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CONTRACT REPORT

Chrysanthemums: The influence of combined supplementary lighting regimes and pot spacings on the quality and economics of the winter production of pot chrysanthemums

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HDC PC92a

Chrysanthemums: The influence of combined supplementary lighting regimes and pot spacings on the quality and economics of the winter production of pot chrysanthemums

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I declare that this work was done under my supervision according to the procedures described herein and that this report represents a true and accurate record of the results obtained.

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RELEVANCE TO GROWERS AND PRACTICAL APPLICATION

Application

A number of treatments were investigated under the overall theme of improving quality through supplementary lighting regimes while assessing how the economics of providing lighting may be improved.

New supplementary lighting regimes, designed from combinations of the standard regimes assessed in previous HDC funded trials, were evaluated for their potential to produce further advantages in pot quality and speed of production. The benefits of each of these new treatments were as follows:

Lighting at 12 W/m² during weeks 1 to 3 of short days moving to lighting at 4.8 W/m² for the remaining period of short days.

This combined treatment significantly improved quality in comparison with the standard treatment of lighting at 12 W/m² during weeks 1 to 3 of short days only and also decreased total production time by up to 5.1 days (depending on sticking date and variety) against the two standard supplementary lighting regimes.

Lighting at 4.8 W/m² during weeks 1 to 7 of short days moving to lighting at 12 W/m² for the remaining period of short days.

This combined treatment produced a deeper petal colour for the variety Charm which improved visual pleasure both at marketing and during shelf-life assessments.

Closer pot spacings (up to 18 pots/m² at final spacing) were investigated as a means of reducing the cost per pot of providing supplementary lighting. Although closer spacings had a negative impact on production time and pot quality, these factors were generally small. There is clearly potential for using closer pot spacing to improve the economics of supplementary lighting. Savings on the cost per pot of providing lighting were 17% for a final spacing of 15 pots/m² or 31% for a final spacing of 18 pots/m² (taking standard spacing as 12.5 pots/m²).

Cerise About Time benefitted from the standard supplementary lighting in a similar way to the American bred varieties previously tested. That is, production time was reduced by both lighting regimes with the fastest production achieved by lighting at 12 W/m² during weeks 1 to 3 of short days alone. Lighting at 4.8 W/m² throughout short days also significantly improved pot quality.

Finally, negative DIF was found to produce a significant reduction in plant height when combined with supplementary lighting at 12 W/m² during weeks 1 to 3 of short days only.

Summary

i. Background and trial details

Supplementary lighting as a technique to improve the production of pot chrysanthemums over the winter period has been the subject of HDC funded trials work at HRI Efford for several seasons with two standard supplementary lighting regimes emerging as standard treatments depending on the benefits required by individual growers. These regimes are:

i) 4.8 W/m^2 throughout short days
ii) 12 W/m^2 during weeks 1 to 3 of short days only.

Both regimes decrease production time in comparison with no supplementary lighting with the fastest rate of production achieved using the second regime. The first regime also improves pot quality. Despite the improvements achieved and the use of these regimes by a number of commercial growers, the marketing of pot mums over the winter period is becoming increasingly difficult and further improvements in quality are being demanded. In addition, the cost of providing supplementary lighting over the winter continues to burden growers.

With this in mind, treatments for the current trial were designed firstly to further improve on production, both in terms of quality and in speed of production, through the use of new supplementary lighting regimes. Secondly, to further stimulate marketing, it was felt that new varieties should be investigated for response to supplementary lighting with the aim of increasing the diversity of good quality of pot mums available for marketing over the winter period, and hopefully continue to maintain consumer interest in this product. Thirdly, to relieve the burden of the cost of providing supplementary lighting (and particularly that of the new lighting regimes), closer pot spacing was investigated in detail for its impact on quality as well as on the economics of providing supplementary lighting. Since supplementary lighting is an expensive technique, wider pot spacing with no supplementary lighting was also investigated as an alternative and cheaper means of increasing the natural light available to each pot and hence hopefully improve quality. Finally, as a natural progression on HDC funded work carried out at HRI Efford over the winter 1993/94 period on DROP regimes in combination with supplementary lighting, a negative DIF treatment was combined with one of the standard lighting regimes and assessed for control of plant height as well as impact on overall quality.

The objectives of the trial were therefore as follows:

- To evaluate the potential for optimising on the benefits of both cropping time and quality on the same pot by combining the standard supplementary lighting treatments identified in earlier studies.

- To extend the range of varieties assessed to date under standard supplementary lighting regimes.

- To assess the influence of closer pot spacings on quality, production time, shelf-life and the economics of production.

- To examine the potential for gaining the benefits observed with supplementary lighting through using wider spacings on a crop receiving no supplementary lighting.

- To evaluate the interaction of negative DIF with supplementary lighting on plant height and overall quality.

The supplementary lighting regimes assessed included:

1) 4.8 W/m^2 throughout short days.

2) 12 W/m^2 during weeks 1 to 3 of short days only.

3) 12 W/m^2 during weeks 1 to 3 of short days followed by 4.8 W/m^2 for the remaining short day period.

4) 4.8 W/m^2 during weeks 1 to 7 of short days followed by 12 W/m^2 for the remaining short day period.

Treatments 1 and 2 of the above represent the two standard regimes recommended from previous trials work and the two types of lighting treatments currently used commercially. Treatments 3 and 4 represent the two new lighting treatments under investigation. Treatment 3 is a combination of treatment 2 followed by treatment 1, where the aim is to achieve the quality benefits on pots normally seen with treatment 1, while optimising rate of production normally achieved with treatment 2. Treatment 4 is a combination of treatment 1 followed by treatment 2, that is, lower intensity lighting during bud initiation and further development for optimum bud count and foliage quality followed by a short period of high intensity lighting during flower development and maturation to specifically improve flower quality. The two varieties Charm and Yuba were assessed for their response to these lighting treatments.

The following three closer pot spacing treatments were assessed:

a) Intermediate at 24 pots/m^2 (i.e. 20.3cm between pots)
Final at 12.5 pots/m^2 (i.e. 28.3 cm between pots).

b) Intermediate at 30 pots/m^2 (i.e. 18.25 cm between pots)
Final at 15 pots/m^2 (i.e. 25.8 cm between pots).

c) Intermediate at 36 pots/m^2 (i.e. 16.67 cm between pots)
Final at 18 pots/m^2 (i.e. 23.57 cm between pots).

All pots were spaced at 41 pots/m^2 during the 14 days in propagation under night break lighting and were then transferred to short days using the intermediate spacing treatments detailed above. After 14 days at intermediate spacing, all pots were moved to the appropriate final spacing treatment.

Spacing treatment a) above represents the standard spacing used for previous trial work on supplementary lighting. Treatments b) and c) represent 25% and 50% closer spacings respectively in comparison with the standard treatment. These spacing treatments were combined with all the lighting treatments detailed above for the varieties Charm and Yuba.

Cerise About Time was introduced as a new variety for assessment against the two standard supplementary lighting treatments 1 and 2 detailed above. In addition the standard spacing treatment was compared with the closer spacing of 15 pots/m^2 for this variety.

Treatments to assess the impact of wider spacing with no supplementary lighting on winter production were as follows:

a) 24 pots/m^2 (i.e. 20.3cm between pots) during the first two weeks of short days
12.5 pots/m^2 (i.e. 28.3 cm between pots) from the third week of short days onwards.

d) 41 pot/m^2 (i.e. pot thick) during the first week of short days
12.5 pots/m^2 (i.e. 28.3 cm between pots) from the second week of short days onwards.

