Trial PC 190 at HRI-Efford in 2001 concentrated on pot chrysanthemums as a model crop and a commercially available climate control programme that allows temperature integration. Temperature integration allows the achieved compartment temperature to vary within prescribed limits that are set in the computer. The limits give the maximum and minimum temperatures permitted about a desired average temperature that the computer maintains. In commercial programmes the computer will maintain the average temperature over a one to seven day cycle as defined by the user. The positive deviations from the desired average occur by allowing the temperature to rise on thermal gain. The accumulated degree hours, above the average, are stored in the computers memory for the period the average is calculated over. The degree hours can then be used during periods of low or no solar gain to allow the temperatures to fall below the average but not below the minimum temperature limit. It is important to remember that as few as possible of the temperature changes are forced (either venting or heating). The aim is that the computer maintains the average over the period set by the grower. In this trial the period was set at 3 days.

PC 190 on pot chrysanthemums demonstrated that temperature integration could be adopted with little change to current commercial pot mum practice. In all aspects the crop from the temperature integration treatments compared favourably to the commercial control. The quality at marketing and shelf life was as good as the control.

The schedule of the crop was delayed by no more than 3 days in some varieties, but compared to the energy savings this delay is hardly significant. The energy saved was between 13 and 35 % depending on the period of the trial considered. It would appear that by using 24hr integration over a three day period a saving of 25% of the energy used for heating could be made, compared to the control. The key to energy savings is the reduction in heat used to maintain the set point in a compartment, this is most clearly demonstrated by the calculated pipe temperatures which show how often a treatment called for heat. The trial has led to commercial demonstrations at nurseries looking at both protected edibles (tomatoes PC 188) and pot chrysanthemums (PC 197).

This year project PC 190 specifically looked at a demonstration of the use of temperature integration in poinsettia production. Poinsettias were used as a crop because over their growing season they respond differently to humidity levels. Early in production (August – September) as cuttings are rooting and young plants growing, high humidities are important to increase rooting and leaf size as much as possible. However once the bracts begin to show first colour (October), high humidity can actually damage bract development by causing cells to rupture and the latex sap to blacken on the developing bract. Another feature of poinsettia is that their production schedule and shelf life have been well quantified so any disturbance due to environmental conditions can be easily identified.

Objectives

- To evaluate the potential energy savings of a temperature integration regime compared to a commercial control.
- To quantify crop speed, quality and shelf life of the poinsettia crops grown under two temperature regimes.

2.2 Methods and Materials

2.2.1 Treatments

The trial took place at HRI Efford using the two central compartments in Q Block, one for the standard commercial treatment and the other for the integrated temperature treatment. The temperature integrated treatment was carried out using a Priva Integro computer applying a three day integration period. 11 cultivars of poinsettia were used giving 22 treatments. A Trojan square plot layout gave two plots of each variety, covering the North and South end of each compartment.

During poinsettia production temperatures are dropped from 20°C to 16°C, which has been shown to improve marketing and shelf life quality. This suggested two possible methods for temperature integration, either a fixed bandwidth of positive and negative temperatures that moved as the set point in the control compartment moved; or maximum and minimum set points for the whole trial with just the desired average maintained the same as the control. The trial attempted to utilise the second method of maintaining wide bands and to just alter the desired average, however, this led to too high temperatures early in production and so we reverted to lowering the upper limit and lowering the lower temperature to try to lower the achieved temperatures.

The set point changes used in the two compartments are shown in table 1. We attempted to keep all settings other than temperature the same in both compartments. Any change to the temperature set point in the control compartment was reflected with a change in 'average temperature' set point in the integrated compartment.

Table 1: Compartment heat and vent set points, and deviation settings for the temperature integration treatment.

Date	**Control (°C)**		**Integration (°C)**		**Deviation (*on integration*)**
	Heat	**Vent**	**Heat**	**Vent**	**Positive/Negative (°C)**
01/08/02	20	22	20	24	4/2 = max 24, min 18
11/09/02	20	22	20	24	4/5 = max 24, min 15
16/09/02	19	21	19	23	4/4 = max 23, min 15
11/10/02	18	20	18	23	4/3 = max 22, min 15
25/10/02	18	20	18	23	4/3 = max 22, min 15
29/10/02	17	19	17	23	4/2.5 = max 21, min 14.5
05/11/02	16 (Night 17 / 19)	18	16.5	19*	4/2 = max 20.5, min 14.5
20/11/02	16	18	16	18*	4/2 = max 20, min 14

* The vent temperature increased by an additional 4°C as radiation rose from 100-300 Wm^{-2}.

No minimum pipe temperature was used until the onset of bract colouring (11 October 2002) when a minimum pipe of 15-20°C (see Table 2) was used to start controlling for humidity. Very strict humidity controls were set up at this stage on a 'heat then vent' strategy. Table 2 gives details of the humidity controls used. The humidity control was very tight with the aim of reducing all peaks of 90% RH or above. The changes were made in an attempt to get the best control with the minimum energy use. Thermal screens were gapped at night from 0 - 10% between 80 to 85% humidity up to 6 November 2002, and between 75 and 80% from then on.

Table 2: The humidity control measures used during the trial period

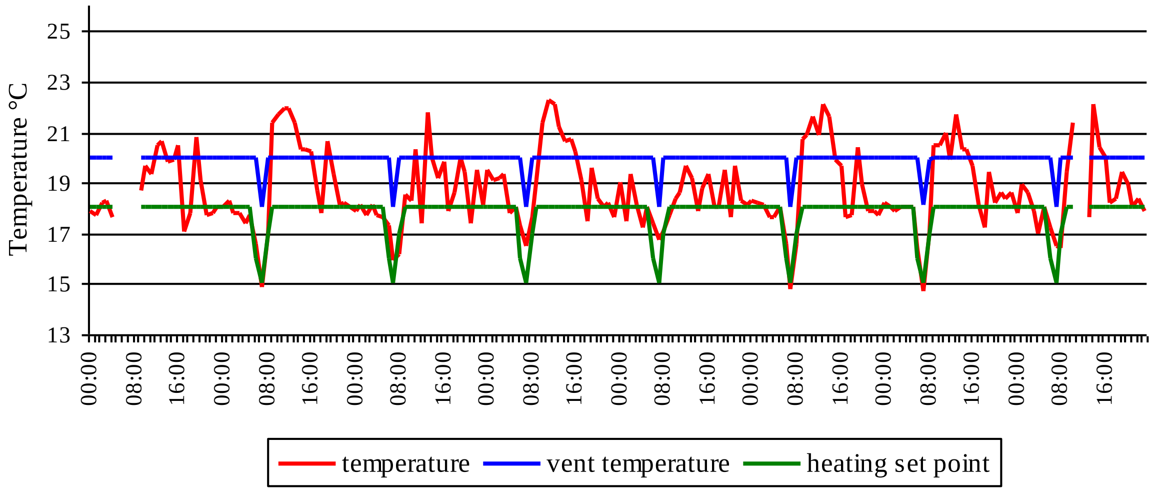
Date	**Pipe temp** Min/Max (°C)	**Humidity Control** %RH / increase in pipe heat °C	**Humidity control** %RH / increase in vent %
31/7/02	0/80	-	-
11/10/02	20/80 (15/80 in drop)	73/0 75/1 79/3 82/5	75/0 77/1 81/2 84/3
21/10/02	15/80	As above	As above
25/10/02	15/80	73/0 75/3 77/4 79/5	75/0 77/3 80/3 82/5
30/10/02	15/80	73/0 75/3 77/5 79/6	As above
01/11/02	20/80	As above	75/0 77/3 79/5 81/7
05/11/02	*20/80	73/0 75/5 77/8 79/10	78/0 80/1 82/2 84/3
19/11/02	*20/80	75/0 77/5 79/8 81/10	As above

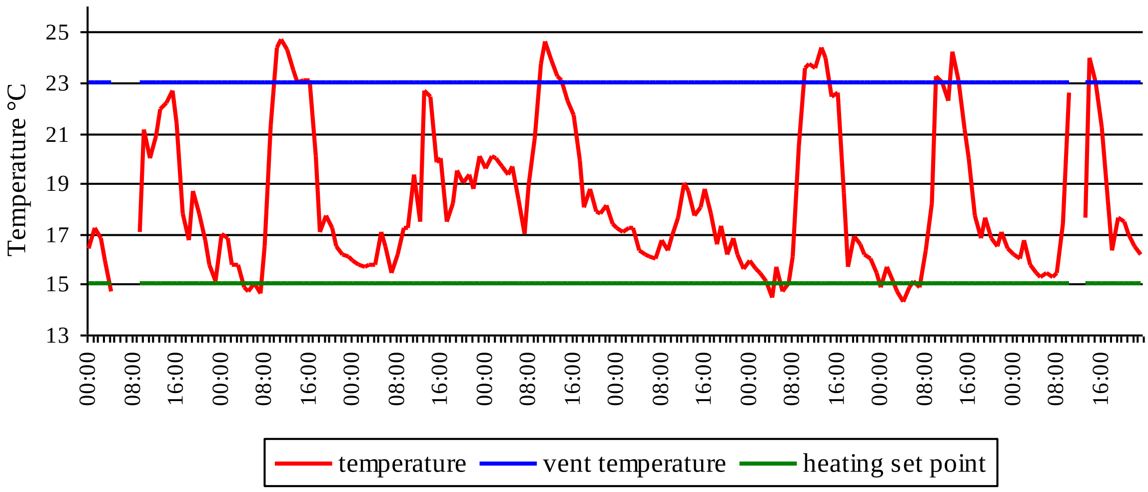
* The minimum pipe was taken out as radiation rose from 100-300 Wm^{-2} in the integrated compartment.

CO_2 enrichment was applied via a forced air system, blowing enriched air through perforated clear plastic tubing. CO_2 enrichment, controlled by the Priva environmental computer, was set to a level of 900ppm. CO_2 enrichment stopped as vents opened between 1-5%. This is a strict strategy that allows very little wasted CO_2 to the atmosphere and accurate volumes of CO_2 used logged. Commercially when CO_2 is taken off the boiler or from another system it may be more usual to keep enriching with CO_2 until the vents are 15% open.

Between 11th and 24th October a DROP period was added to the control compartment. The integrated compartment achieved a natural DROP when the screens came off in the morning due to the negative deviation on set point used for temperature integration. Figure 1 shows the supervision graphs of temperature and vent set points in each compartment during part of the DROP period along with the achieved temperature. You can see that the actual DROP achieved was very similar in both compartments. On the 23rd and 24th of October, for example, both compartments show a good DROP with the compartment temperature down below 15°C in the early morning. Conversely, neither compartment reached the DROP set point temperature on the 21st or 22nd October.

Figure 1: Temperature graphs showing the achieved temperature (red line), vent temperature (blue line) and heating temperature (green line) between 18.10.02 and 25.10.02. Top graph shows the control environment and the lower graph is the integrated environment. Both graphs have the same scale.





2.2.2 Cultural Details

Plant material

Rooted cuttings of the 11 cultivars from two suppliers were used for the trial (Table 3). Cuttings were potted in week 31 into 13cm pots using Sinclair Poinsettia mix. They were pinched between weeks 32 - 34 and spaced between weeks 35 – 40 as needed, to a final spacing of 9/m² (See Appendix 1 for full crop diary).

Table 3: Details of cultivars used in trial

Supplier	Cultivar	Response group (weeks)
Hollyacre Plants Ltd	Spotlight Dark Red	8
	Eurostar	8
	Eternity Red	7
	Premium Red	7
	Elegance Pink	8
	Elegance White	8
Yoder Toddington	Sonora	8
	Red Elf	7
	Da Vinci	7
	Cortez	7.5
	Marblestar	8

Growing Environment

PGR

PGR's were applied according to each variety's requirement from the graphical tracking as well as some for 'shaping'. All environmental controls were based on the commercial control variety Sonora. Cycocel was applied, at 2 rates, to each cultivar as needed between weeks 34 and 43. Alar, at 500ppm, was also applied to Sonora in both treatment regimes in week 37 and to Sonora, Cortez and Elegance Pink in week 38 in the integrated regime (Table 4).

Table 4: Summary of PGR applications. 1st figure is CCC @ 500 ppm, 2nd is CCC @ 1000 ppm.

Cultivar	Standard Regime	Integrated Regime	% increase (extra no. of applications)
Sonora	14 + 2 + 1 alar @ 500ppm	15 + 3 + 2 alar @ 500ppm	17 (3)
Cortez	10 + 6	11 + 7 + 1 alar @ 500ppm	19 (3)
Spotlight Dark Red	10 + 6	10 + 7	6 (1)
Eternity	8 + 6	10 + 5	7 (1)
Eurostar	0 + 13	0 + 15	15 (2)
Premium	0 + 1	0 + 1	0
Red Elf	0 + 1	0 + 1	0
Da Vinci	0 + 12	0 + 15	25 (3)
Elegance Pink	3 + 12	11 + 7 + 1 alar @ 500ppm	26 (4)
Elegance White	0 + 11	0 + 15	27 (4)
Marblestar	0 + 7	0 + 9	28 (2)

Spacing

Pots were spaced at 25/m² initially and then half-spaced to 15/m² and to a final spacing of 9/m² as each cultivar required (See Appendix 1 for full crop diary).

Crop Nutrition

Liquid feeding was via a hose and lance initially, followed by seep hoses after first spacing. The feed regime was according to commercial practice at each stage of production.

Pest & Disease Control

Pest control was monitored daily with a crop walk examining the plants and yellow and blue sticky traps. *Encarsia* was introduced on a fortnightly basis and *Hypoapsis* was introduced once in week 37.

Graphical Tracking

'TRACKER TM, the HDC graphical tracking tool, was used for graphical tracking. The results from this were used as a guide to any temperature set-point adjustments needed, the use of DROP and DIF and the application of any PGRs. Sonora was used as the standard variety and changes to the environmental conditions were based upon its development.

During home-life

Six pots per treatment were sleeved, boxed and placed into the pack-house under ambient conditions for 48 hours. They were then removed from the boxes, and placed on benches for a further 5 days in their sleeves, at 18°C with 1000 lux (via fluorescent tubes) for 14 hours a day. They were then de-sleeved and remained in the same environment for another 6 weeks.

2.2.3 Assessments

Environmental records

External ambient light MJ/m²

Internal ambient light (PAR) MJ/m²

Compartment temperatures

CO2 levels achieved and logged inputs

Relative Humidity

Comparisons of 'actual' achieved environment to the set-point environment

Energy usage was recorded using flow meters with data converted to kWh.

Production records

Weekly heights for graphical tracking (cm)

Time to first colour

Time to first visible cyathia

Marketing records

Plant height - cm (from bench to top of foliage)

Plant diameter - cm (across widest point and at 90 degrees)

Number of breaks on each plant

Number of heads on each plant within each of four size grades:

Size grade (i) < 150 mm

Size grade (ii) 150 – 200 mm

Size grade (iii) 200 – 225 mm

Size grade (iv) > 225 mm

Cyathia number (dominant break)

Cyathia stage of development (dominant break)

Stage 1 = tight green bud

Stage 2 = bud colour

Stage 3 = pollen showing

Stage 4 = stigma open

Stage 5 = pollen and stigma

Score of overall quality

0 = Unmarketable (few uneven heads)

1 = Second Grade (3 – 4 heads above canopy)

2 = First Grade (5-6 coloured heads at canopy height)

Shelf-life records

Cyathia number on the tagged break

Leaf loss per plant

Red bract loss per plant

Incidence of bract necrosis and pale edges

Incidence of *Botrytis* on leaves and bracts

Mechanical damage score at de-sleeving:

0 = none

1 = slight

2= moderate

3 = severe

Bract and leaf colour loss

Plant longevity: determined as time up to which plant would be fit to remain on display

Final leaf count at end of 6 weeks to estimate % leaf loss during shelf life

Expert Scoring (done by Gary Shorland, DoubleH Nurseries)

Bract quality

Leaf quality

Cyathia quality

Overall quality

Note: All scores done on a 10 – 0 basis where 10 = excellent

2.3 Results and Discussion

2.3.1 Environmental conditions

The average temperature over the whole period of the trial was only 0.2°C different between compartments, 20.9°C for control and 21.1°C for the integrated compartment. However, the deviation from set point was greater in the integrated compartments (Table 5). This is important as variation from growing temperatures may speed up or delay a crop. If one were growing at the optimum temperaure a deviation either positive or negative would slow development. All physiological processes will have their own optimum temperature and the optimum for flowering may not be the optimum for leaf expansion, rooting or bract development. However most crops are grown for flowers and so average temperatures below the optimum for flowering would be expected to slow development and a positive deviation to hasten it.