Treatment a represents standard spacing as used throughout the trial and treatment d represents the wider spacing treatment. For the wide spacing treatment, pots were actually spaced wider than the standard treatment during the second week of short days when flowers would be initiating. As above, all pots were kept at pot thick or 41 pots/m^2 for the 14 day period in propagation. This treatment was assessed using the varieties Charm, Yuba and Cerise About Time.

The negative DIF treatment involved dropping the desired day time temperature to 16 °C (i.e. 2 °C below the temperature set point for the standard temperature regime) from 0700 to 1900 hrs. To achieve a 24 hour average temperature of 18 °C which would prevent delays in flowering, temperature compensation was used during the night period using a temperature set point of 20 °C from 1900 to 0700 hrs. This treatment was combined with the standard supplementary lighting regime of 12 W/m^2 during weeks 1 to 3 of short days only. Comparisons were made with plants grown under the same lighting regime but standard temperature set points (i.e. 18 °C day and night) and height regulation through the application of B-Nine. Plants grown with DIF were not treated with chemical plant growth regulators so that a measure of the height reduction achieved through the negative DIF treatment could be assessed. The varieties Charm, Yuba and Cerise About Time were all assessed for their response to the negative DIF treatment.

All of the above treatments were repeated on the varieties specified on three sticking dates over the winter period. These were week 40, to represent a crop growing under good initial levels of solar radiation but poorer levels later in the crop, week 45 to represent a crop growing under poor natural solar radiation conditions throughout production and week 50 to represent low initial solar radiation moving to better conditions towards the end of production.

All plants were assessed for quality at marketing stage 3 (i.e. 12 flowers all with petals just bending outwards, 50% of petals at least 20 mm long) through records of plant form and flower development. Plants from all treatments were assessed under simulated shelf-life conditions to assess the effect the treatments may have on keeping quality for the consumer.

ii. Results

Combining the standard lighting treatments to form the two new lighting treatments had beneficial effects on the winter production of pot mums. By combining high light intensity (12 W/m^2) during flower initiation (or the first three weeks of short days) with lower light intensity (4.8 W/m^2) for the remaining short day period, a significant improvement in quality was achieved in comparison with the standard lighting treatment of 12 W/m^2 during weeks 1 to 3 of short days only. A significant reduction in production time was also achieved against both of the standard supplementary lighting regimes, with an average saving of 1.3 days overall or up to 4.5 days on individual treatment means in comparison with lighting at 12 W/m^2 during weeks 1 to 3 of short days alone, and of 1.9 days overall or up to 5.1 days on individual treatments means in comparison with lighting at 4.8 W/m^2 throughout short days.

By combining lower light intensity (4.8 W/m^2) during flower initiation and further development with higher intensity (12 W/m^2) during flower maturation (i.e. the second combined treatment), flower colour was enhanced for the variety Charm. This benefit was observed both at marketing and also during shelf-life (i.e. when petal colour normally fades quite rapidly in the winter period).

Economic evaluation of the lighting treatments indicates that the cost of lighting alone would increase by 33% per pot for both of the combined treatments assessed in comparison with the most expensive of the standard supplementary lighting treatments (i.e. lighting at 4.8 W/m^2 throughout short days). The value of the benefits of the individual treatments as outlined above would need to be balanced against these extra costs. With increasing emphasis being put on the shelf-life of ornamentals by outlets such as the multiples, the benefit of the second combined treatment in particular may be of value.

To counteract the increasing cost of these combined treatments it is clear that closer pot spacings may be successfully achieved for pots receiving supplementary lighting during the winter period. In this trial, small penalties both in terms of quality and rate of production resulted from decreasing the spacing between pots. However pots receiving supplementary lighting at closer spacing were still of superior quality to those at standard spacing with no supplementary lighting or even at wider spacing with no supplementary lighting, and speed of production was also on average four days faster. It must be noted that the success of spacing pots closer together will depend on individual growing conditions, and plants growing more vigorously (either due to variety type or cultural conditions) may not be as successfully grown at the closest spacing treatment for example than they were in the current trial. Growing systems which create particularly high humidity may also constrain how close together pots may successfully be grown.

The economic benefits of closer spacing equate to a saving of 17% for the 15 $pots/m^2$ treatment or 31% for the 18 $pots/m^2$ treatment (in comparison with spacing at 12.5 $pots/m^2$) on the costs per pot of providing supplementary lighting. The costs per pot of the individual lighting treatments for each spacing treatment were calculated and are summarised in table 1.

Table 1 **Summary of costings calculated for supplying the supplementary lighting regimes at the three pot spacings assessed**

	Treatment	Total cost in p/pot*
1.	***4.8 W/m² throughout short days***	
	12.5 pots/m² at final spacing	19.8 (15.2)
	15 pots/m² at final spacing	16.5 (12.6)
	18 pots/m² at final spacing	13.6 (10.5)
2.	***12 W/m² during weeks 1 to 3 of short days only***	
	12.5 pots/m² at final spacing	11.7 (9.0)
	15 pots/m² at final spacing	9.4 (7.4)
	18 pots/m² at final spacing	8.3 (6.0)
3.	***12 W/m² during weeks 1 to 3 of short days followed by 4.8 W/m² for remaining short days***	
	12.5 pots/m² at final spacing	26.4 (20.3)
	15 pots/m² at final spacing	21.7 (16.8)
	18 pots/m² at final spacing	18.1 (13.8)
4.	***4.8 W/m² during weeks 1 to 7 of short days followed by 12 W/m² for remaining short days***	
	12.5 pots/m² at final spacing	26.3 (20.2)
	15 pots/m² at final spacing	22.0 (16.7)
	18 pots/m² at final spacing	18.2 (14.0)

The method for calculating these costings is presented in full in Appendix III, page 131 of the full report. Two basic sets of assumptions have been used for these calculations as follows:

i)	Capital cost per lamp including installation	=	£160
	Interest rate on loans	=	14%
	Electricity charges (standard rate)	=	7.78 p/kWhr
ii)	Capital cost per lamp including installation	=	£150
	Interest rate on loans	=	9%
	Electricity charges (standard rate)	=	5.50 p/kWhr

* Costs based on the second set of assumptions are presented in brackets in Table 1 above.

These two sets of assumptions relate to average figures applicable in 1993 (i.e. assumptions i), presented in previous HDC project reports (e.g. PC13b, PC13c, PC92) and figures applicable to the date of the current trial (assumptions ii). The difference in final figures calculated using these two sets of figures serves to illustrate the importance of calculating figures based on individual circumstances. The economic costings presented in Table 1 (page 7) however are still valuable for comparing treatments against each other and also assessing the impact of closer pot spacing on the final costing.

Cerise About Time benefitted from the standard supplementary lighting treatments in a similar way to that observed for other varieties in previous trials. That is, both of the standard lighting regimes significantly reduced production time with the greatest savings (of up to 11.2 days on individual treatment means) achieved through lighting at 12 W/m^2 during weeks 1 to 3 of short days alone. In addition, pot quality and foliage colour was significantly improved through lighting at 4.8 W/m^2 throughout short days.

Negative DIF was effective at reducing plant height when combined with supplementary lighting at 12 W/m^2 during weeks 1 to 3 alone and was more effective than DROP regimes previously examined in combination with standard supplementary lighting regimes. This treatment could therefore be successfully combined with supplementary lighting for reducing inputs of chemical plant growth regulators.

iii. Conclusions

This study has illustrated that :

- Combinations of the standard supplementary lighting regimes identified in previous trials may successfully be used to produce benefits in terms of either quality or rate of production, depending on the combination in question. Specific benefits need to be assessed against the extra cost of providing these treatments.

- The variety Cerise About Time benefits from the standard supplementary lighting regimes in a similar way to that noted for both Princess Anne types and American bred varieties in previous trials.

- Closer pot spacing does provide a means of reducing costs per pot for supplementary lighting and may be achieved with minimal disadvantages in terms of quality and rate of production. Pot quality at the closest spacing treatment assessed was still superior to that of standard spacing where no supplementary lighting was provided.

- Increasing pot spacing during the second week of short days only (i.e. the wider spacing treatment) was insufficient to reproduce the types of benefits achieved through supplementary lighting.

- Negative DIF may successfully be combined with supplementary lighting at 12 W/m^2 during weeks 1-3 of short days to reduce plant height with no impact on the benefit of this lighting treatment.

EXPERIMENTAL SECTION

INTRODUCTION

Supplementary lighting has become a recognised technique for improving the quality and production of pot chrysanthemums during the winter period when solar radiation levels are below the minimum required for satisfactory growth.

Trial work initially at Lee Valley EHS and latterly at HRI Efford has clearly demonstrated that high intensity supplementary lighting can be effective on a commercial scale for both increasing the rate of bud initiation, and hence reducing cropping time, and improving pot quality. This work has identified the following two successful supplementary lighting protocols for a range of commercial varieties:

i. 12 W/m^2 for the first three weeks of short days.

ii. 4.8 W/m^2 throughout the short day period.

The benefits of these two lighting regimes may be summarised as reduced production time for the 12 W/m^2 (weeks 1-3 S.D.) treatment and improvements in quality along with smaller reductions in production time for the 4.8 W/m^2 (throughout S.D.) treatment. It is possible however that full production time and quality benefits may be achieved in the same treatment if the two lighting regimes are combined. Furthermore, strategic work by Cockshull and Hughes (1971) predicted that benefits in terms of flower quality would be achieved through the use of high intensity lighting (12 W/m^2) towards the end of the crop when buds are developing into open flowers.

Previous trials on supplementary lighting for pot chrysanthemums concentrated on Princess Anne types initially and latterly on American bred varieties. There is still however only a limited range of varieties produced commercially over the winter, even by growers who have supplementary lighting available. There is therefore also a need to examine other varieties under the standard lighting regimes identified in order to attempt to increase the range available over the winter and hopefully maintain consumer interest in this product.

Economic evaluations of supplementary lighting conducted in the HDC funded trial PC13b (Finlay, 1993) indicated that the 4.8 W/m^2 throughout S.D. treatment would cost 17.7 p per pot in addition to normal production costs and the 12 W/m^2 weeks 1-3 S.D. treatment would cost 11.7 p per pot. (NOTE: Costings in these original calculations were based on the assumption that pots were marketed at stage 2 during the winter. Since later work under the project PC13c,

Wilson 1994a, illustrated that marketing stage 3 is more suitable in the winter, the updated costings, as in section 6, page 78 and table 1 page 7, for the 4.8 W/m^2 treatments throughout S.D. are higher to allow for the extra week required to acheive marketing stage 3.) The potential for improving the economics of using supplementary lighting through increasing the number of pots per unit area (and hence reducing the cost of lighting per pot) was therefore examined in the HDC funded trial PC92 1993/94 (Wilson, 1994b) on an observational basis. A closer pot spacing of 15 pots/m^2 (i.e. where standard spacing was taken as 12.5 pots/m^2) reduced the cost of lighting by 17% to 18% per pot depending on treatment, but was also found to influence plant height and delay flowering slightly. This indicated that closer pot spacings may indeed provide a realistic means of decreasing the cost of lighting on a pot basis and warranted closer examination. There was therefore a need to fully assess the potential for using closer pot spacings when treating pots with supplementary lighting including the impact on quality and shelf life performance and the investigation of even closer spacing treatments than those already assessed.

Spacing may also be used to improve the light received by a pot, particularly in the absence of supplementary lighting. The potential for improving quality at wider spacings during bud initiation therefore needs to be assessed against the quality achieved both at standard spacing with no supplementary lighting as well as production under standard supplementary lighting regimes.

Finally, it was found through HDC funded work at HRI Efford in 1993/94 (PC92, Wilson, 1994b) that the standard supplementary lighting regimes mentioned above, may be combined with DROP to reduce plant height and hence the rate or frequency of application of chemical plant growth regulators required. Since the DROP technique involves lowering the compartment temperature for only a short period of the day (in PC92, 0700 to 1000 hrs was the period of time over which the DROP was applied) it is possible that a full DIF treatment (i.e. where the whole day period is set at a lower temperature than the night period) may be more effective at controlling height when combined with supplementary lighting.

Hence the main aims of PC92a included the assessment of the combined effects of supplementary lighting and pot spacing to optimise on both production time and quality whilst maximising returns in terms of throughput of pots. An observation trial also investigated the potential to control plant height using DIF in combination with supplementary lighting with the aims of further reducing the use of chemical plant growth regulators.

OBJECTIVES

The objectives were:

1) To evaluate the potential for optimising on the benefits of both cropping time and quality on the same pot by combining the standard supplementary lighting treatments identified in earlier studies.

2) To extend the range of varieties assessed to date under standard supplementary lighting regimes.

3) To assess the influence of closer pot spacings on quality, production time, shelf-life and the economics of production.

4) To examine the potential for gaining the benefits observed with supplementary lighting through using wider spacings on an unlit crop.

5) To evaluate the interaction of negative DIF with supplementary lighting on plant height and overall quality.

MATERIALS AND METHODS

1. Treatments

1.1 The influence of combined lighting treatments on winter quality

Lighting treatments:

1) 4.8 W/m² supplementary lighting throughout short days.

2) 12 W/m² supplementary lighting for weeks 1-3 short days only.

3) 12 W/m² supplementary lighting for weeks 1-3 short days moving to 4.8 W/m² for remaining short days.

4) 4.8 W/m² supplementary lighting for weeks 1-7 short days moving to 12 W/m² for remaining short days.

Treatments 1 and 2 represent the two most favourable supplementary lighting regimes of those investigated in previous studies. These were compared with treatments 3 and 4 as new, combined, lighting regimes.

Supplementary lighting was provided continuously by 400W high pressure sodium (SON/T) lamps during short days for 11 hrs from 0700-1800 daily.

Varieties: Charm, Yuba

Sticking Dates: Week 40, Week 45, Week 50

1.2 The influence of standard supplementary lighting treatments on the winter quality of new varieties

Lighting treatments:

1) 4.8 W/m² supplementary lighting throughout short days.

2) 12 W/m² supplementary lighting for weeks 1-3 short days only.

3) No supplementary lighting throughout short days.

Cerise About Time was assessed as a new variety for investigation under standard supplementary lighting regimes. Comparisons were also made against production under no supplementary lighting (or ambient light levels) to enable quantification of the benefits of supplementary lighting for this variety.

Supplementary lighting was provided continuously by 400W high pressure sodium (SON/T) lamps during short days for 11 hrs from 0700-1800 daily.

Sticking Dates: Week 40, Week 45, Week 50

1.3 The influence of closer pot spacings on quality and production

Lighting treatments:

1) 4.8 W/m^2 supplementary lighting throughout short days.

2) 12 W/m^2 supplementary lighting for weeks 1-3 short days only.

3) 12 W/m^2 supplementary lighting for weeks 1-3 short days moving to 4.8 W/m^2 for remaining short days.

4) 4.8 W/m^2 supplementary lighting for weeks 1-7 short days moving to 12 W/m^2 for remaining short days.

Supplementary lighting was provided continuously by 400W high pressure sodium (SON/T) lamps during short days for 11 hrs from 0700-1800 daily.