Examination of the data from the last 3 weeks of production (Table 5) show that the average temperature in the integrated compartments was higher than desired. This was caused by the way integration and humidity control were interacting. At this time the integrated compartment had an average set at either 17 or 16°C but with an upper compensation temperature between 23 and 18°C (Table 1). The humidity control was set to increase pipe temperature by as much as 10°C as the humidity rose to 80% RH (Table 2). This led to increases in compartment temperature that were not caused by solar radiation but still increased the average. The average temperatures in the integrated compartment at this time are higher than the control and high temperatures at the end of poinsettia production are known to lead to poorer shelf life quality (PC 71 a-d, PC 156). Operating humidity control on a 'vent then heat' rather than 'heat then vent' strategy and reducing the integrated vent temperature nearer to the desired average would have maintained a lower average temperature during this critical period of production.

Table 5: The weekly temperature set point versus the achieved temperature and average deviation from the set point in both compartments. * Numbers in brackets indicate the increase in deviation from the set point when compared to the control environment.

		Control		Integration	
Week	Set Point °C	Avg Temp °C	Avg Deviation °C	Avg Temp °C	Avg Deviation °C *
31	20	25.0	6.4	25.0	6.1 (-0.3)
32	20	23.7	4.7	24.0	4.8 (0.1)
33	20	23.9	5.8	24.4	5.8 (0.0)
34	20	23.7	5.4	24.2	5.6 (0.2)
35	20	22.5	3.6	22.7	4.1 (0.5)
36	20	22.2	3.4	22.3	3.8 (0.4)
37	20	21.6	3.9	21.9	4.6 (0.7)
38	19	20.5	2.7	20.2	3.5 (0.8)
39	19	20.5	2.6	20.3	3.4 (0.8)
40	19	20.1	2.4	19.4	3.4 (1.0)
41	19	19.0	1.3	19.3	1.8 (0.5)
42	18	18.7	1.7	18.3	2.9 (1.2)
43	18	18.1	1.4	17.3	2.5 (1.1)
44	17	18.2	2.0	19.6	3.4 (1.4)
45	16	18.2	2.3	18.6	3.1 (0.8)
46	16	17.7	2.1	19.0	3.6 (1.5)

2.3.2. Plant responses: scheduling

All cultivars except one (Red Elf) were on average 1½ days earlier to show first colour in the standard regime compared to the integrated (Fig 2). Most cultivars were also earlier to first visible cyathia in the standard regime, averaging ½ day less (Fig 3). There was no perceived difference in time to market between the two treatments. (See Appendix 2 for full results). In part this reflects that poinsettias are sold on coloured bracts rather than actual stage of flowering.

Figure 2: Mean number of days from potting to first colour for each cultivar

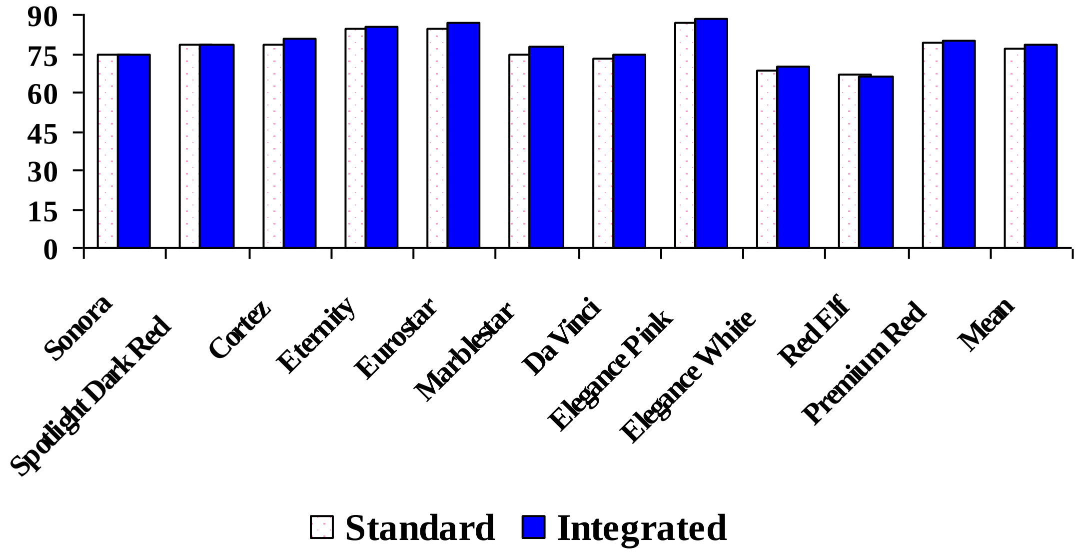
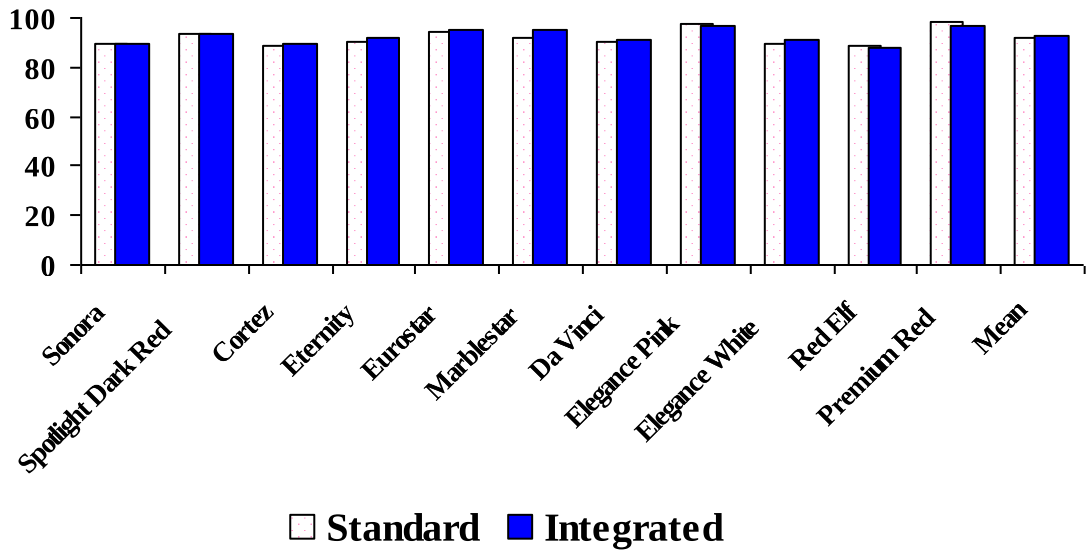


Figure 3: Mean number of days from potting to first visible cyathia



Marketing

The height specification for standard poinsettias grown in a 13cm pot was 36-42cm from the bench in 2003 (Fig 4). This was where the biggest difference between treatments could be seen. With the exception of Sonora, which was the cultivar being used to guide the integration adjustments and PGR applications, all other cultivars were taller in the Integrated regime (Fig 5 & 6), which could be helpful with modern less vigourous varieties.

Figure 4: Heights of each cultivar at marketing (cm.)

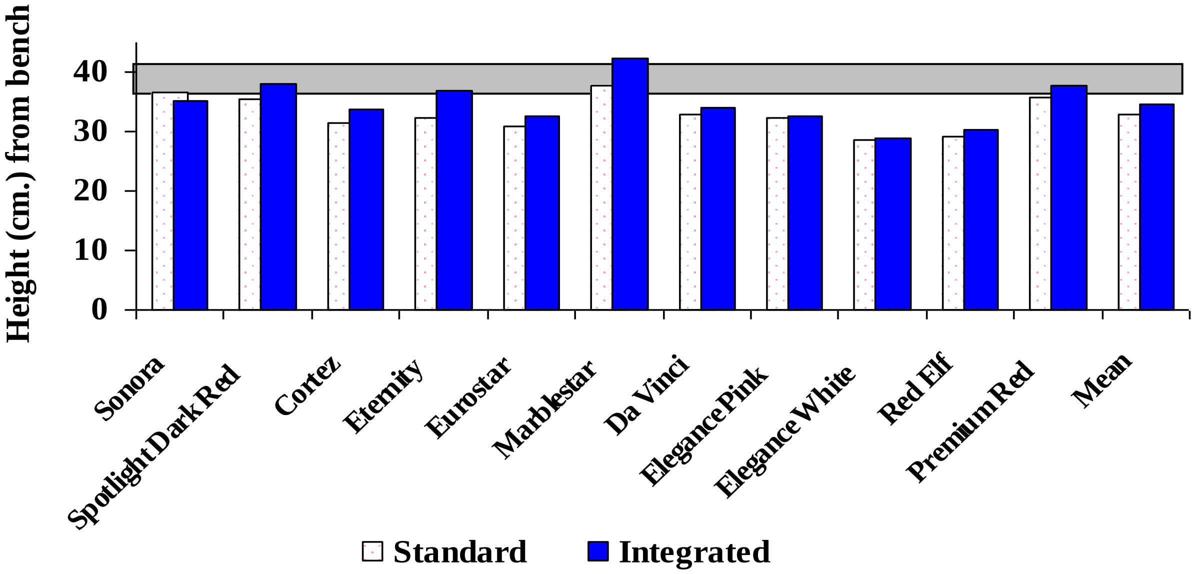
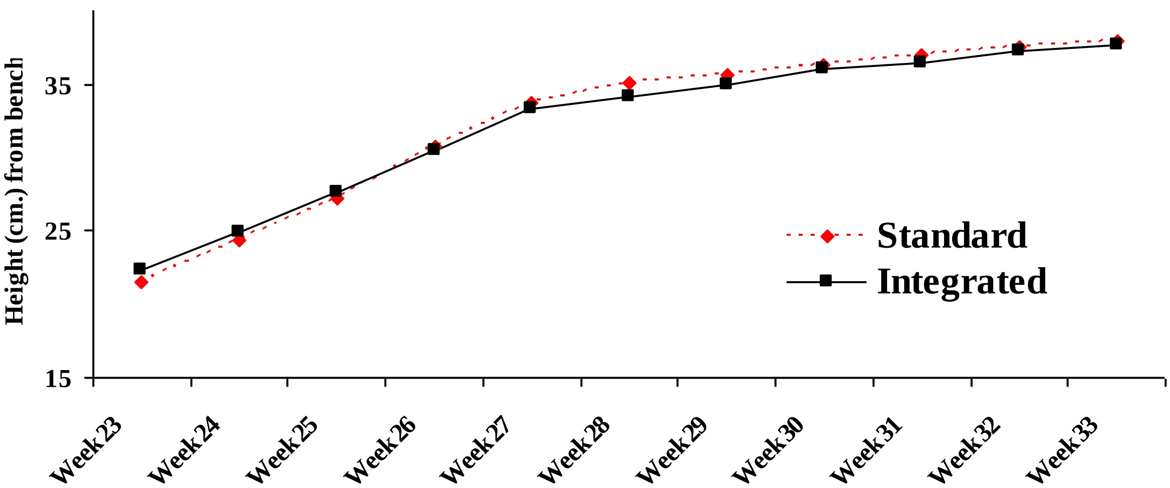
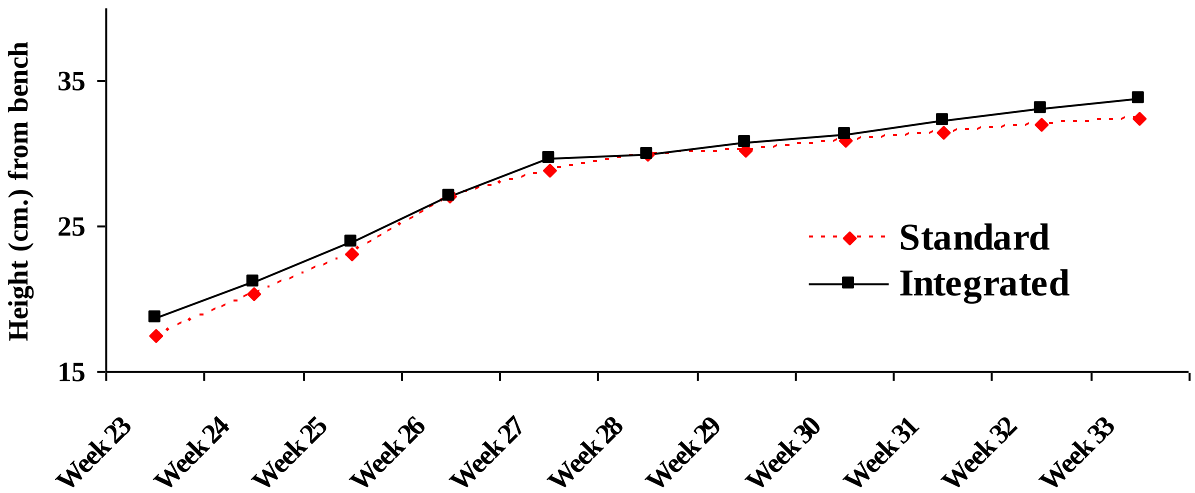


Table 5: Graphical Tracking heights - Sonora



The height of some cultivars was below market specification, especially the coloured varieties and the newer more compact red varieties. In part this is a problem of growing eleven cultivars in one unit, but after consultation with the grower co-ordinator, the quality of the plants was so good that it was not deemed to be of sufficient significance to downgrade the plants in the quality assessment at marketing. It is interesting to note that the standard variety, Sonora, was no different between treatments, this should give confidence that if integration was used in a single unit with one variety, market specification could easily be reached.

Table 6: Graphical tracking heights - Marblestar



All cultivars, except one (Marblestar) in the Standard regime, had more than 4 primary heads. Eight of the 11 cultivars had a higher number of primary heads in the Integrated regime. There was no significant difference in plant spread between the treatments, or between numbers of cyathia and stage of development.

The overall quality score was not significantly different between the treatments. This confirms the visual impression at marketing that, apart from some height differences, the quality of plants from each treatment regime could not be differentiated. This result aligns with the previous results on pot-mums in the 2001 PC 190 trial which demonstrated that no marketing differences could be seen between crops from temperature integration treatments.

Fresh and Dry weights

Both the fresh and dry weights at marketing showed plants from the Integrated regime were significantly heavier than those from the Standard regime. (Figs. 7 & 8). The only variety not to do so was Da Vinci. The increase in weight may be because the integrated environment had higher levels of CO_2 as the vents were closed for longer each day. This is again confirmation of a result seen in 2001 on pot chrysanthemums.