Spacing treatments:

a) Intermediate at 24 pots/m^2 (ie 20.3cm pot centre to centre) weeks 1-2 of short days
Final at 12.5 pots/m^2 (ie 28.3 cm pot centre to centre) week 3 of short days onwards.

b) Intermediate at 30 pots/m^2 (ie 18.25 cm pot centre to centre) weeks 1-2 of short days
Final at 15 pots/m^2 (ie 25.8 cm pot centre to centre) week 3 of short days onwards.

c) Intermediate at 36 pots/m^2 (ie 16.67 cm pot centre to centre) weeks 1-2 of short days
Final at 18 pots/m^2 (ie 23.57 cm pot centre to centre) week 3 of short days onwards.

Where spacing a) represents standard spacing, with treatments b) and c) representing 25% and 50% closer spacings (in comparison with the standard) respectively.

Varieties: Charm, Yuba (all lighting and spacing treatments)
Cerise About Time (lighting treatments 1 and 2 x spacings a) and b) only)

Sticking Dates: Week 40, Week 45, Week 50

1.4 The influence of wider spacing for unlit crops on quality and production time

Lighting treatment:

No supplementary lighting throughout short days.

Spacing treatments:

a) Intermediate at 24 pots/m^2 (ie 20.3cm between pots) weeks 1-2 of short days
Final at 12.5 pots/m^2 (ie 28.3 cm between pots) week 3 of short days onwards.

d) Intermediate at 41 pots/m^2 (ie pot thick as in propagation) week 1 of short days
Final at 12.5 pots/m^2 (ie 28.3 cm between pots) week 2 of short days onwards.

Spacing treatment d) represents the wider spacing treatment (to be combined with no supplementary lighting). The wider spacing occurred during the second week of short days when pots in standard spacing (treatment a) were spaced at 24 pots/m^2 (in comparison with 12.5 pots/m^2 for the wider spacing treatment). From week three of short days onwards however, treatments a) and d) were both spaced at 12.5 pots/m^2.

Varieties: Charm, Yuba, Cerise About Time

Sticking Dates: Week 40, Week 45, Week 50

1.5 The influence of negative DIF combined with supplementary lighting on winter quality

Lighting treatment:

12 W/m² supplementary lighting for weeks 1-3 short days moving to no supplementary lighting for remaining short days combined with negative DIF

Negative DIF treatment:

This regime involved dropping the desired day time temperature (i.e. 0700 to 1900 hrs) by 2 °C below the conventional set point temperature of 18 °C to 16 °C. To maintain an average 24 hour temperature of 18 °C, which is necessary for optimum speed of production, the desired night temperature was therefore raised to 20 °C. Hence, the temperature regimes were set as follows:

Standard temperature:	18 °C day and night heating set points 23 °C day and night ventilation set points Etradiazole (as B-Nine) applied as required.
Negative DIF regime:	16 °C day and 20 °C night heating set points 19 °C day and 23 °C night ventilation set points No chemical plant growth regulators.

2. Cultural details

2.1 Plant material

Unrooted cuttings of Charm and Yuba were purchased from Yoder Toddington Ltd. Unrooted cuttings of Cerise About Time were purchased from Ficor Ltd.

2.2 Propagation (long days)

Cuttings were stuck into Fisons Levington M2 compost in 140mm half pots (14D) with 5 cuttings per pot. Bottom heating was applied to achieve a compost temperature of 20 °C. After sticking, pots were covered with clear polythene which remained in place for 10 days before weaning the plants off. Night break lighting during the long day period (14 days from sticking) was supplied for 5 hours per night from 2230 to 0330 hrs using tungsten lamps (15 minutes on, 15 minutes off cycle) at 8.4 W/m² at plant height.

2.3 Short day environment

For the standard temperature regime a heating set point of 18 °C was used day and night with venting set at 23 °C. Details of temperature regime for the negative DIF treatment are provided above.

CO_2 enrichment was given to maintain levels to 1000 vpm when the vents were less than 5% open and to 500 vpm with vents at or above 5% open using pure CO_2 .

2.4 Growth regulation

Plants were pinched back to 7 to 8 leaves when the growing tip was of sufficient size to handle. Plants in all treatments were treated with daminozide (as B-Nine), and phosphon according to variety as follows:

Variety	Phosphon[1] g/l[3]	B-Nine[2] g/l[3]	B-Nine[2] ppm[4]
Charm	0.2	1.5	1250
Yuba	Nil	1.5	1250
Cerise About Time	Nil	1.5	1250

[1] incorporated into compost
[2] applied when breaks 2.0 to 2.5 cm long
[3] rate of formulated product
[4] rate of active ingredient

2.5 Pot spacing

Except for pots receiving close or wide spacing treatments as described above, pots were spaced at 41 pots/m² (or pot thick) during the 14 day propagation period. On moving to the short day environment, pots were spaced at 24 pots/m² for the first 14 days of short days before moving to a final spacing of 12.5 pots/m².

2.6 Nutrition

Liquid feeding commenced at the start of short days and continued with every watering. The dilute feed supplied 300 mg/l N, 60 mg/l P_2O_5 (26 mg/l P) and 250 mg/l K_2O (207 mg/l K).

2.7 Pest and disease control

A routine, preventative spray programme was employed against Western Flower Thrip, alternating the chemicals malathion (as MTM Malathion 60 at 1.8 ml/l), endosulfan (as Thiodan at 2mls/l) and dichlorvos (as Nuvan 500 EC at 1 ml/l). Additional treatments included iprodione (as Rovral at 5g/l) and *Verticillium lecannii* (as Mycotal at 1 g/l) during propagation for prevention of *Botrytis spp.* and Western Flower Thrip respectively, zineb (at 2 g/l) for further treatment against *Botrytis spp.* and Nemasys (at 1 pack per 1000 pots) for prevention of sciarid fly during shelf-life. Further details of specific treatments are included in the crop diary for each sticking date in Appendix V, page 160.

2.8 Shelf-life environment

Plants were selected at marketing stage 3 (i.e. 12 flowers all with petals just bending outwards, 50% of petals at least 20mm long) and packaged in polythene sleeves inside cardboard boxes. The boxes were transferred to a cool chamber (5-6 °C) for three days before transferring to an environment of 18-20 °C lit for 12 hours per day at 800 lux using warm white fluorescent lamps where sleeved pots were removed from the boxes and placed on individual saucers. After four days in this environment, the polythene sleeves were removed and pots were watered as necessary with plain water.

3. Assessments

The effect of treatments on production time and plant quality was assessed at marketing stage 3 (i.e. 12 flowers all just bending outwards, 50% of petals at least 20 mm long) by recording:

i. Time taken to reach marketable stage (days).

ii. Plant height from stem base to tallest flower (cm).

iii. Maximum and minimum plant spread per pot (cm).

iv. Number of developing (i.e. bud stages 1-3) and open (i.e. bud stages 4+) buds/flowers per pot.

v. Uniformity of flower development, recorded as maximum bud stage per plant as defined by Cockshull and Hughes (1972), and averaged for each pot.

vi. Leaf quality assessed as a qualitative score, where score 0 = no damage, score 1 = minor damage, score 2 = moderate damage and score 3 = severe damage. Damage to lower leaves in particular was considered. A photographic key to these scores is presented in Appendix IV, page 151.

vii. Growing media analysis eight weeks after the start of short days.

viii. Environmental and solar radiation measurements.

ix. Photographic record as appropriate

The effect of treatments on the shelf life performance of plants was assessed on a sub sample of three pots per plot selected at marketing stage 3. Details of the shelf-life environment are given above. Plants were assessed for extent of flower development and overall deterioration at weekly intervals as follows.

i. Pot deterioration score, where a qualitative score was assigned according to the overall condition of the pot. Score 0 = no deterioration, score 1 = minor deterioration (i.e. the first signs of deterioration beginning to show), score 2 = moderate deterioration and score 3 = severe deterioration (i.e. the pot would no longer be kept on display be the consumer). A photographic key to these scores is provided in Appendix IV, page 151.

ii. Leaf quality score using the same qualitative scores as for marketing records described above.

iii. Extent of flower development, recorded as number of open flowers (i.e. buds at stages 4+) per pot.

iv. Extent of flower distortion (as illustrated in Appendix IV, page 151), recorded as number of distorted flowers per pot.

Since records commenced after sleeves were removed from the pots each weekly record corresponded to the following total number of days in shelf-life:

Week 1 record = 3 days in cold store + 4 days in sleeves + 7 days to first record
= 14 days from 'marketing'.
Week 2 record = 21 days from 'marketing'.
Week 3 record = 28 days from 'marketing'.

4. Statistical analyses

Analysis of variance was carried out to assess the significance of data collected. Replication of treatments was based on time (stick dates) and varieties. Effects examined included, combined and standard supplementary lighting treatments, spacing and DIF and their interaction with both variety and sticking date. Main effects will be presented as figures meaned across variety, sticking date and in some cases also spacing or lighting treatment, depending on the comparison in question. The use of these means increases the power of the test and enables smaller difference to be detected. All individual treatment means are however presented in Appendix I, page 85, so that results for different varieties and sticking dates can be examined independently with the main observations in mind from the statistical testing.

Standard deviation of both plant height and maximum bud stage per pot were also analysed to indicate variability per pot relative to treatment (where a small standard deviation indicates greater uniformity).

Statistical terms

N.S.	Not significant
L.S.D.	The least (minimum) difference when comparing two means within a given data set that is required for the means to be statistically different.
$P<0.05$	The probability of this result occurring by chance is equal to or less than 1 in 20 (0.05 = 5%).
$P<0.01$	The probability of this result occurring by chance is equal to or less than 1 in 100 (0.01 = 1%).
$P<0.001$	The probability of this result occurring by chance is equal to or less than 1 in 1000 (0.001 = 0.1%).

RESULTS

1. The influence of combined supplementary lighting treatments on winter quality.

Full treatment means are recorded in Appendix I, page 85. The following key observations were noted when pots were suitable for marketing (i.e. marketing stage 3).

1.1 Vegetative development and flower production.

a. Effect of combined supplementary lighting treatments on production time ($P < 0.001$)

Mean number of days from sticking to marketing stage 3

4.8 W/m² throughout S.D.	12 W/m² weeks 1-3 S.D. to unlit	12 W/m² weeks 1-3 S.D. to 4.8 W/m²	4.8 W/m² weeks 1-7 S.D. to 12 W/m²
79.2 a	78.6 a	77.3 b	78.5 a

L.S.D. (P= 0.05) = 0.723

Means followed by different letters differ significantly at the 5% level.

The shortest production time was achieved by combining high intensity (12 W/m²) supplementary lighting during flower initiation (weeks 1-3 S.D.) with a lower intensity lighting (4.8 W/m²) for the remaining S.D. period. This treatment was significantly faster than the other lit treatments assessed, with mean production time decreases of 1.2 to 1.9 days overall. There were no significant differences between the remaining lit treatments assessed.

Comparisons between supplementary lighting treatments and no supplementary lighting (or unlit) were not a formal component of this trial. It is interesting to note however that the mean production time without supplementary lighting was 82.9 days (meaned over the three sticking dates and spacing treatments). Hence, in agreement with previous trials (e.g. PC13b, Finlay, 1993 and PC13c, Wilson, 1994a), a significant reduction in production time was achieved with all supplementary lighting treatments. As detailed in Table 1, Appendix I (pages 86-88), reductions in production time of up to 8.1 days for Charm, 10.3 days for Yuba and 11.2 for Cerise About Time (discussed later) were achieved through supplementary lighting, compared with no lighting, for individual treatment means.

There was no significant interaction between lighting and stick week or lighting treatment and variety. Hence the trends discussed above for meaned data apply to the individual varieties and stick weeks.

b. Effect of combined supplementary lighting treatments on plant height (N.S)

Mean plant height (cm)

4.8 W/m² throughout S.D.	12 W/m² 1-3 S.D. to unlit	12 W/m² weeks 1-3 S.D.to 4.8 W/m²	4.8 W/m² weeks 1-7 S.D. to 12 W/m²
16.6	16.9	17.5	16.8

All treatments were treated with a common regime of daminozide (as B-Nine) and produced no significant differences overall in mean plant height.

There were also no significant interactions between lighting and stick week or lighting and variety in terms of plant height.

c. Effect of combined supplementary lighting treatments on uniformity of plant height ($P < 0.001$)

Uniformity of plant height was assessed using the standard deviation of the five individual plant heights recorded per pot. The larger the standard deviation, the less uniform, or balanced, the pot was in terms of plant height.

Mean standard deviation of plant height

4.8 W/m² throughout S.D.	12 W/m² weeks 1-3 S.D. to unlit	12 W/m² weeks 1-3 S.D.to 4.8 W/m²	4.8 W/m² weeks 1-7 S.D. to 12 W/m²
1.231 a	1.736 b	1.375 a	1.392 a

L.S.D (P =0.05) = 0.172

Means followed by different letters differ significantly at the 5% level.

High intensity (12 W/m²) supplementary lighting during bud initiation (weeks 1-3 S.D.) followed by no supplementary lighting produced the least uniform pots. The remaining treatments, which all received supplementary lighting throughout S.D., were more uniform with no significant differences between them in terms of uniformity of plant height.

d. Effect of combined supplementary lighting treatments on maximum pot spread. (N.S.)

Mean maximum pot spread (cm)

4.8 W/m² throughout S.D.	12 W/m² weeks 1-3 S.D. to unlit	12 W/m² weeks 1-3 S.D. to 4.8 W/m²	4.8 W/m² weeks 1-7 S.D. to 4.8 W/m²
31.9	30.9	31.6	31.5

Maximum pot spread meaned across the varieties Charm and Yuba for the three sticking dates was not significantly influenced by the lighting treatments assessed.

e. The interaction between combined supplementary lighting treatments and sticking date on maximum pot spread (P= 0.036)

Mean maximum pot spread (cm)

Stick week	4.8 W/m² throughout S.D.	12 W/m² weeks 1-3 S.D. to unlit	12 W/m² weeks 1-3 S.D. to 4.8 W/m²	4.8 W/m² weeks 1-7 S.D. to 12W/m²
40	33.2 a	31.3 b	33.3 a	31.5 bc
45	31.9 ab	30.9 b	31.5 bc	32.8 ac
50	30.5 b	30.5 b	30.1 b	30.2 b

L.S.D (P =0.05) = 1.366

Means followed by different letters differ significantly at the 5% level.

While mean maximum pot spread was not significantly influenced by supplementary lighting treatments meaned across the three stick dates, significant differences were found for individual stick dates. Hence, for sticking in week 40, greater maximum spread was recorded for lighting at 4.8 W/m² throughout S.D. and at 12 W/m² weeks 1-3 S.D. followed by 4.8 W/m² for remaining S.D. For pots stuck in week 45 however, the greatest maximum pot spread resulted from either lighting at 4.8 W/m² throughout S.D. or at 4.8 W/m² weeks 1-7 S.D. followed by 12 W/m² for the remaining S.D. Thus where the later stages of growth occurred under poorer ambient light conditions (i.e. pots stuck in week 40 or 45), supplementary lighting had a greater impact or maximum pot spread. In particular, treatments which provided lighting during the whole S.D. period, favoured greater maximum pot spread.

f. Effect of combined supplementary lighting treatments on minimum pot spread (P=0.046)

Mean minimum pot spread (cm)

4.8 W/m² throughout S.D.	12 W/m² weeks 1-3 S.D. to unlit	12 W/m² weeks 1-3 S.D. to 4.8 W/m²	4.8 W/m² weeks 1-7 S.D. to 12 W/m²
28.6 a	27.7 b	28.5 a	28.6 a

L.S.D. (P=0.05) = 0.733

Means followed by different letters differ significantly at the 5% level.