Figure 7: Mean Fresh weight/plant (g) at marketing

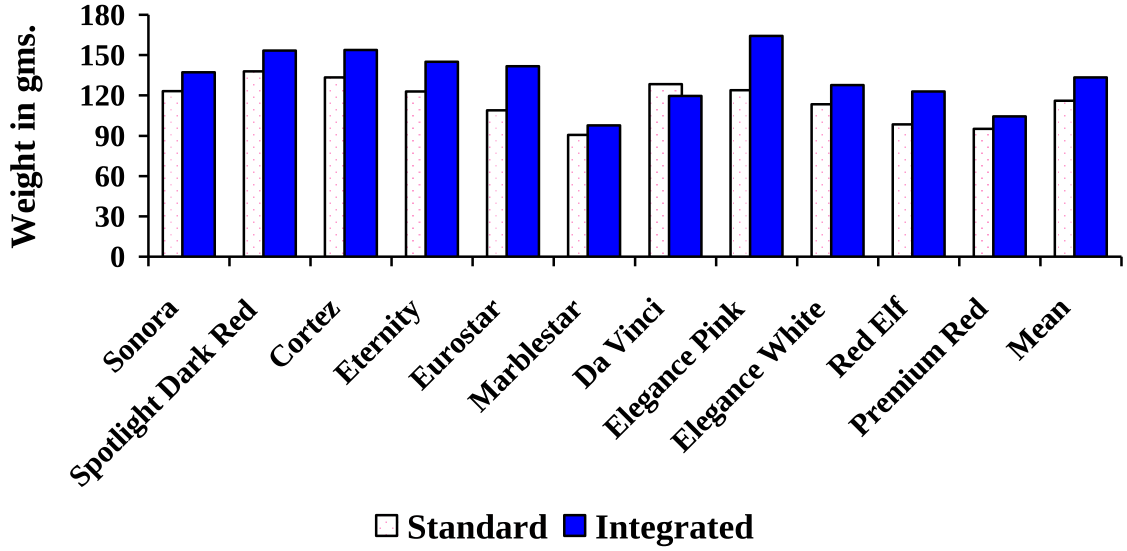
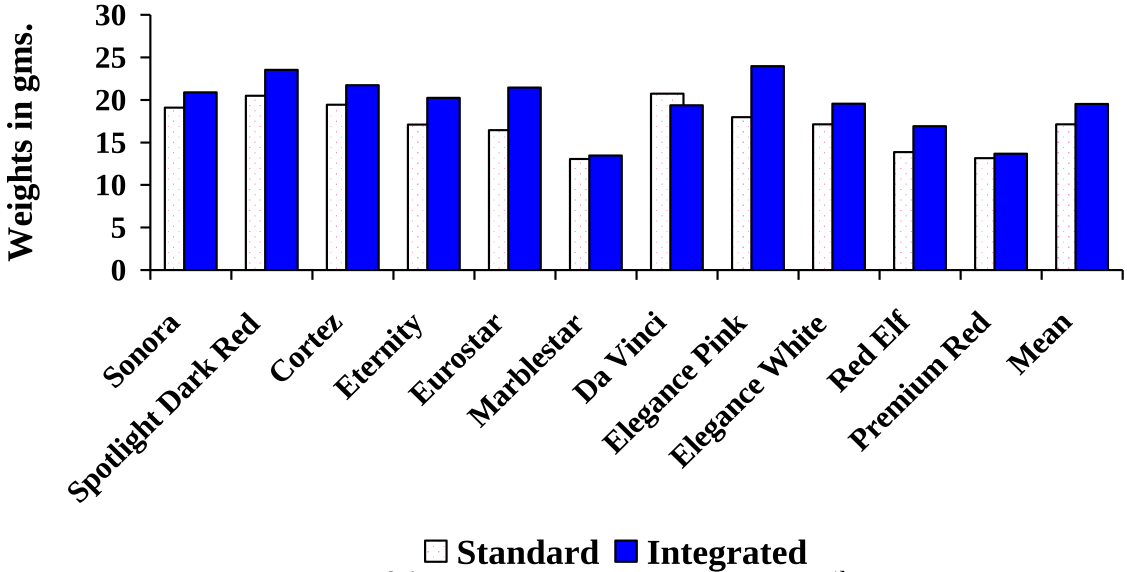


Figure 8: Mean Dry weight/plant (g) at marketing

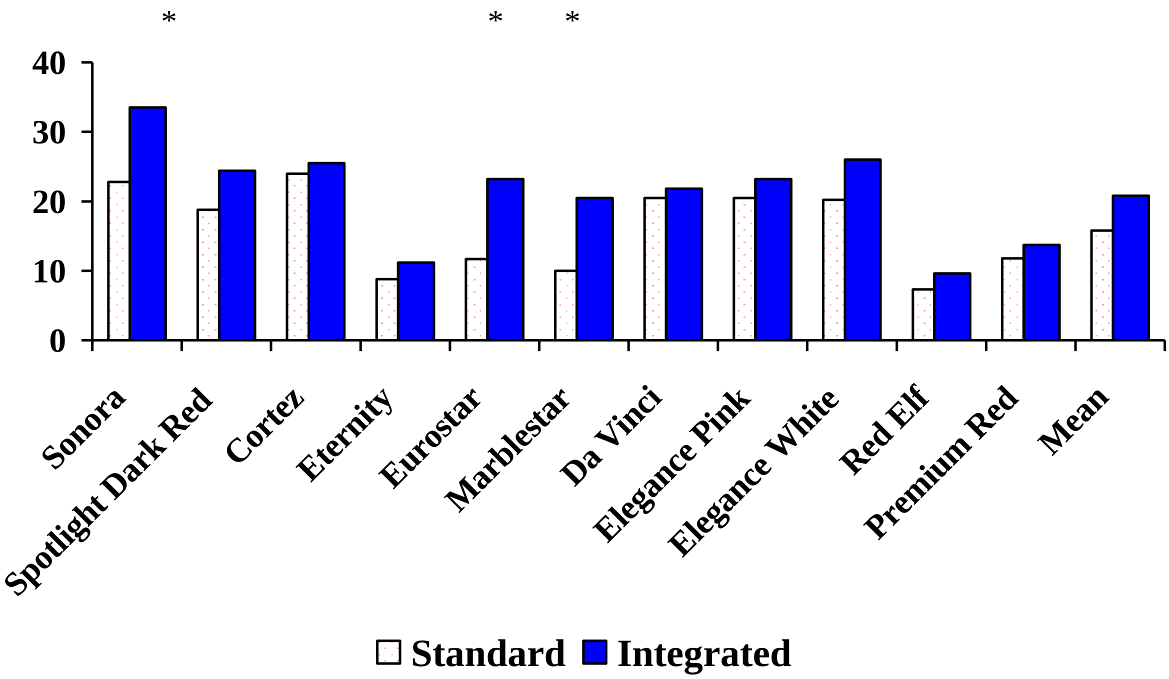


Shelf life

Green leaf loss

Sonora, Eurostar and Marblestar had a significantly higher leaf loss in the integrated regime (Fig. 9). All other varieties had higher cumulative leaf loss from the integrated regime.

Figure 9: Mean Cumulative leaf loss/plant throughout shelf life. * indicates a significant difference



It was possible that the increased leaf loss was due to a higher leaf number at the start of shelf-life. Final leaf count data was collected and converted to percentage of leaves lost during shelf life (Fig.10). This confirmed that several varieties from the integrated regime had lost more leaves cumulatively. The varieties that did not loose more leaves were Spotlight, Cortez, Eternity, Elegance Pink and Premium Red. It is possible that the varieties that lost more leaf are more sensitive to finishing at higher temperatures which occurred in the integrated regime.

Bract loss

The cumulative number of bract leaves dropped during shelf life was also higher from the integrated regime plants throughout the six weeks. By week three of shelf life the difference was highly significant and remained so to the end of shelf life (Fig. 11). Both the increased bract and leaf loss suggests the plants from the integrated treatment had poorer shelf life, although again there were some varietal differences.

Figure 10: Mean percentage of green leaves/plant lost during shelf life; * indicates a significant difference

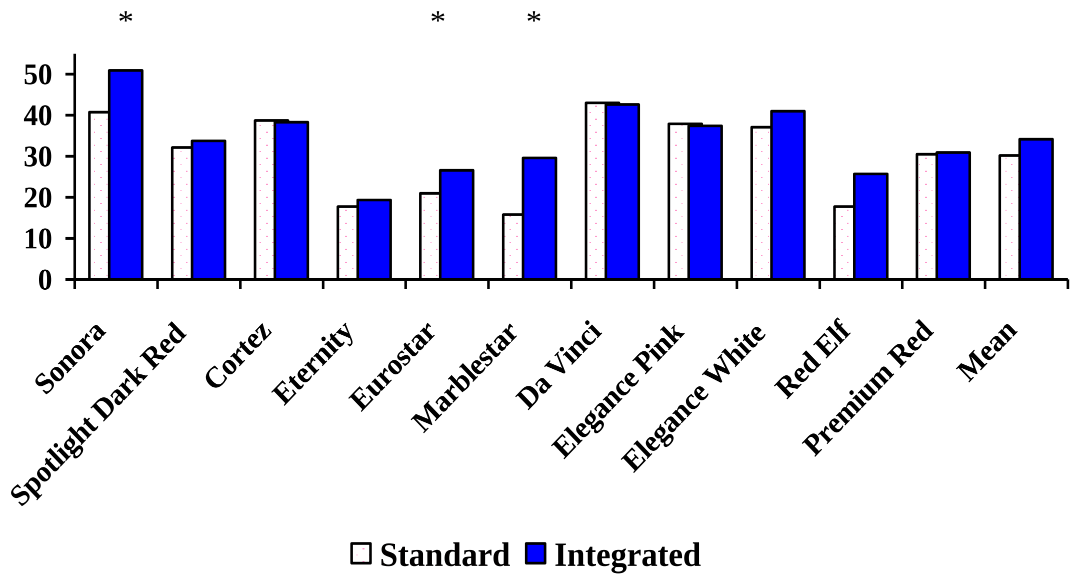
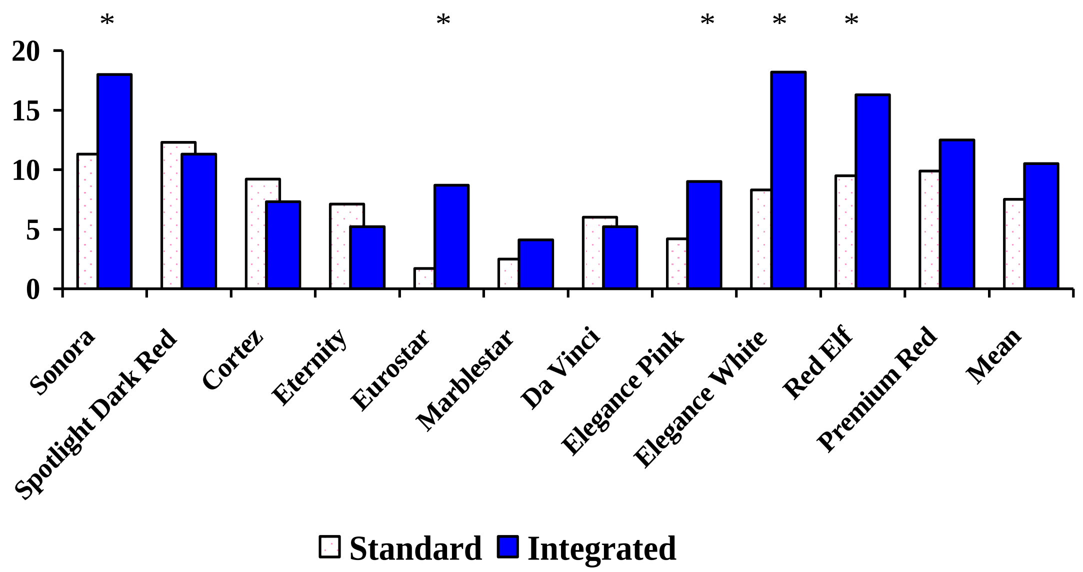


Figure 11: Mean cumulative number of bract leaves/plant lost during shelf life; * denotes a significant difference



Leaf Colour

The foliage and bract colour loss was slightly higher in plants from the integrated regime, although not significant. This again suggests that the integrated plants were finished at a higher temperature and this is causing poorer shelf life.

Cyathia

All plants kept some cyathia throughout shelf life with some cultivars losing very few. By the end of shelf-life the plants from the standard regime had a significantly greater number of cyathia remaining than those from the integrated regime. This was also noted by the expert score on cyathia quality.

Disease

There was a significantly higher incidence of botrytis in plants from the integrated regime. This was seen from the first week of shelf life. More plants died from the integrated compartment and although botrytis infections were noted, lab analysis suggests this was not causal. Most of the plants that died wilted severely beforehand and some of them had poor root systems. Approximately 21% of the integrated regime plants had to be disposed of before the end of shelf life testing compared to 7.6% of the plants from the standard regime. This level of plant loss is unacceptable and when considered alone would lead one to conclude that the method of temperature integration used in this trial was not optimised and would not be appropriate for adoption for commercial poinsettia production. Turning TI off for the last month of production or altering the venting and humidity strategy would certainly lower the average temperature and may help to offset the adverse effects on shelf-life noted here. See Appendix 3 for summary of all shelf-life data.

Expert Assessments

Despite very little difference at the start of shelf life, by week 4 the expert assessed the overall quality to be superior for the plants from the standard regime. This was due mainly to a loss in bract quality in those plants from the integrated regime and partly to a lower leaf quality score in the same plants. The cyathia score, while appearing not to have an influence on the overall quality, was significantly higher in the Standard regime plants by the end (See Appendix 4 for summary of results).

2.3.3 Energy Savings

The energy inputs for each treatment were monitored from pulsed output meters attached to the electricity and gas (heat) inputs as well as CO_2 input. These were logged by the PRIVA environmental computer. In the first year, PC190 independently logged the energy use (in collaboration with FEC Services) as well as the PRIVA computer, both sets of logged figures showed the same energy use, giving confidence to the data logged by the PRIVA.

The figures for CO_2 use were very similar in both compartments by the end of the trial although at times throughout the trial the integrated compartment had used more (Figure 12). CO_2 enrichment stopped as the vents open (to 5%) so the control compartment, which was generally venting more frequently due to its lower vent set point, tended to enrich the environment less. Early and late in the trial we attempted to maintain ambient levels at 330 vpm even when the vents were open, however during the middle of the trial this was switched off. The data suggests that had we tried to maintain ambient throughout or indeed supplement CO_2 then the control would have used far more CO_2. As it was the treatments used about the same. This was reflected in the achieved levels of CO_2 which were generally greater in the integrated compartment (Figure 13).

Figure 12: The cumulative CO_2 use for each treatment for the whole trial. 1st August 2002 – 22nd November 2002.