Mean minimum pot spread was significantly smaller for lighting at high intensity (12 W/m²) during bud initiation (weeks 1-3 S.D.) with no subsequent supplementary lighting. The remaining treatments did not significantly influence minimum pot spread.

g. The interaction between combined supplementary lighting treatments and sticking date on minimum pot spread (P= 0.002)

Mean minimum pot spread (cm)

Stick week	4.8 W/m² throughout S.D.	12 W/m² weeks 1-3 S.D. to unlit	12 W/m² weeks 1-3 S.D. to 4.8 W/m²	4.8 W/m² weeks 1-7 S.D. to 12 W/m²
40	30.1 a	27.9 b	30.0 a	28.2 b
45	28.4 b	28.1 b	28.6 b	29.7 b
50	27.5 b	27.1 b	27.0 b	27.7 b

L.S.D (P= 0.05) = 1.270

Means followed by different letters differ significantly at the 5% level.

As with maximum pot spread data above, a significant interaction was found between minimum pot spread and sticking date. That is, pots stuck in week 40 (i.e. stuck in good ambient light but growing into poorer ambient light) were smaller in terms of minimum pot spread from the treatments 12 W/m² 1-3 S.D. only and 4.8 W/m² weeks 1-7 S.D. to 12 W/m² for remaining S.D.

The maximum and minimum pot spread data were assessed for uniformity of pot spread using the following calculation:

$$\frac{\text{Maximum spread - minimum spread}}{2}$$

Uniformity of spread was not however influenced by lighting treatment.

h. Effect of combined supplementary lighting treatments on number of expanding ($P < 0.001$) and open ($P < 0.001$) buds

Mean number of buds/flowers per pot

	4.8 W/m² throughout S.D.	12 W/m² weeks 1-3 S.D. to unlit	12 W/m² weeks 1-3 S.D. to 4.8 W/m²	4.8 W/m² weeks 1-7 S.D. to 12 W/m²
Stages 1 - 3	24.4 a	17.4 b	22.7 a	25.6 a
Stages 4+	18.8 a	13.3 b	19.1 a	19.9 a

L.S.D (P= 0.05) = 2.46 Stages 1-3
1.36 Stages 4+

Means within rows followed by different letters differ significantly at the 5% level.

All treatments providing supplementary lighting throughout the S.D. period produced significantly higher numbers of both expanding and open buds at marketing stage 3. Supplementary lighting at high intensity (12 W/m²) during flower initiation alone (weeks 1-3 S.D.) produced significantly fewer expanding and open buds. By combining this high intensity lighting during initiation with a lower intensity for the remaining S.D. period, significant increases in numbers of both expanding and open buds were achieved.

Unlit treatments were again not a formal component of this trial but numbers of expanding and open buds may be compared with these treatments. Thus, unlit pots produced an overall mean of 18.4 expanding buds per pot and 13.5 open buds/flowers per pot. In both cases, there was no significant difference between the unlit treatment and lighting at 12 W/m² weeks 1-3 S.D. only in terms of the number of buds produced. The other three lighting treatments however significantly increased both numbers of expanding buds (by a mean of 4.3-7.2 buds per pot overall) and open buds (by a mean of 5.3-6.4 buds per pot overall).

i. Interaction of variety and lighting treatment on number of expanding (P= 0.017) and open (P<0.001) buds

Mean number of buds per pot.

	4.8 W/m² throughout S.D.	12 W/m² weeks 1-3 S.D. to unlit	12 W/m² weeks 1-3 S.D. to 4.8 W/m²	4.8 W/m² weeks 1-7 S.D. to 12 W/m²
Charm				
Stages 1 - 3	27.6 a	16.2 b	23.7 c	26.8 ac
Stages 4+	13.5 d	11.3 e	13.3 d	14.6 d
Yuba				
Stages 1 - 3	21.2 ab	18.6 b	21.6 ab	24.3 a
Stages 4+	24.2 c	15.2 d	24.9 c	25.2 c

L.S.D (P= 0.05) = 3.47 Stages 1-3
1.92 Stages 4+

Means within rows followed by different levels differ significantly at the 5% level.

The general trend in the number of expanding and open buds/flowers per pot is reflected in the mean results for the individual varieties. That is the supplementary lighting treatments which continue throughout S.D. produce higher numbers of expanding and open buds than lighting at high intensity during bud initiation only.

With the variety Charm, however there is a further distinction between treatments in terms of number of expanding buds produced. That is, there were significantly fewer expanding buds where lighting at 12 W/m² weeks 1-3 S.D. was followed by 4.8 W/m² than where lighting at 4.8 W/m² was given throughout S.D. This trend was not however reflected in the numbers of open buds produced, and hence reflects changes in total bud production rather than state maturity or relative proportions of expanding and open buds at maturity.

With the variety Yuba, a different trend occurred, where only the treatment 4.8 W/m² weeks 1-7 S.D. followed by 12 W/m² for remaining S.D. produced significantly more expanding buds than the treatment 12 W/m² weeks 1-3 S.D. only. Again, trends in number of open buds were not affected by these differences.

Overall, both varieties would achieve enhance visual pleasure in the winter period as a result of lighting for the whole S.D. period.

j. Effect of combined supplementary lighting treatments on total bud number ($P < 0.001$)

Mean number of buds per pot

4.8 W/m² throughout S.D.	12 W/m² weeks 1-3 S.D. to unlit	12 W/m² weeks 1-3 S.D. to 4.8 W/m²	4.8 W/m² weeks 1-7 S.D. to 12 W/m²
43.2 a	30.7 b	41.7 a	45.5 a

L.S.D (P= 0.05) = 2.64

Means followed by different letters differ significantly at the 5% level.

As may be expected, total buds followed the same trends as expanding and open buds discussed above. That is all lighting treatments which provide an intensity of 4.8 W/m² or greater throughout S.D., increased the number of buds produced in comparison with lighting at 12 W/m² during bud initiation only.

High intensity supplementary lighting during bud initiation is therefore sufficient to speed up the rate of bud production, as reflected in production time figures above, but does not maximise on the number of buds which can be produced.

The lighting treatments assessed had no significant influence on the average of maximum bud stage per pot or uniformity of flowering. It was noted however that a deeper petal colour resulted for the variety Charm from lighting at high intensity as flowers were maturing (i.e. from week 7 of S.D. onwards). Since this treatment was combined with lighting at lower intensity (4.8 W/m²) during the first seven weeks of S.D. it is unclear whether the high intensity treatment at the end of production alone would produce a similar result. Enhanced petal colour was only achieved for the first two sticking dates where background light during the period of flower maturation was poor.

k. Effect of combined supplementary lighting treatments on foliage quality (N.S)

Mean leaf quality score

4.8 W/m² throughout S.D.	12 W/m² weeks 1-3 S.D. to unlit	12 W/m² weeks 1-3 S.D. to 4.8 W/m²	4.8 W/m² weeks 1-7 S.D. to 12 W/m²
0.8	0.9	0.8	0.7

Leaf quality (where score 0= no damage and score 3= severe damage) was not significantly influenced by any of the combined supplementary lighting treatments. Overall, low mean scores were recorded reflecting the general high quality of leaves across all treatments.

l. Effect of variety on foliage quality (P<0.001)

Mean leaf quality score

Charm	Yuba
0.3 a	1.4 b

L.S.D (P<0.005) = 0.143

Means followed by different letters differ significantly at the 5% level.

Yuba clearly suffered greater levels of leaf damage during production than Charm. This is also reflected in the individual treatment means in Tables 8a to 8c, Appendix I, pages 107-109.