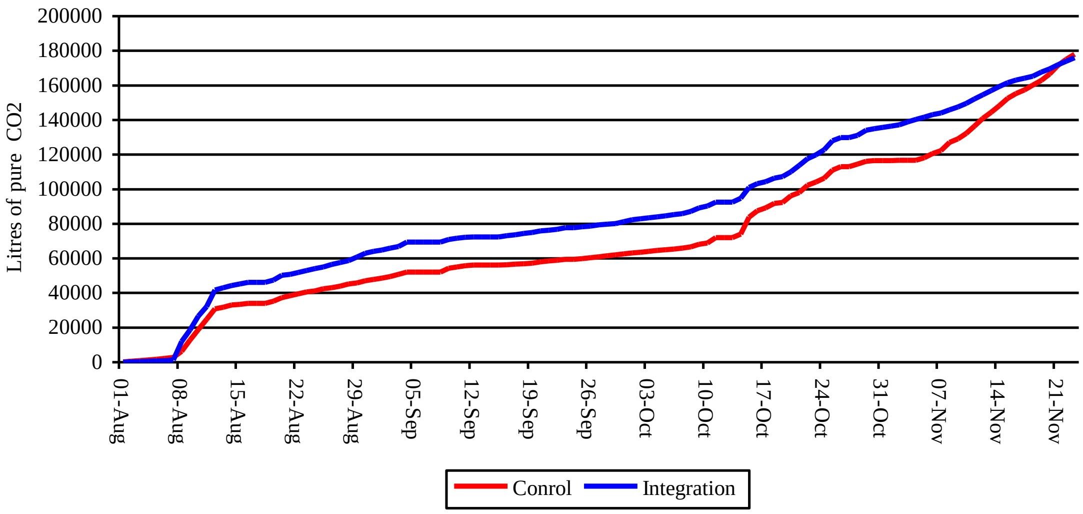
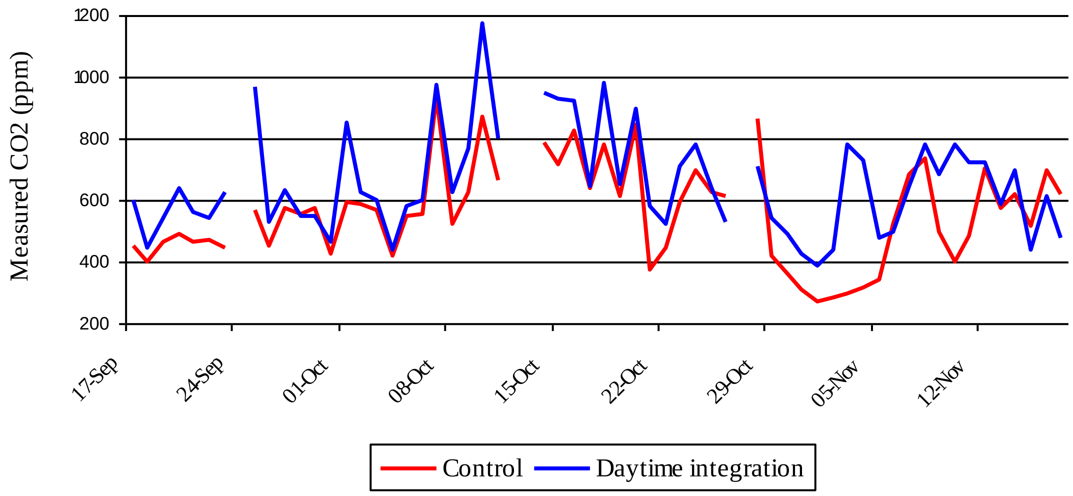
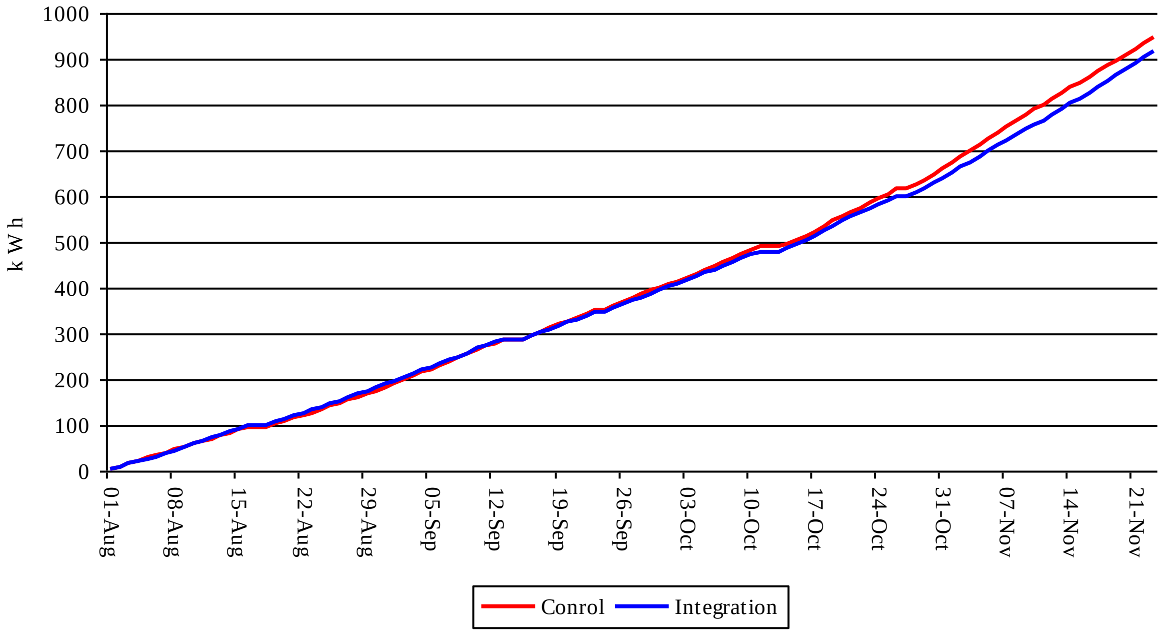


Figure 13: Average daily CO_2 levels from 17th September to 22nd November 2002.



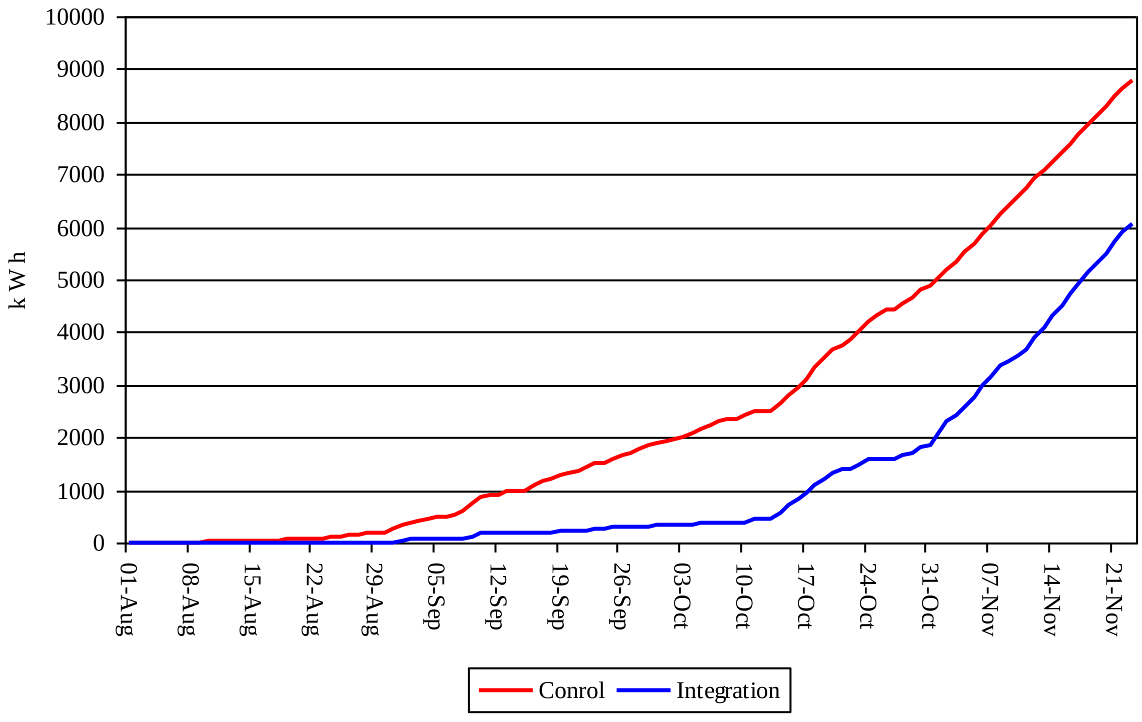
The figures for the electricity use were not significantly different for either treatment (Figure 14). The primary use of electricity for this trial was the forced air CO_2 system, vents and thermal screens. No lighting is used in poinsettia production so electricity use is minimal in comparison with energy used for heating and humidity control.

Figure 14: The cumulative electricity use for each treatment for the whole trial from 1st August 2002 – 22nd November 2002.



The main use of energy was in heating the compartments (Figure 15). The heating pipe temperature in to and out of each compartment was measured along with the flow rate and these figures converted to kWh. Both compartments used in this trial were inner compartments with one South facing outside wall each. The trial compartments were next to each other with one other compartment adjoining each that was maintained at 18°C. **The total energy saving from the integration treatment for the whole trial period was 32%.**

Figure 15: The cumulative energy use for each treatment for the whole trial from 1st August 2002 – 22nd November 2002.

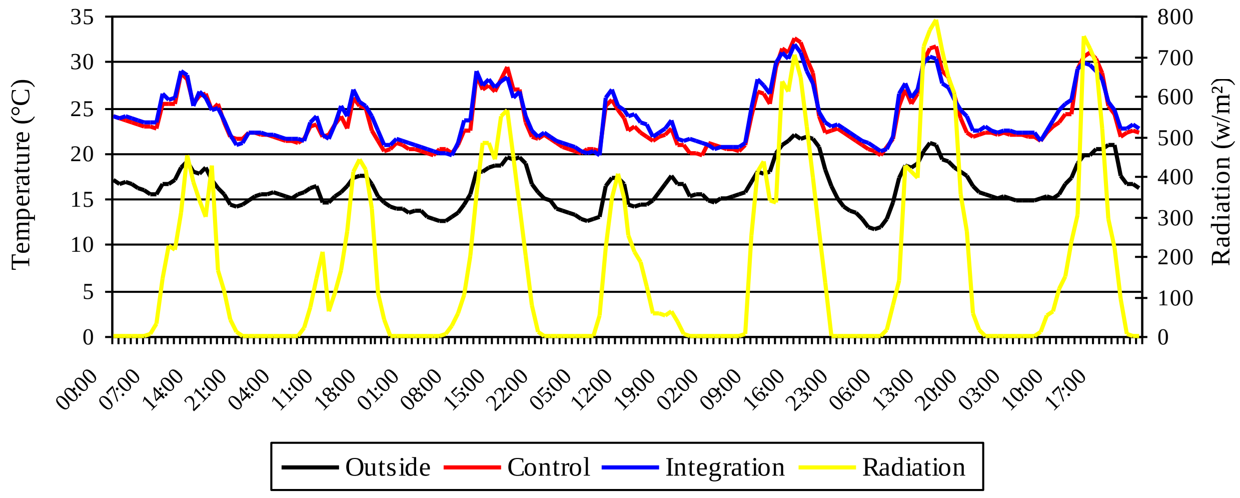


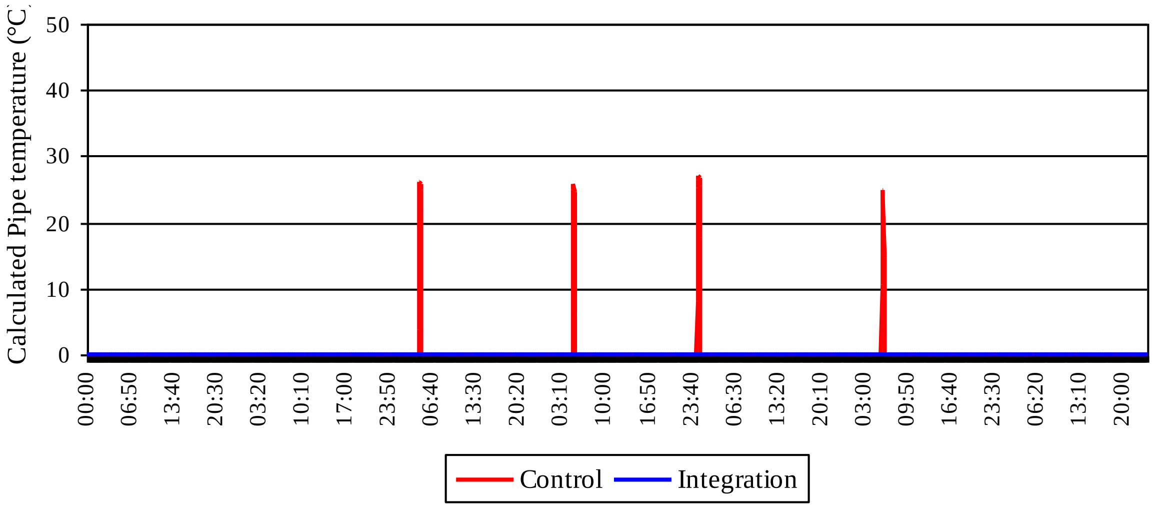
The graphs that follow show the energy saving that was achieved using temperature integration over specific weeks in each month of the trial (Fig 16). Each of these graph sets contains the same three graphs: the first is the achieved compartment temperature in each regime, along with the outside temperature and the radiation received on that day. The second graph shows the calculated pipe temperature for each compartment, which indicates when the treatments have called for heat. The peaks show how hot the water is required to be to deliver the desired temperature lift to a compartment.

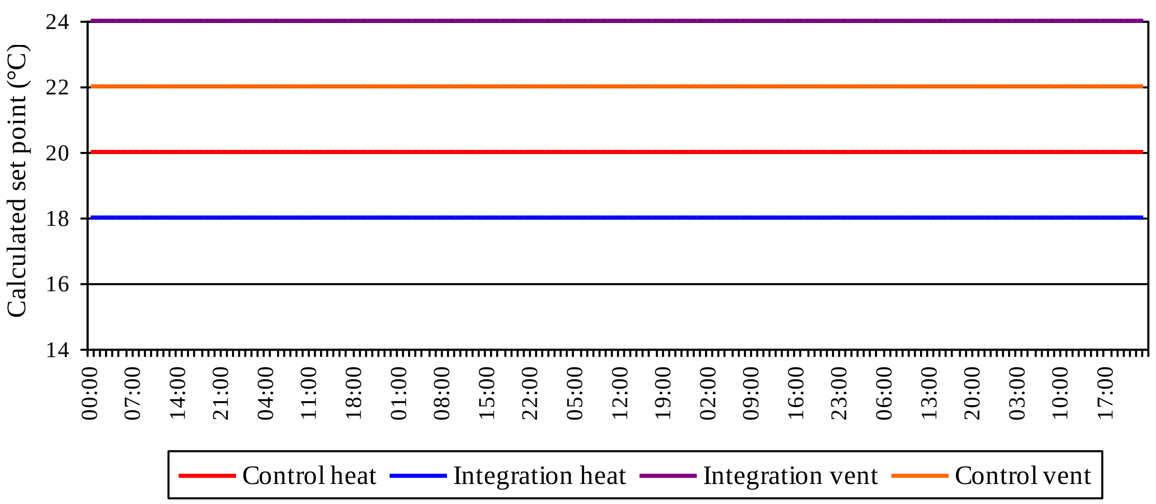
The third graph shows the calculated set points for heating and venting in each treatment. It is important to remember that a compartment will only call for pipe heat if the air temperature drops to the heating set point *(unless pipe heat is being used for humidity control)*. The heating set point is usually the temperature at which the grower wishes the crop to be maintained (remembering that, as a general rule, the heating set point controls your night-time temperature while your vent set point controls your day-time temperature, given sufficient solar gain). While using temperature integration however, the heating set point is controlled by the environmental computer (within specified limits). The computer can change the heating set point depending on the amount of solar gain and therefore the number of degree hours banked. The computer only raises the heating set point above the minimum that you have set if it has not gained enough degree hours.

Figure 16 (on subsequent pages): A series of graphs showing achieved treatment temperatures, calculated pipe heat and treatment calculated set points. The graphs are for a week each in August, September, October and November.