Observations on colour (or darkness) of foliage were also made at maturity. The lighting treatments assessed can be ranked in the following order for foliage colour:

Dark foliage
↓
↓
Pale foliage

1. 4.8 W/m² throughout S.D.
   & 4.8 W/m² weeks 1-7 S.D. to 12 W/m²
2. 12 W/m² weeks 1-3 S.D. to 4.8 W/m²
3. 12 W/m² weeks 1-3 S.D. only

Foliage colour of plants receiving the treatment 12 W/m^2 weeks 1-3 S.D. only was generally comparable with that of plants receiving no supplementary lighting. Hence foliage quality (in terms of colour) as well as bud and flower counts (discussed above) benefitted most where supplementary lighting continued throughout the S.D period.

1.2 Shelf-life performance

As described in the materials and methods section previously (section 3, page 18), shelf-life was recorded at weekly intervals following a 3 day cold store period and 4 days in sleeves in the shelf-life environment. Thus, the total number of days from marketing to the week 3 assessment was 28.

a. Effect of combined supplementary lighting treatments on pot deterioration score, during shelf-life

Mean pot deterioration score

	4.8 W/m^2 throughout S.D.	12 W/m^2 weeks 1-3 S.D. to unlit	12 W/m^2 weeks 1-3 S.D. to 4.8 W/m^2	4.8 W/m^2 weeks 1-7 S.D. to 12 W/m^2
Week 1 (N.S.)	0.3	0.5	0.4	0.3
Week 2 (P=0.03)	1.1 a	1.4 b	1.2 a	1.0 a
Week 3 (N.S.)	2.2	2.2	2.2	1.9

L.S.D (P= 0.005) = 0.291 week 2

Means within rows followed by different letters differ significantly at the 5% level.

At both the start (week 1) and the end (week 3) of the shelf-life assessment period, there were no significant differences between lighting treatments in terms of overall pot deterioration. In the middle of the shelf-life period however deterioration of pots lit during production at 12 W/m^2 weeks 1-3 S.D only, was significantly more advanced than for the remaining treatments where supplementary lighting was used throughout the S.D. period. Hence the onset of deterioration was apparently most rapid for the lighting treatment 12 W/m^2 weeks 1-3 S.D. only compared with the remaining lighting treatments.

It is also of note, that although not found to be statistically significant, lighting at 4.8 W/m^2 weeks 1-7 S.D. to 12 W/m^2 for remaining S.D. (i.e high intensity lighting during flower maturation) produced the lowest mean pot deterioration score on each assessment. Conversely, no supplementary lighting (assessed fully in section 4, page 62) produced high pot deterioration scores at each assessment (i.e. 0.6 week 1, 1.3 week 2 and 2.3 week 3) and these figures were comparable with those from the lighting treatment 12 W/m^2 weeks 1-3 S.D. only. That is greater pot deterioration scores were apparently linked to those treatments where supplementary lighting was not used for majority of the S.D. period.

b. Effect of combined supplementary lighting treatments on foliage quality during shelf-life

Mean leaf damage score

	4.8 W/m^2 throughout S.D.	**12 W/m^2 weeks 1-3 S.D. to unlit**	**12 W/m^2 weeks 1-3 S.D. to 4.8 W/m^2**	**4.8 W/m^2 weeks 1-7 S.D. to 12 W/m^2**
Week 1 (N.S.)	0.9	1.1	1.1	0.9
Week 2 (N.S.)	1.3	1.5	1.4	1.1
Week 3 (N.S.)	1.4	1.5	1.5	1.4

There were no significant differences between the lighting treatments assessed in terms of leaf quality (assessed as extent of disease/damage) during shelf-life. As may be expected, leaf damage increased with length of time in shelf-life (although differences between scores at different assessment dates were not analysed statistically).

c. Effect of variety on leaf quality during shelf-life

Mean leaf damage score

	Charm	Yuba
Week 1 (P<0.001)	0.0 a	0.8 b
Week 2 (P<0.001)	0.7 a	1.9 b
Week 3 (P<0.001)	0.9 a	2.0 b

L.S.D. (P= 0.05) = 0.23 week 1
0.28 week 2
0.25 week 3

Means within rows followed by different letters differ significantly at the 5% level.

As noted for records taken at marketing stage 3, variety had the most significant effect on leaf quality. Yuba suffered much more with damage and disease of lower leaves during shelf-life resulting in a greater leaf damage score.

d. Effect of combined supplementary lighting treatments on number of open flowers in shelf-life

Mean number of flowers at stages 4+ per pot

	4.8 W/m² throughout S.D.	12 W/m² weeks 1-3 S.D. to unlit	12 W/m² weeks 1-3 S.D. to 4.8 W/m²	4.8 W/m² weeks 1-7 S.D. to 12 W/m²
Week 1 (P<0.001)	19.3 a	13.4 b	20.4 a	22.5 c
Week 2 (P<0.001)	21.6 a	14.6 b	20.6 a	23.3 c
Week 3 (P<0.001)	21.3 a	14.6 b	20.4 a	24.0 b

L.S.D. (P> 0.05) = 1.31 week 1
1.50 week 2
1.54 week 3

Means within rows followed by different letters differ significantly at the 5% level.

At each assessment, number of open flowers per pot followed the same trend as observed for assessments at marketing stage 3. That is, there were significantly fewer open buds in pots from the lighting treatment 12 W/m^2 weeks 1-2 S.D. to unlit than from the remaining lighting treatments. Number of open flowers in shelf-life in unlit pots (discussed fully in section 4) were also comparable with this treatment with 14.4 flowers in week 1, 16.6 in week 2 and 14.8 in week 3.

All treatments had at least a slight increase in number of open flowers as the period in shelf-life increased. Hence flowers continued to open for all treatments when transferred to shelf-life. It was also observed that for pots stuck in week 40 and week 45, the deeper petal colour of Charm associated with the lighting treatment 4.8 W/m^2 weeks 1-7 S.D. to 12 W/m^2 for remaining S.D., was maintained during the shelf-life period. In contrast, Charm produced under the remaining lighting treatments quickly lost petal colour in shelf-life (as has previously been noted with this variety, Wilson 1994a/1994b).

e. Interaction of sticking date and combined supplementary lighting treatment on number of open (stages 4+) flowers in shelf-life

Mean number of flowers at stages 4+ per pot.

	4.8 W/m² throughout S.D.	12 W/m² weeks 1-3 S.D. to unlit	12 W/m² weeks 1-3 S.D. to 4.8 W/m²	4.8 W/m² weeks 1-7 S.D. to 12 W/m²
Week 1 Assessment (P<0.001)				
Week 40	13.1 a	11.3 a	15.8 a	18.6 b
Week 45	21.3 c	10.5 a	21.4 c	26.7 d
Week 50	23.5 c	18.5 b	23.9 c	22.4 c
Week 2 Assessment (P<0.001)				
Week 40	19.0 a	12.5 b	17.7 a	19.7 a
Week 45	21.5 ad	11.9 b	21.3 a	27.1 c
Week 50	24.2 cd	19.4 a	22.8 ad	23.1 ad
Week 3 Assessment (P<0.001)				
Week 40	18.6 a	12.2 b	17.1 a	19.9 ad
Week 45	27.7 ad	11.7 b	21.6 ad	26.5 c
Week 50	23.7 cd	19.9 ad	22.4 a	25.7 c

L.S.D. (P=0.05) = 2.62 week 1
3.01 week 2
3.08 week 3

Means within each weekly assessment followed by different letters differ significantly at the 5% level.