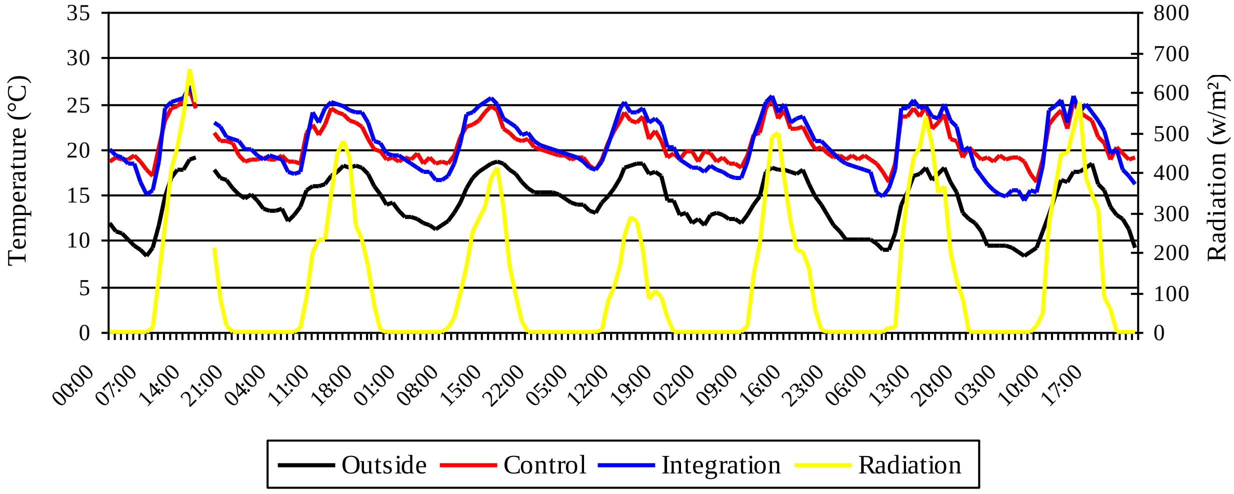
8 – 14 August 2002

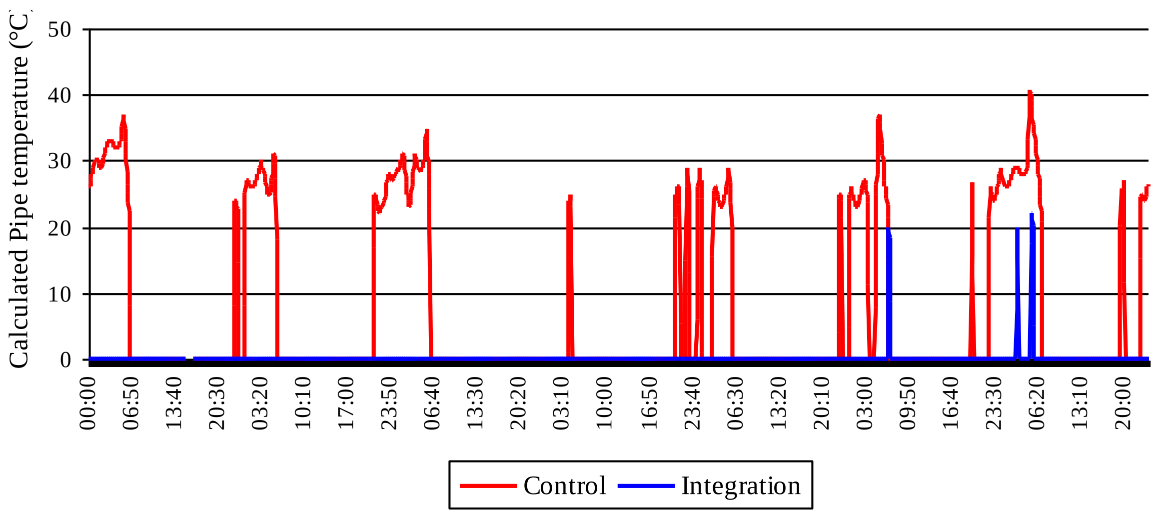


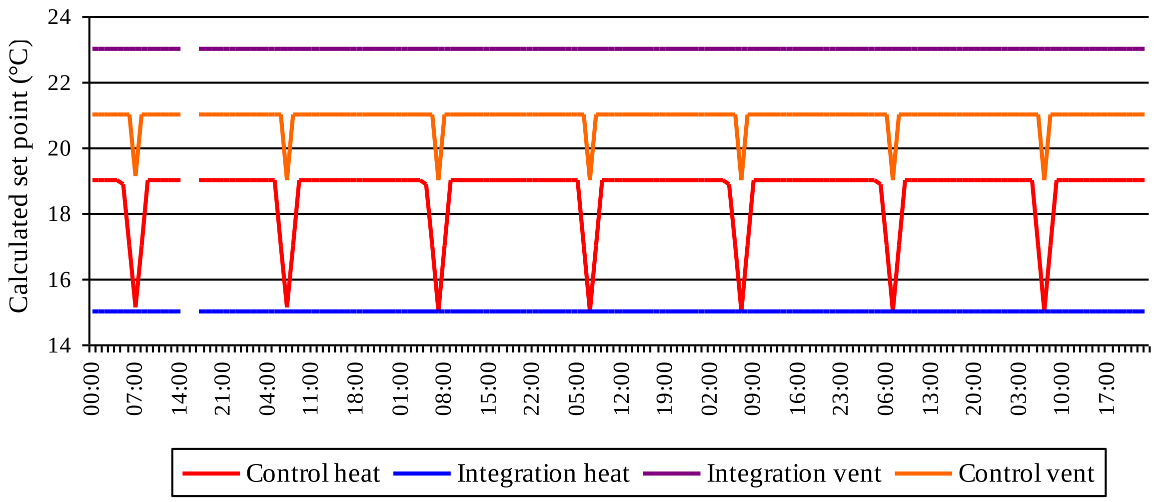




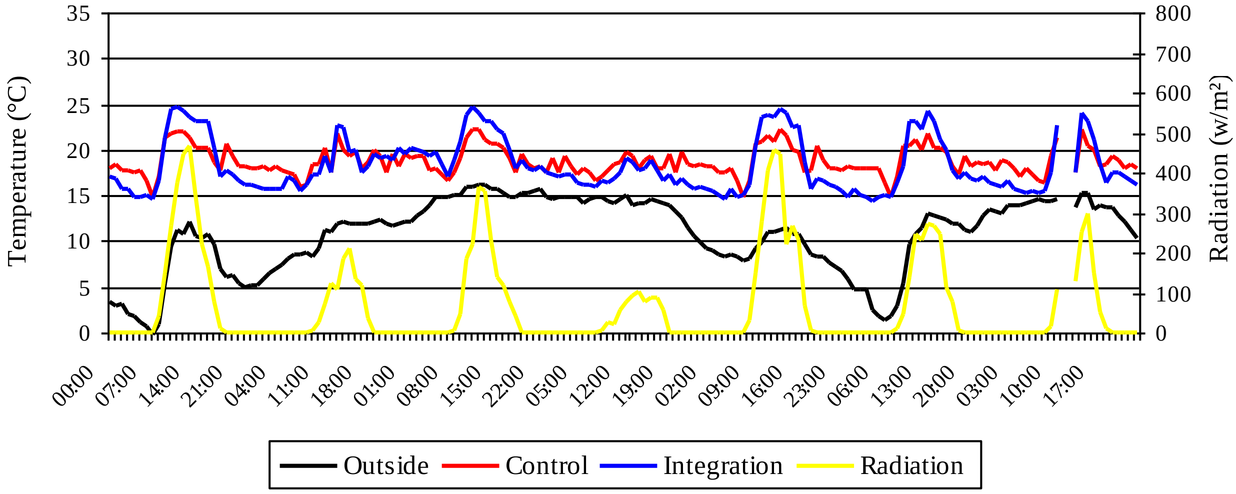
17 – 23 September 2002

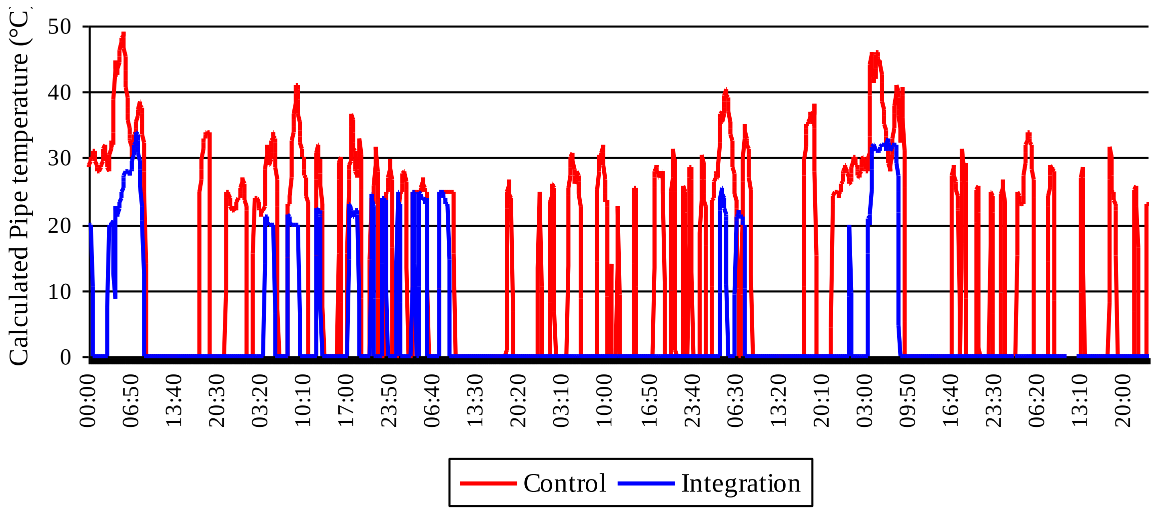


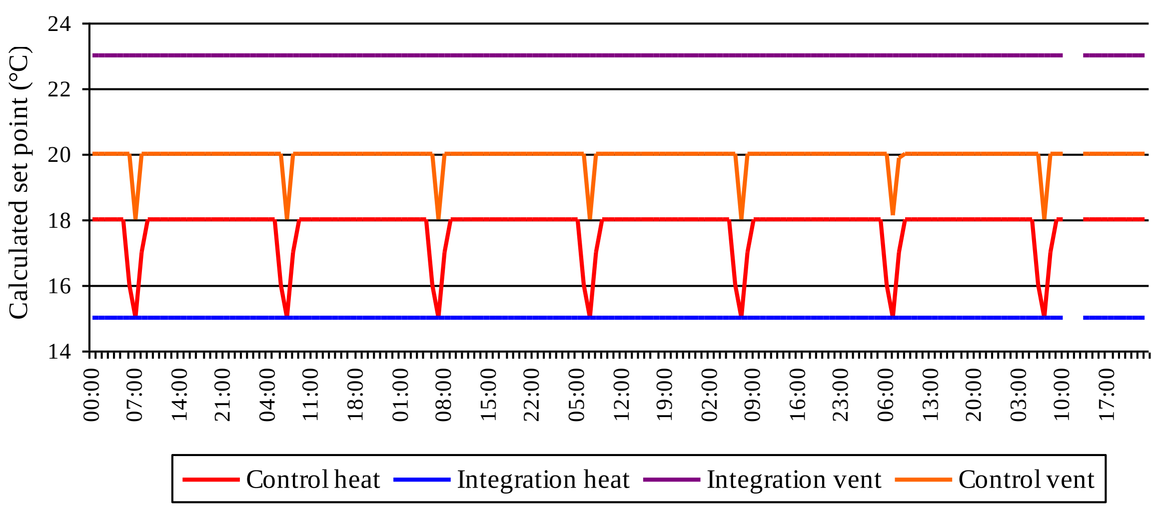




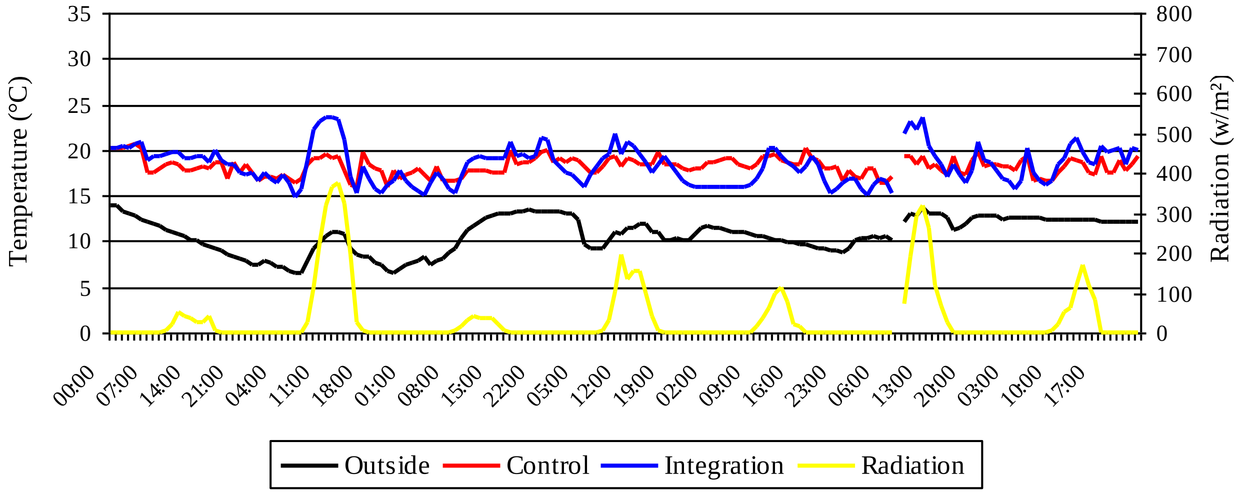
19 – 25 October 2002

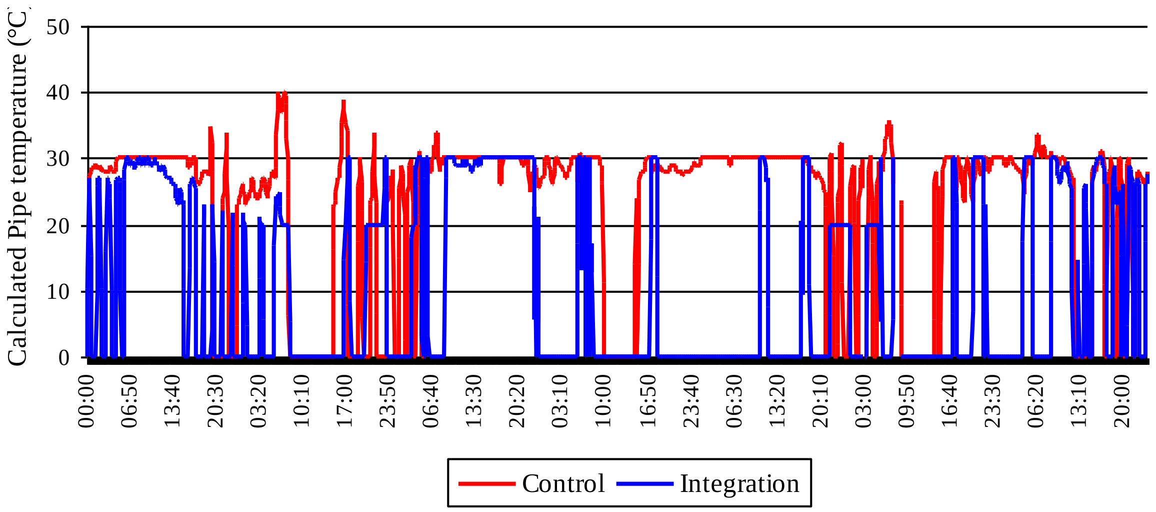


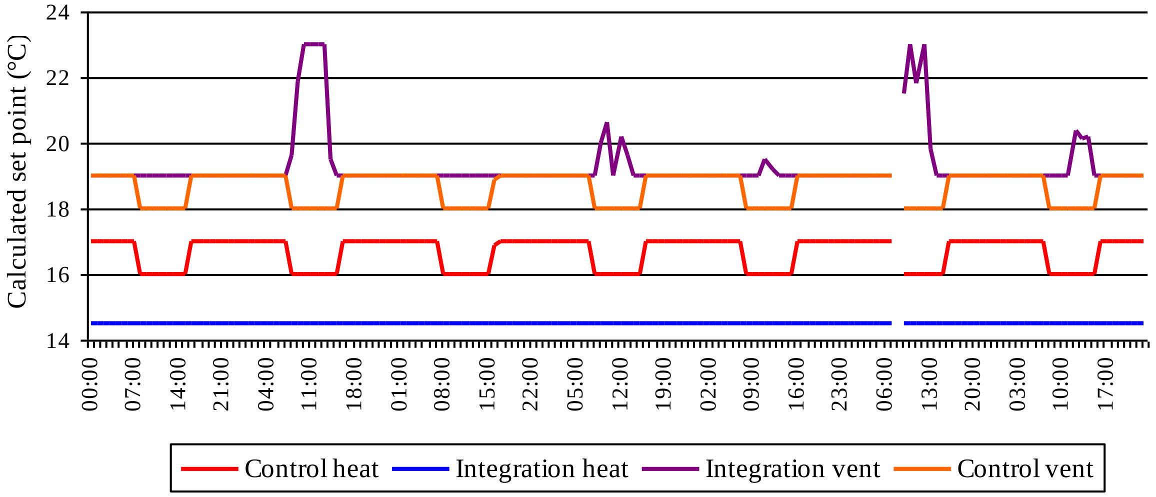




6 – 12 November 2002







Page 33 shows the graphs for the period from 8th – 14th August. The calculated heating set point for the integrated compartment remained on the lower level of 18°C for the whole week, which shows that enough degree hours were accumulated to integrate fully. The average temperatures over this week were very similar in both treatments (Table 6). The deviation from the set point was also very similar in both compartments as it was a sunny week so both areas were venting frequently. The energy use is this week was fairly low, as you would expect for this time of year, nevertheless the energy saving from running temperature integration was 100%. The calculated pipe heat graph shows that the integrated compartment never had to call for heat.

Table 6: Data from the two compartments between 8th and 14th August, 2002.

8th – 14th August 2002	**Control**	**Integration**
Average temperature (°C)	23.5	23.8
Average deviation (°C)	4.7	4.8
Average Humidity (RH)	65.7	63.9
Energy Use (kWh)	38	0
Energy Saved (%)		100

Page 34 shows the graphs for the period from 17th – 23rd September. The radiation levels are just starting to drop off here so we are beginning to see differences in the deviation from the set point. The temperature graph shows slightly warmer days in the integrated compartments followed by slightly cooler nights. The integrated compartment only called for heat on two days during this week for short bursts. Table 7 shows an achieved energy saving of 84% in the integrated compartment during this week. The temperature set point in the integrated compartment was able to sit at 15°C (maximum negative deviation) for the entire week showing that enough degree hours had accumulated to integrate fully. Although there is only a slight difference in temperature during the day between the two compartments, note that the temperature in the integrated compartment is generally higher as the light level is falling. This is because the vent set point is higher in the integrated compartment, which means that the vents will close sooner and the temperature tends to drop to the heating set point slower.

Table 7: Data from the two compartments between 17th and 23rd September, 2002.

17th–23rd September 2002	Control	Integration
Average temperature (°C)	20.7	20.7
Average deviation (°C)	2.8	3.6
Average Humidity (RH) (Replaced wicks)	-	-
Energy Use (kWh)	419	68
Energy Saved (%)		84

Page 35 shows the graphs for the period from 19th – 25th October. The average temperature over this week was 0.5°C lower in the integrated compartment with a larger deviation from the set point (Table 8). Temperature integration is working well here with significantly less energy used on the two coldest nights when outside temperatures dropped to less than 3 °C. Humidity control measures began on 11th October so some of the energy use in the integrated compartment was to maintain minimum pipe. At times pipe heat was called for before the integrated compartment temperature dropped to its heating set point of 15°C. This shows energy being used for humidity control. This week illustrates typical temperature graphs that you would expect from temperature integration regimes, with the higher daytime temperature and the lower night temperatures. Once again the calculated heating temperature in the integrated compartments stayed at its lowest value of 15°C as plenty of degree hours were accumulated. During this week 49% energy saving was achieved in the integrated regime.

Table 8: Data from the two compartments between 19th and 25th October, 2002.

19th – 25th October 2002	Control	Integration
Average temperature (°C)	18.7	18.2
Average deviation (°C)	1.7	2.8
Average Humidity (RH)	73.8	74.7
Energy Use (kWh)	974	502
Energy Saved (%)		49

Page 36 shows the graphs from 6th – 12th November. The average temperature during this week was very similar in both compartments (Table 9). The deviation from the set point was larger in the integrated compartment by 0.6°C. By this time a large proportion of energy use is related to humidity control. The integrated compartment saved 10% of energy use during this week. The graphs show how important solar radiation is to raise temperatures above the desired average, as seen on the 7th and 11th of November, and therefore contribute to degree hours.

Table 9: Data from the two compartments between 6th and 12th November, 2002.

6th – 12th November 2002	Control	Integration
Average temperature (°C)	18.2	18.3
Average deviation (°C)	2.4	3.0
Average Humidity (RH)	76.0	73.6
Energy Use (kWh)	1231	1104
Energy Saved (%)		10

Clearly humidity control uses a lot of energy as soon as we begin to implement control (11 October). In both temperature regimes it makes up for over 60 % of the total energy use. When one examines the average humidities they are not significantly different. Both compartments were using the same humidity control strategy and this explains why the energy consumption lines run parallel after October 11th. However the higher vent set point of the integration compartment meant that this treatment achieved higher average temperatures.

A difficult feature of the humidity control is that there are very few recommendations on strategies as no assessment of risk to the crop has been calculated. Clearly something affected the shelf life of the crop in the integrated compartment that was not detected at marketing. At marketing there were no effects of temperature integration on the plants except for the fact the integrated plants appeared heavier. The most likely reason for the poorer shelf life was that the integrated plants were finished at higher temperatures. This is known to reduce shelf life (PC 71a - d, PC 156) and is probably a result of how temperature integration was implemented rather than an effect of temperature integration alone.

Inspection of the average humidities achieved (Table 10) shows very little difference in the average humidity recorded in each compartment. However higher temperatures were consistently recorded in the temperature integration treatment for the last month of the trial. Examination of the temperature integration strategy shows that at this time a heat then vent strategy was implemented in both compartments, and when combined with the higher vent temperatures in the integrated compartment, this has led to increased heating of the treatment.

Table 10: Average humidity for each week of trial. The table contains the average, maximum and minimum humidity recorded each week. (A – indicates that a wick dried or was changed that week and so the average humidity would be artificially high or low)

Date	**Control (°C)**			**Integration (°C)**		
	Average	**Min**	**Max**	**Average**	**Min**	**Max**
1-7 Aug	60	28	81	58	27	81
8-14 Aug	66	31	86	64	31	83
15-21 Aug	64	32	81	62	30	82
22-28 Aug	61	27	82	60	26	80
29-4 Sep	73	45	91	–	30	86
5-11 Sep	72	43	93	72	41	88
12-18 Sep	73	53	88	70	40	86
19-25 Sep	71	40	87	74	43	87
26 -2 Oct	75	39	92	76	40	91
3-9 Oct	75	45	94	76	44	93
10-16 Oct	79	–	–	78	–	–
17-23 Oct	73	44	91	74	36	90
24-30 Oct	77	52	91	78	48	92
31-6 Nov	–	–	–	77	52	90
7-13 Nov	75	51	86	75	–	84
14-20 Nov	75	57	83	75	64	83

Financial benefits

The costs of heating poinsettia crops is significant; it can be estimated using published information to be approximately £737, 000. This is based on some 44.4 hectares of poinsettia in production in the UK, and the average cost of heating at approximately £4,000/hectare/month, therefore the production area would cost in excess of £737, 000 nationally. A reduction in energy consumption via the use of temperature integration of between 10 and 30% would save between £73, 000 and £221, 000 per annum.

The trial has also demonstrated the significant amount of energy that is required for humidity control. Therefore energy efficient strategies for humidity control should be a high priority for new R&D.

General Conclusions

- Temperature integration was used and demonstrated the potential to save 30% of the energy used for heating a poinsettia crop; ~£220,000 per annum for UK poinsettia production area.
- 11 varieties were evaluated and no variety was delayed more than 1.5 days to show colour or visible cyathia.
- During production poinsettias grown with temperature integration often required additional applications of PGR (between 0 and 28% depending upon variety), this is known to increase leaf loss in shelf life and potentially delay the crop.
- Poinsettias grown with temperature integration were taller, suggesting that the higher average temperatures early in production were counterproductive, using lower vent temperatures in temperature integration at this time would lower this.
- No variety was delayed at marketing and the expert assessment was that all plants were of excellent quality.
- Both the fresh and dry weights of all varieties were increased in the integrated compartment, confirming a similar result in pot mums in 2001.
- All varieties lost more leaves and bracts in shelf life from temperature integration compartments, but this was only significant for 6 out of the 11 varieties tested.
- Increased numbers of plants had to be disposed of prematurely from shelf life from the temperature integration treatment (7.6 % Standard, 21 % Integrated).

- The poor shelf life and increased plant losses suggest the method of temperature integration used was incorrect. Either not integrating for the last month or trying an alternative humidity control strategies would be advised.
- Revisiting how integration is used and during which periods, is crucial to improving shelf life quality.
- The trial has also demonstrated the significant amount of energy that is required for humidity control. Therefore energy efficient strategies for humidity control should be a high priority for new R&D.

Appendix 1: Crop Diary

Week	Activity
31	Potted all cultivars
32	Pinched Cortez, Sonora and Elegance Pink Encarsia introduced
33	Pinched Spotlight Dark Red, Eurostar, Elegance White and Da Vinci
34	Pinched Eternity, Marblestar, Red Elf and Premium Red Q2 & Q3 - ccc 500ppm: Cortez, Sonora & El. Pink Encarsia
35	Q3 - Spaced Cortez, Sonora & El. Pink to 25/m² Q2 – ccc 500ppm: Cortez, Sonora, El. Pink, Spot. Dk Red, Eurostar, El. White & Da Vinci Q3 – ccc 500ppm: Spot. Dk Red, Eurostar, El. White & Da Vinci Q3 - ccc 500ppm x 2: Cortez, Sonora & El. Pink
36	Q2 - Spaced Cortez, Sonora, El. Pink, Spot. Dk Red, Eurostar, El. White, Da Vinci & Eternity to 25/m² Q3 – Spaced Spot. Dk Red, Eurostar, El. White, Da Vinci, Eternity & Marblestar to 25/m² Q2 – ccc 500ppm: Spot. Dk Red, Eurostar, El. White, Da Vinci, Eternity, Marblestar, Red Elf & Premium Red Q2 - ccc 1000ppm x 2: Cortez, Sonora & El. Pink Q3 – ccc 500ppm: El. White, Da Vinci, Marblestar, Red Elf & Premium Red Q3 – ccc 500ppm x 2: Eternity, Spot. Dk Red & Eurostar Q3 – ccc 1000ppm x 3: Cortez, Sonora & El. Pink Encarsia

Appendix 1: Crop Diary (cont)

Week	Activity
37	Q2 – Spaced Marblestar, Red Elf & Premium Red to 25/m² Q3 – Spaced Red Elf & Premium Red to 25/m² and Cortez, Sonora, El. Pink, Spot. Dk Red, Eurostar, Eternity & Marblestar to 15/m² Q2 – ccc 500ppm x 2: El. Pink, Eurostar, El. White, Da Vinci, Eternity & Spot. Dk Red Q2: - ccc 1000ppm: Spot Dk Red, Sonora & El. Pink Q2 – ccc 1000ppm x 2: Sonora Q2 – ccc 1000ppm x 3: Cortez Q2 – alar 500ppm: Sonora Q3 – ccc 500ppm: Eternity Q3 – ccc 500ppm x 2: Marblestar, Spot. Dk Red Q3 – ccc 500ppm x 3: Eurostar, El. White & Da Vinci Q3 – ccc 1000ppm: Spot. Dk Red & Eternity Q3 – ccc 1000ppm x 2: Sonora Q3 - ccc 1000 x 3: Cortez & El. Pink Q3 – alar 500ppm: Sonora Hypoapsis
38	Q2 – Spaced Cortez, Sonora, El. Pink, Spot. Dk Red, Eurostar, El. White, Da Vinci, Eternity & Marblestar to 15/m² Q3 – Spaced El. White & Da Vinci to 15/m² Q2 – ccc 500ppm: Eurostar, El. White, Da Vinci & Eternity Q2 – ccc 1000ppm: Spot. Dk Red Q3 – ccc 500ppm: Eurostar, El. White & Da Vinci Q3 – ccc 1000ppm: Spot. Dk Red & Eternity Q3 - alar 500ppm: Cortez, Sonora & El. Pink Encarsia
39	Q2 & Q3 – Spaced Red Elf & Premium Red to 15/m² Q2 – ccc 500ppm: Marblestar, Eurostar, El. White, Da Vinci & El. Pink Q2 – ccc 1000ppm: Eternity, Spot. Dk Red, Cortez & Sonora Q3 – ccc 500ppm: Marblestar, Eurostar, El. White & Da Vinci Q3 – ccc 1000ppm: Eternity, Spot. Dk Red, Cortez, Sonora & El. Pink

Appendix 1: Crop Diary (cont)

40	Q2 & Q3 – Spaced all cultivars to 9/m² Q2 – ccc 500ppm: Marblestar, El. White & Da Vinci Q2 – ccc 500ppm x 2: Eurostar & El. Pink Q2 – ccc 1000ppm x 2: Eternity, Spot. Dk Red, Cortez & Sonora Q3 – ccc 500ppm: Marblestar Q3 – ccc 500ppm x 2: Eurostar, El. White & Da Vinci Q3 – ccc 1000ppm x 2: Spot. Dk Red, Eternity, Cortez, Sonora & El. Pink Encarsia
41	Q2 – ccc 500ppm: Marblestar & Cortez Q2 – ccc 500ppm x 2: El. White & El. Pink Q2 – ccc 500ppm x 3: Eurostar & Da Vinci Q2 – ccc 1000ppm x 2: Cortez Q2 – ccc 1000ppm x 3: Eternity, Spot. Dk Red & Sonora Q3 – ccc 500ppm: Marblestar, Cortez & El. Pink Q2 – ccc 500ppm x 3: Eurostar, El. White & Da Vinci Q3 – ccc 1000ppm x 2: Cortez, El. Pink Q3 – ccc 1000ppm x 3: Sonora. Spot. Dk Red & Eternity
42	Q2 – ccc 500ppm: Marblestar, Eurostar, El. White, Da Vinci, Cortez & El. Pink Q2: - ccc 1000ppm x 2: Eternity, Spot. Dk Red, Sonora Q3 – ccc 500ppm: Marblestar, Eurostar, Cortez & El. Pink Q3 – ccc 500ppm x 2: El. White & Da vinci Q3 – ccc 1000ppm x 2: Spot. Dk Red, Eternity & Sonora Encarsia
43	Q2 & Q3– ccc 500ppm: Eurostar, El. White, Da Vinci Q2 & Q3 – ccc 500ppm x 2: Eternity, Marblestar, Spot. Dk Red, Cortez & El. Pink Q2 & Q3 – ccc 1000ppm x 2: Sonora
44	Encarsia

Appendix 2: Summary of data from production and marketing

Cultivar	Number of days from potting to first colour		Number of days from potting to first visible cyathia	
	Standard	**Integrated**	**Standard**	**Integrated**
Sonora	74.8	74.5	89.4	89.3
Cortez	78.3	78.8	93.8	93.5
Spotlight Dark Red	79.1	80.1	98.5	96.7
Eternity	74.5	77.5	92.2	95.5
Eurostar	73.1	74.5	90.6	90.8
Premium	68.5	70.3	89.8	91.3
Red Elf	66.6	66.1	89.0	88.2
Da Vinci	78.7	81.2	88.8	89.9
Elegance Pink	84.6	85.6	90.7	92.3
Elegance White	84.7	87.0	94.5	95.4
Marblestar	87.2	88.2	97.8	96.6
Mean	77.3	78.5	92.3	92.7

Appendix 2: Summary of data from production and marketing

Q2: Standard regime

Cultivar	Day no. of record	Height (cm)	Spread (cm)	Number of primary heads in size ranges:				No. of sec. heads
				<150mm	150-200mm	200-225mm	>225mm	
Sonora	336.0	36.6	45.6	0.4	1.6	2.4	0.5	2.9
Cortez	338.0	35.5	48.8	0.1	0.8	2.3	1.1	3.2
Spotlight Dark Red	340.0	35.7	51.2	0.2	1.1	2.5	1.1	2.5
Eternity	339.0	37.9	45.5	0.2	0.5	2.0	1.7	2.5
Eurostar	336.0	33.1	41.5	0.1	1.2	2.3	0.6	3.0
Premium	337.0	28.6	38.4	0.2	1.1	2.2	1.0	2.8
Red Elf	333.0	29.1	41.3	0.0	1.1	2.6	1.0	2.8
Da Vinci	337.0	31.6	43.9	0.1	1.2	2.3	1.1	2.4
Elegance Pink	338.0	32.4	43.2	0.0	0.6	2.3	1.5	2.4
Elegance White	338.0	30.9	43.7	0.1	1.0	2.8	0.8	2.5
Marblestar	340.0	32.4	41.6	0.6	1.4	1.5	0.4	3.8
Mean	337.5	33.1	44.0	0.2	1.0	2.3	1.0	2.8

Appendix 2: Summary of data from production and marketing

Q2: Standard regime

Cultivar	Number of cyathia on dominant break at Stage:						Quality
	1	2	3	4	5	6	
Sonora	2.5	7.5	0.1	0.0	0.0	0.0	2.0
Cortez	1.5	9.3	0.0	0.0	0.0	0.0	1.9
Spotlight Dark Red	3.2	10.0	0.0	0.0	0.0	0.0	1.9
Eternity	2.7	3.1	0.1	0.2	0.0	0.1	1.5
Eurostar	1.3	8.7	0.1	0.0	0.0	0.0	2.0
Premium	2.2	3.2	0.4	0.0	0.0	0.0	2.0
Red Elf	1.0	8.1	0.5	0.0	0.0	0.0	2.0
Da Vinci	2.2	9.1	0.3	0.0	0.0	0.3	2.0
Elegance Pink	1.1	5.6	0.1	0.0	0.0	0.2	2.0
Elegance White	1.8	8.1	0.0	0.0	0.0	0.0	2.0
Marblestar	2.6	9.2	0.0	0.0	0.0	0.0	1.8
Mean	2.0	7.4	0.1	0.0	0.0	0.1	1.9

Appendix 2: Summary of data from production and marketing

Q3: Integrated regime

Cultivar	Day no. of record	Height (cm)	Spread (cm)	Number of primary heads in size ranges:				No. of sec. heads
				<150mm	150-200mm	200-225mm	>225mm	
Sonora	336.0	35.3	44.9	0.1	1.2	2.5	0.9	3.3
Cortez	337.3	38.1	48.8	0.1	0.6	2.0	1.7	2.6
Spotlight Dark Red	339.0	37.7	49.9	0.1	1.2	2.6	1.2	2.8
Eternity	339.0	42.4	46.7	0.2	1.0	2.6	1.6	1.8
Eurostar	334.5	34.2	43.4	0.4	1.5	3.0	0.4	2.6
Premium	336.5	28.9	39.5	0.2	1.4	3.1	0.6	2.5
Red Elf	333.0	30.5	40.2	0.2	1.0	2.5	1.5	2.2
Da Vinci	337.0	33.7	42.3	0.0	0.5	2.0	2.0	1.8
Elegance Pink	338.0	37.0	49.1	0.1	0.4	2.1	2.4	2.1
Elegance White	338.5	32.7	43.6	0.0	0.7	2.5	1.2	2.4
Marblestar	340.0	32.7	42.4	0.3	0.9	2.0	0.9	3.4
Mean	337.2	34.8	44.6	0.1	0.9	2.4	1.3	2.5

Appendix 2: Summary of data from production and marketing

Q3: Integrated regime

Cultivar	Number of cyathia on dominant break at Stage:						Quality
	1	2	3	4	5	6	
Sonora	2.3	8.2	0.2	0.0	0.0	0.0	2.0
Cortez	1.0	8.6	0.1	0.0	0.0	0.0	2.0
Spotlight Dark Red	2.0	8.2	0.0	0.0	0.0	0.0	2.0
Eternity	1.9	3.3	0.1	0.0	0.0	0.0	1.8
Eurostar	0.7	7.6	0.2	0.0	0.0	0.0	2.0
Premium	3.1	3.3	0.2	0.0	0.0	0.0	2.0
Red Elf	1.7	6.7	1.4	0.0	0.0	0.0	2.0
Da Vinci	1.7	8.7	0.2	0.0	0.0	0.1	1.9
Elegance Pink	1.1	6.1	0.2	0.0	0.0	0.1	2.0
Elegance White	0.7	8.3	0.0	0.0	0.0	0.0	2.0
Marblestar	3.1	8.7	0.2	0.0	0.0	0.0	1.8
Mean	1.7	7.0	0.2	0.0	0.0	0.0	1.9

Appendix 3: Summary of shelf-life assessments – Q2: Standard regime

Cultivar	Stage	Number of leaves dropped		% Cyathia lost	Mec. Dam. at de-sl	Foliage colour		Bract col.	Bract pale edges	Bract necrosis	Botrytis	No. of plants disposed
		Green	Red			Upper	Lower					
Sonora	**Sleeve**			0.00		0.00	0.83	0.00	0.00	0.00	0.00	0
	De-sleeve	0.00	0.00	0.00	0.67	0.00	0.83	0.00	0.00	0.00	0.00	0
	Week 1	6.67	0.00	0.00		0.00	1.00	0.00	0.00	0.17	0.00	0
	Week 2	7.75	0.50	0.00		0.00	1.00	0.00	0.00	0.75	0.00	0
	Week 3	0.00	0.00	0.00		0.00	1.00	0.00	0.00	0.75	0.00	0
	Week 4	5.25	5.58	1.28		0.00	1.42	0.00	0.00	0.75	0.00	0
	Week 5	2.00	3.67	16.67		0.00	1.42	0.17	0.00	0.75	0.00	0
	Week 6	1.17	1.58	23.38		0.00	1.42	0.17	0.00	0.75	0.00	0
Cortez	**Sleeve**			0.00		0.00	0.83	0.00	0.00	0.00	0.00	0
	De-sleeve	1.00	0.00	0.00	0.33	0.00	0.83	0.00	0.00	0.67	0.00	0
	Week 1	17.17	4.33	0.00		0.00	1.00	0.00	0.50	0.67	0.00	0
	Week 2	3.67	2.33	0.00		0.00	1.17	0.00	0.50	0.50	0.00	0
	Week 3	0.00	0.00	0.00		0.00	1.17	0.00	0.50	0.50	0.00	0
	Week 4	0.67	0.50	0.00		0.00	1.17	0.00	0.50	0.67	0.00	0
	Week 5	0.50	1.50	7.04		0.00	1.17	0.17	0.50	0.67	0.00	0
	Week 6	1.00	0.50	14.08		0.17	1.33	0.50	0.50	0.67	0.00	0

Appendix 3: Summary of shelf-life assessments – Q2: Standard regime

Cultivar	Stage	Number of leaves dropped		% Cyathia lost	Mec. Dam. at de-sl	Foliage colour		Bract col.	Bract pale edges	Bract necrosis	Botrytis	No. of plants disposed
		Green	Red			Upper	Lower					
Spotlight	Sleeve			0.00		0.00	0.83	0.00	0.00	0.00	0.00	0
Dark Red	De-sleeve	1.33	0.50	0.00	0.67	0.00	0.83	0.00	0.00	0.50	0.00	0
	Week 1	10.67	3.50	11.83		0.17	1.17	0.50	1.17	0.50	0.00	0
	Week 2	1.17	0.00	15.96		0.17	1.17	0.50	1.17	0.50	0.00	0
	Week 3	2.17	1.33	26.60		0.17	1.33	0.50	1.17	0.83	0.00	0
	Week 4	1.33	3.83	29.67		0.00	1.50	1.00	1.17	1.00	0.00	0
	Week 5	1.00	2.17	30.77		0.00	1.50	1.00	1.00	1.00	0.00	0
	Week 6	1.17	1.00	30.77		0.00	1.50	1.00	1.00	1.00	0.00	0
Eternity	Sleeve			0.00		0.00	0.33	0.00	0.00	0.00	0.00	0
	De-sleeve	0.83	0.00	0.00	0.83	0.17	0.33	0.00	0.00	0.50	0.00	0
	Week 1	1.67	1.83	21.05		0.00	0.00	0.00	1.00	0.17	0.33	0
	Week 2	2.50	1.67	31.58		0.00	0.33	0.00	1.17	0.50	0.33	0
	Week 3	1.17	2.17	60.53		0.00	0.83	0.33	1.17	0.50	0.33	0
	Week 4	0.33	0.33	61.54		0.00	1.17	0.17	1.17	0.50	0.33	0
	Week 5	1.17	0.67	74.36		0.00	1.17	0.17	1.17	0.50	0.33	1
	Week 6	1.17	0.42	72.50		0.00	1.17	0.50	1.25	0.75	0.25	1

Appendix 3: Summary of shelf-life assessments – Q2: Standard regime

Cultivar	Stage	Number of leaves dropped		% Cyathia lost	Mec. Dam. at de-sl	Foliage colour		Bract col.	Bract pale edges	Bract necrosis	Botrytis	No. of plants disposed
		Green	Red			Upper	Lower					
Eurostar	**Sleeve**			0.00		0.00	1.00	0.00	0.00	0.00	0.00	0
	De-sleeve	0.00	0.00	1.56	0.17	0.00	1.00	0.00	0.00	0.00	0.00	0
	Week 1	1.00	0.00	4.48		0.00	1.00	0.00	1.00	0.00	0.17	0
	Week 2	2.83	0.00	22.08		0.00	1.00	0.00	1.00	0.00	0.17	0
	Week 3	0.00	0.00	22.08		0.00	1.00	0.00	1.00	0.00	0.00	0
	Week 4	1.33	0.50	41.56		0.00	1.17	0.00	1.00	0.00	0.17	0
	Week 5	1.00	0.33	45.45		0.00	1.50	0.00	1.00	0.00	0.00	0
	Week 6	5.50	0.83	62.82		0.00	1.50	0.50	1.00	0.17	0.00	1
Premium	**Sleeve**			0.00		0.00	0.17	0.00	0.00	0.00	0.00	0
	De-sleeve	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.17	0.00	0
	Week 1	5.00	3.83	26.47		0.00	0.33	0.00	0.00	0.00	0.33	0
	Week 2	2.50	3.67	32.35		0.00	0.33	0.00	0.00	0.33	0.83	0
	Week 3	0.00	0.00	32.35		0.00	0.33	0.00	0.00	0.33	0.83	0
	Week 4	2.33	0.67	44.12		0.00	0.33	0.00	0.00	0.50	0.67	1
	Week 5	1.42	0.83	54.05		0.25	0.58	0.00	0.00	0.83	0.58	0
	Week 6	0.50	0.92	59.46		0.00	1.00	0.00	0.00	0.83	0.33	1

Appendix 3: Summary of shelf-life assessments – Q2: Standard regime

Cultivar	Stage	Number of leaves dropped		% Cyathia lost	Mec. Dam. at de-sl	Foliage colour		Bract col.	Bract pale edges	Bract necrosis	Botrytis	No. of plants disposed
		Green	Red			Upper	Lower					
Red Elf	Sleeve			0.00		0.00	0.33	0.00	0.00	0.00	0.00	0
	De-sleeve	0.00	0.00	0.00	0.17	0.00	0.33	0.00	0.00	0.83	0.00	0
	Week 1	0.83	1.33	1.67		0.00	0.33	0.00	0.00	1.00	0.00	0
	Week 2	3.50	2.33	26.67		0.00	0.33	0.00	0.00	0.50	0.00	0
	Week 3	0.50	2.00	28.33		0.00	0.50	0.00	0.00	0.50	0.00	0
	Week 4	1.67	2.00	31.67		0.00	1.00	0.00	0.00	0.17	0.00	0
	Week 5	0.50	1.33	35.00		0.17	1.00	0.00	0.00	0.50	0.00	0
	Week 6	0.33	0.50	38.33		0.17	1.00	0.00	0.00	0.50	0.00	0
Da Vinci	Sleeve			0.00		0.00	0.00	0.00	0.00	0.00	0.00	0
	De-sleeve	3.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0
	Week 1	10.00	3.17	9.76		0.00	0.67	0.17	0.00	0.83	0.17	0
	Week 2	4.33	0.50	17.07		0.00	0.83	0.17	0.00	0.83	0.17	0
	Week 3	0.00	0.00	17.07		0.00	0.83	0.17	0.00	0.83	0.17	0
	Week 4	2.33	1.17	34.15		0.00	0.83	0.17	0.00	1.00	0.17	0
	Week 5	0.67	0.83	58.54		0.00	0.83	0.67	0.00	1.00	0.17	0
	Week 6	0.17	0.17	60.98		0.17	0.83	1.00	0.00	1.00	0.17	0

Appendix 3: Summary of shelf-life assessments – Q2: Standard regime

Cultivar	Stage	Number of leaves dropped		% Cyathia lost	Mec. Dam. at de-sl	Foliage colour		Bract col.	Bract pale edges	Bract necrosis	Botrytis	No. of plants disposed
		Green	Red			Upper	Lower					
Elegance	Sleeve			0.00		0.00	0.00	0.00	0.00	0.00	0.00	0
Pink	De-sleeve	2.50	0.00	0.00	0.17	0.00	0.00	0.00	0.50	0.17	0.00	0
	Week 1	6.17	1.83	28.57		0.00	0.67	0.00	0.50	0.33	0.17	0
	Week 2	4.00	0.50	34.09		0.00	0.83	0.00	0.67	0.33	0.17	0
	Week 3	0.00	0.00	34.09		0.00	0.83	0.00	0.67	0.33	0.17	0
	Week 4	6.00	0.83	40.91		0.00	0.33	1.00	1.17	0.33	0.17	0
	Week 5	1.83	0.33	43.18		0.00	0.33	1.50	1.17	0.33	0.17	0
	Week 6	0.00	0.67	40.91		0.00	0.33	2.00	1.17	0.50	0.00	0
Elegance	Sleeve			0.00		0.00	0.33	0.00	0.00	0.00	0.00	0
White	De-sleeve	1.33	0.00	0.00	1.00	0.00	0.17	0.00	0.00	0.50	0.00	0
	Week 1	7.33	6.17	3.08		0.00	0.83	0.00	0.00	0.50	0.33	0
	Week 2	3.83	0.67	3.08		0.00	0.83	0.00	0.00	0.50	0.67	0
	Week 3	1.17	0.00	4.41		0.00	0.67	0.00	0.00	0.33	0.50	0
	Week 4	2.50	0.67	9.86		0.00	1.00	0.17	0.00	0.50	0.50	0
	Week 5	2.50	0.67	10.81		0.00	1.00	0.50	0.00	0.83	0.50	0
	Week 6	1.50	0.17	13.51		0.00	1.00	0.67	0.00	0.83	0.67	0

Appendix 3: Summary of shelf-life assessments – Q2: Standard regime

Cultivar	Stage	Number of leaves dropped		% Cyathia lost	Mec. Dam. at de-sl	Foliage colour		Bract col.	Bract pale edges	Bract necrosis	Botrytis	No. of plants disposed
		Green	Red			Upper	Lower					
Marble-	Sleeve			0.00		0.00	1.00	0.00	0.00	0.00	0.00	0
star	De-sleeve	1.17	0.00	0.00	0.17	0.00	1.00	0.00	0.00	0.17	0.00	0
	Week 1	3.17	0.83	0.00		0.00	0.83	0.00	0.00	0.00	0.00	0
	Week 2	1.00	0.00	0.00		0.00	1.00	0.00	0.00	0.33	0.17	0
	Week 3	2.00	0.67	0.00		0.00	1.33	0.00	0.00	0.17	0.17	0
	Week 4	0.83	0.50	0.00		0.83	2.00	0.00	0.00	0.33	0.17	0
	Week 5	1.00	0.33	4.49		1.00	2.00	0.00	0.00	0.33	0.17	0
	Week 6	0.83	0.17	5.62		1.00	2.00	0.00	0.00	0.33	0.17	0
Mean	Sleeve			0.00		0.00	0.52	0.00	0.00	0.00	0.00	0
across all	De-sleeve	1.02	0.06	0.14	0.38	0.02	0.50	0.00	0.05	0.36	0.00	0
cultivars	Week 1	6.33	2.44	9.72		0.02	0.71	0.06	0.38	0.38	0.14	0
	Week 2	3.37	1.11	16.62		0.02	0.80	0.06	0.41	0.46	0.23	0
	Week 3	0.64	0.56	20.50		0.02	0.89	0.09	0.41	0.46	0.20	0
	Week 4	2.23	1.51	26.80		0.08	1.08	0.23	0.45	0.52	0.20	0
	Week 5	1.23	1.15	34.58		0.13	1.14	0.38	0.44	0.61	0.17	0
	Week 6	1.21	0.63	38.40		0.14	1.19	0.58	0.45	0.67	0.14	0

Appendix 3: Summary of shelf-life assessments – Q3: Integrated regime

Cultivar	Stage	Number of leaves dropped		% Cyathia lost	Mec. Dam. at de-sl	Foliage colour		Bract col.	Bract pale edges	Bract necrosis	Botrytis	No. of plants disposed
		Green	Red			Upper	Lower					
Sonora	**Sleeve**			0.00		0.00	0.33	0.00	0.00	0.00	0.00	0
	De-sleeve	0.00	0.00	0.00	0.33	0.00	0.33	0.00	0.00	0.00	0.00	0
	Week 1	16.83	1.67	1.37		0.33	1.33	0.17	0.67	0.17	0.17	0
	Week 2	9.33	2.50	1.32		0.33	1.33	0.17	0.67	0.17	0.83	0
	Week 3	0.00	0.00	1.32		0.33	1.33	0.17	0.67	0.17	0.83	0
	Week 4	2.67	4.83	21.05		0.33	1.33	0.17	0.67	0.17	0.83	0
	Week 5	3.17	6.83	32.89		0.00	1.33	1.00	0.67	0.50	0.83	0
	Week 6	1.50	2.17	43.42		0.00	1.33	1.00	0.67	0.67	0.83	0
Cortez	**Sleeve**			0.00		0.00	0.83	0.00	0.00	0.00	0.00	0
	De-sleeve	2.83	0.00	0.00	0.33	0.00	0.83	0.00	0.00	0.50	0.00	0
	Week 1	14.17	3.00	0.00		0.17	0.83	0.00	0.33	0.50	0.17	0
	Week 2	4.33	1.00	0.00		0.17	1.00	0.00	0.33	0.50	0.33	0
	Week 3	0.00	0.00	0.00		0.17	1.00	0.00	0.33	0.33	0.33	0
	Week 4	1.67	1.83	5.00		0.17	1.17	0.00	0.33	0.50	0.67	1
	Week 5	1.75	0.92	7.75		0.17	1.33	0.17	0.17	0.92	0.17	1
	Week 6	0.75	0.50	11.63		0.50	1.25	1.00	0.00	1.25	0.00	0

Appendix 3: Summary of shelf-life assessments – Q3: Integrated regime

Cultivar	Stage	Number of leaves dropped		% Cyathia lost	Mec. Dam. at de-sl	Foliage colour		Bract col.	Bract pale edges	Bract necrosis	Botrytis	No. of plants disposed
		Green	Red			Upper	Lower					
Spotlight	Sleeve			0.00		0.00	0.83	0.00	0.00	0.00	0.00	0
Dark Red	De-sleeve	2.67	0.00	1.27	0.50	0.00	0.33	0.00	0.00	0.50	0.00	0
	Week 1	13.17	3.17	24.72		0.17	1.00	0.83	1.17	0.50	0.00	0
	Week 2	2.17	0.67	31.87		0.17	1.00	0.83	1.17	0.67	0.17	0
	Week 3	3.33	3.67	42.86		0.17	1.00	0.83	1.17	0.83	0.17	0
	Week 4	1.00	1.83	49.45		0.17	1.00	1.00	1.17	0.67	0.33	1
	Week 5	1.58	0.92	50.00		0.17	1.25	1.00	1.17	0.67	0.17	0
	Week 6	0.50	1.00	52.69		0.17	1.42	1.17	1.17	0.67	0.17	0
Eternity	Sleeve			0.00		0.00	0.00	0.00	0.00	0.00	0.00	0
	De-sleeve	0.17	0.00	5.26	0.50	0.00	0.00	0.00	0.00	0.17	0.00	0
	Week 1	3.83	1.50	21.05		0.00	0.17	0.17	0.83	0.17	0.00	0
	Week 2	1.17	0.50	23.08		0.00	0.67	0.17	0.83	0.33	0.00	0
	Week 3	2.17	2.17	35.90		0.00	0.67	0.00	0.50	0.33	0.00	0
	Week 4	0.50	0.83	45.00		0.00	0.67	0.00	0.83	0.33	0.00	0
	Week 5	2.50	0.17	55.00		0.00	1.00	0.00	0.83	0.50	0.00	0
	Week 6	0.83	0.00	67.50		0.00	1.17	0.67	0.67	0.50	0.00	1

Appendix 3: Summary of shelf-life assessments – Q3: Integrated regime

Cultivar	Stage	Number of leaves dropped		% Cyathia lost	Mec. Dam. at de-sl	Foliage colour		Bract col.	Bract pale edges	Bract necrosis	Botrytis	No. of plants disposed
		Green	Red			Upper	Lower					
Eurostar	**Sleeve**			0.00		0.00	0.67	0.00	0.00	0.00	0.00	0
	De-sleeve	0.00	0.00	0.00	0.33	0.00	0.33	0.00	0.00	0.00	0.00	0
	Week 1	2.00	0.33	3.57		0.00	0.83	0.00	0.50	0.17	0.00	0
	Week 2	5.67	3.50	28.33		0.00	0.50	0.00	1.00	0.00	0.50	0
	Week 3	1.50	0.17	43.33		0.00	0.67	0.00	1.00	0.33	0.50	0
	Week 4	6.17	3.00	57.14		0.00	1.67	0.00	1.00	0.67	0.83	2
	Week 5	1.50	0.67	75.00		0.00	1.17	0.17	0.50	0.50	0.00	0
	Week 6	6.33	1.00	76.67		0.00	1.67	0.50	0.50	0.50	0.00	0
Premium	**Sleeve**			0.00		0.00	0.17	0.00	0.00	0.00	0.00	0
	De-sleeve	0.00	0.00	0.00	0.50	0.00	0.33	0.00	0.00	0.17	0.00	0
	Week 1	6.67	7.00	36.00		0.00	0.67	0.00	0.17	0.33	0.67	0
	Week 2	3.83	3.83	50.00		0.00	0.67	0.00	0.17	0.50	0.67	0
	Week 3	0.00	0.00	50.00		0.00	0.67	0.00	0.17	0.50	0.50	0
	Week 4	1.17	0.67	66.00		0.00	0.67	0.17	0.00	0.33	0.83	2
	Week 5	1.50	0.50	65.63		0.00	1.00	0.25	0.00	0.50	0.00	0
	Week 6	0.50	0.50	65.63		0.25	1.00	0.25	0.00	0.50	0.00	1

Appendix 3: Summary of shelf-life assessments – Q3: Integrated regime

Cultivar	Stage	Number of leaves dropped		% Cyathia lost	Mec. Dam. at de-sl	Foliage colour		Bract col.	Bract pale edges	Bract necrosis	Botrytis	No. of plants disposed
		Green	Red			Upper	Lower					
Red Elf	**Sleeve**			0.00		0.00	0.17	0.00	0.00	0.00	0.00	0
	De-sleeve	0.00	0.00	1.72	1.00	0.00	0.17	0.00	0.00	0.83	0.00	0
	Week 1	1.00	1.67	3.45		0.00	0.17	0.00	0.00	1.00	0.00	0
	Week 2	5.08	7.00	7.89		0.00	0.50	0.00	0.25	0.83	0.25	0
	Week 3	1.67	2.67	21.93		0.00	0.50	0.00	0.58	0.83	0.00	0
	Week 4	0.50	2.75	29.82		0.00	0.50	0.00	0.58	1.00	0.25	1
	Week 5	0.50	1.00	22.22		0.00	0.50	0.00	0.33	0.50	0.50	0
	Week 6	0.83	1.17	22.22		0.00	0.83	0.00	0.33	0.50	0.50	1
Da Vinci	**Sleeve**			0.00		0.00	0.00	0.00	0.00	0.00	0.00	0
	De-sleeve	1.33	0.00	2.70	0.17	0.00	0.00	0.00	0.00	0.83	0.00	0
	Week 1	9.33	1.33	8.75		0.00	0.33	0.00	0.00	0.83	0.00	0
	Week 2	5.17	2.33	7.69		0.17	0.50	0.00	0.00	0.67	0.17	0
	Week 3	0.00	0.00	7.69		0.17	0.50	0.00	0.00	0.67	0.17	0
	Week 4	2.17	0.83	48.72		0.17	1.00	0.00	0.00	0.83	0.17	0
	Week 5	1.83	0.50	64.10		0.17	1.00	0.50	0.00	0.83	0.17	0
	Week 6	2.00	0.17	73.42		0.17	1.00	1.00	0.00	0.83	0.17	0

Appendix 3: Summary of shelf-life assessments – Q3: Integrated regime

Cultivar	Stage	Number of leaves dropped		% Cyathia lost	Mec. Dam. at de-sl	Foliage colour		Bract col.	Bract pale edges	Bract necrosis	Botrytis	No. of plants disposed
		Green	Red			Upper	Lower					
Elegance	Sleeve			0.00		0.00	0.00	0.00	0.00	0.00	0.00	0
Pink	De-sleeve	3.00	0.00	6.52	0.50	0.00	0.00	0.00	0.33	0.50	0.00	0
	Week 1	11.33	4.67	43.48		0.00	0.50	1.00	0.67	0.33	0.67	0
	Week 2	2.67	2.17	54.35		0.00	0.50	1.00	0.67	0.33	0.67	0
	Week 3	0.00	0.00	54.35		0.00	0.50	1.00	0.67	0.33	0.67	0
	Week 4	3.17	0.33	56.52		0.00	1.00	1.00	0.67	0.00	0.67	0
	Week 5	2.67	0.83	56.52		0.00	0.83	0.83	0.50	0.00	0.67	0
	Week 6	0.33	1.00	58.70		0.00	1.00	1.50	0.83	0.00	0.50	0
Elegance	Sleeve			0.00		0.00	0.50	0.00	0.00	0.00	0.00	0
White	De-sleeve	1.33	0.00	0.00	1.17	0.00	0.00	0.00	0.00	1.17	0.00	0
	Week 1	11.17	14.67	1.43		0.00	0.67	0.00	0.00	0.83	1.50	0
	Week 2	5.83	1.33	1.43		0.00	0.67	0.00	0.00	1.33	1.50	0
	Week 3	3.50	0.17	2.82		0.00	0.67	0.00	0.00	1.50	1.33	0
	Week 4	0.67	1.17	10.39		0.00	1.00	0.00	0.00	1.83	1.17	0
	Week 5	2.00	0.33	12.82		0.00	1.00	1.00	0.00	1.83	1.17	0
	Week 6	1.50	0.50	14.10		0.00	1.00	1.00	0.00	1.83	1.17	1

Appendix 3: Summary of shelf-life assessments – Q3: Integrated regime

Cultivar	Stage	Number of leaves dropped		% Cyathia lost	Mec. Dam. at de-sl	Foliage colour		Bract col.	Bract pale edges	Bract necrosis	Botrytis	No. of plants disposed
		Green	Red			Upper	Lower					
Marble-	Sleeve			0.00		0.00	1.00	0.00	0.00	0.00	0.00	0
star	De-sleeve	2.00	0.00	0.00	0.50	0.00	1.00	0.00	0.00	0.50	0.00	0
	Week 1	5.17	0.83	0.00		0.17	1.17	0.00	0.00	0.00	0.17	0
	Week 2	0.67	0.00	2.63		0.00	1.17	0.00	0.00	0.00	0.33	0
	Week 3	4.67	0.67	5.00		0.17	1.33	0.00	0.00	0.33	0.17	0
	Week 4	3.00	1.33	7.50		0.83	2.00	0.00	0.00	0.67	0.17	0
	Week 5	3.17	0.83	17.50		1.00	2.00	0.00	0.00	0.33	0.17	1
	Week 6	1.83	0.42	18.06		1.00	2.00	0.00	0.00	0.33	0.00	1
Mean	Sleeve			0.00		0.00	0.41	0.00	0.00	0.00	0.00	0
across all	De-sleeve	1.21	0.00	1.59	0.53	0.00	0.30	0.00	0.03	0.47	0.00	0
cultivars	Week 1	8.61	3.62	13.07		0.08	0.70	0.20	0.39	0.44	0.30	0
	Week 2	4.17	2.26	18.96		0.08	0.77	0.20	0.46	0.48	0.49	0
	Week 3	1.53	0.86	24.11		0.09	0.80	0.18	0.46	0.56	0.42	0
	Week 4	2.06	1.77	36.05		0.15	1.09	0.21	0.48	0.64	0.54	0
	Week 5	2.02	1.23	41.77		0.14	1.13	0.45	0.38	0.64	0.35	0
	Week 6	1.54	0.77	45.82		0.19	1.24	0.73	0.38	0.69	0.30	0

Appendix 4: Summary of Expert scores during shelf-life

Score For:	Stage	Standard	Integrated
Bract Quality	**Week 1**	9.5	9.8
	Week 2	9.2	9.1
	Week 3	8.8	8.7
	Week 4	8.6	7.8
	Week 5	7.8	6.7
	Week 6	7.0	7.1
Leaf Quality	**Week 1**	8.9	8.9
	Week 2	8.0	7.9
	Week 3	7.4	7.4
	Week 4	7.0	6.2
	Week 5	6.2	5.4
	Week 6	5.6	5.6
Cyathia Quality	**Week 1**	8.5	8.5
	Week 2	6.9	7.6
	Week 3	4.7	5.5
	Week 4	3.6	3.2
	Week 5	2.9	2.5
	Week 6	2.0	1.3
Overall Quality	**Week 1**	8.8	8.7
	Week 2	8.0	7.8
	Week 3	7.2	7.1
	Week 4	6.7	5.9
	Week 5	6.1	5.3
	Week 6	5.5	5.5