The general trend discussed above was also noted for each stick week (i.e. fewer open flowers from lighting at 12 W/m² 1-3 weeks S.D. followed by no lighting and an increase in open flowers from lighting at 4.8 W/m² weeks 1-7 S.D. to 12 W/m²). However the differences between treatments were generally greater for plants stuck in week 45, particularly the increase in open flowers from lighting at 4.8 W/m² weeks 1-7 S.D. followed by 12 W/m² for remaining S.D.

The extent of flower development in shelf-life (as indicated by increases in number of open flowers as the shelf-life period progresses) was clearly better for pots stuck in week 40, than those stuck in week 45 or week 50. Majority of flower development was also generally confined to the first two weeks of the shelf-life period with either no change or only slight decreases in number of open flowers by week 3 of shelf-life (Note: decreases in number of open flowers were due to flower drop as plants deteriorated.)

f. Effect of combined supplementary lighting treatments on number of distorted flowers in shelf-life

Mean number of distorted flowers per pot

	4.8 W/m² throughout S.D.	**12 W/m² weeks 1-3 S.D. to unlit**	**12 W/m² weeks 1-3 S.D. to 4.8 W/m²**	**4.8 W/m² weeks 1-7 S.D. to 12 W/m²**
Week 1 (N.S.)	5.2	3.4	4.0	3.7
Week 2 (N.S.)	4.7	2.8	4.7	4.4
Week 3 (P=0.003)	4.1 a	1.5 b	4.1 a	3.1 a

L.S.D. ($P<0.05$) = 1.55 week 3

Means within rows followed by different letters differ significantly at the 5% level.

Fewer distorted flowers were recorded in shelf-life for lighting at 12 W/m² weeks 1-3 S.D. followed by no lighting. This difference was however only significant in week 3 of shelf-life. Number of distorted flowers also decreased with time indicating that distorted flowers developed into normal flowers with time or dropped off the plant.

It is noticeable that the number of distorted flowers from lighting at 12 W/m² weeks 1-3 S.D. followed by no supplementary lighting showed the biggest relative decrease with time (leading to the significant difference in week 3 of shelf-life). These figures should be considered within the context of total number of open flowers per pot (see page 31). That is, pots lit at 12 W/m² weeks 1-3 S.D. with an average of 13-15 open flowers per pot had fewer open flowers than the remaining lighting treatments with 19-24 open flowers per pot.

g. Effect of variety on number of distorted flowers in shelf-life

Mean number of distorted flowers per pot

	Charm	Yuba
Week 1 (P<0.001)	1.9 a	6.3 b
Week 2 (P<0.001)	2.5 a	5.8 b
Week 3 (P<0.001)	1.6 a	4.7 b

L.S.D. (P<0.05) = 2.05 week 1
1.20 week 2
1.04 week 3

Means within rows followed by different letters differ significantly at the 5% level.

Yuba produced significantly more distorted flowers throughout shelf-life than Charm. The incidence of distorted flowers declined with time for Yuba but increased in the middle of the shelf-life period for Charm before decreasing again.

h. Interaction of variety and combined supplementary lighting treatment on number of distorted flowers in shelf-life

Mean number of distorted flowers per pot

	4.8 W/m² throughout S.D.	12 W/m² weeks 1-3 S.D. to unlit	12 W/m² weeks 1-3 S.D. to 4.8 W/m²	4.8 W/m² weeks 1-7 S.D. to 12 W/m²
Variety: Charm				
Week 1 (N.S.)	1.7	2.0	1.9	1.9
Week 2 (N.S.)	3.0	1.8	2.3	2.9
Week 3 (P=0.003)	1.7 a	1.6 a	1.5 a	1.8 a
Variety: Yuba				
Week 1 (N.S.)	8.7	4.9	6.1	5.5
Week 2 (N.S.)	6.5	3.9	7.0	5.9
Week 3 (P=0.003)	6.5 b	1.4 a	6.7 b	4.3 b

L.S.D. ($P<0.05$) = 2.07 week 3

Mean within rows followed by different letters differ significantly at the 5% level.

The significant difference noted in section f above (page 34), where less distorted buds were associated with the lighting treatment 12 W/m² weeks 1-3 S.D. to unlit, can be attributed to differences for the variety Yuba alone. There were no significant differences in number of distorted flowers for the variety Charm relative to lighting treatment throughout the shelf-life assessment.

1.3 Compost Analyses

Since only one sample of compost was taken per plot, figures were not analysed statistically. Individual treatment results are presented in Appendix II, page 122, but figures were meaned across spacing treatments and sticking dates to give the following summaries for the two varieties.

Lighting Treatment	pH	Ec (μS)	NO_3-N (mg/l)	NH_4-N (mg/l)	P (mg/l)	K (mg/l)	Mg (mg/l)
Variety: Charm							
4.8 W/m^2 throughout S.D.	5.26	255	160	3.8	22	90	70
12 W/m^2 weeks 1-3 S.D. to unlit	5.26	227	133	3.1	22	93	59
12 W/m^2 weeks 1-3 S.D. to 4.8 W/m^2	5.27	259	150	5.1	26	93	73
4.8 W/m^2 weeks 1-7 S.D. to 12 W/m^2	5.30	215	127	2.2	18	72	55
Variety: Yuba							
4.8 W/m^2 throughout S.D.	5.53	201	113	0.8	23	68	59
12 W/m^2 weeks 1-3 S.D. to unlit	5.62	193	108	1.9	23	62	59
12 W/m^2 weeks 1-3 S.D. to 4.8 W/m^2	5.53	210	113	0.6	23	77	56
4.8 W/m^2 weeks 1-7 S.D. to 12 W/m^2	5.56	181	99	1.1	22	49	55

Very similar analytical results were found for the four lighting treatments for each variety. Nutrient uptake by Yuba was apparently higher than by Charm with slightly lower levels of nutrient within the compost after eight weeks and a corresponding increase in pH.

1.4 Summary: Combined Lighting Treatments.

Combining the standard lighting treatment of 4.8 W/m^2 throughout S.D. with an increased intensity during flower maturation (i.e. lighting at 4.8 W/m^2 weeks 1-7 S.D. followed by 12 W/m^2 remaining S.D.) did not significantly reduce total production time. Vegetative development (as indicated by plant height and pot spread) as well as flower development (as indicated by number of expanding and open buds/flowers per pot) were also not significantly affected by this increase in light intensity at the end of short days. Visual observations however indicated that increasing intensity from 4.8 W/m^2 to 12 W/m^2 from week 7 of S.D. onwards resulted in a deeper petal colour for the variety Charm. This observation was noted for pots stuck in week 40 and in week 45, but was not apparent for sticking in week 50 when background solar radiation during the flower maturation period was improving.

This improved petal colour was also noted during shelf-life assessments when petal colour was fading on remaining treatments (as it normally does for Charm during shelf-life in the winter period). There were also other apparent shelf-life improvements to supplementing 4.8 W/m^2 during S.D. with 12 W/m^2 from week 7 S.D. onwards. Notably number of open flowers was consistently higher for this treatment in shelf-life, and was significantly greater after 2 weeks in shelf-life. Pot deterioration was also apparently slightly lower for this treatment throughout shelf-life although this difference was not found to be significant.

Considerable improvements were achieved by combining the lighting treatment 12 W/m^2 during weeks 1-3 S.D. with 4.8 W/m^2 during the remaining S.D. period. These included a significant reduction in production time by an overall mean of 1.3 days, or of up to 2.7 days when comparing individual treatment means (where the greatest reduction was achieved on pots stuck in week 45).

Uniformity of plant height within a pot was significantly increased with this treatment. Flower development was also improved by combining 12 W/m^2 weeks 1-3 S.D. with 4.8 W/m^2 for remaining S.D. with increases in numbers of both developing and open buds at marketing stage 3. Foliage colour at marketing was also darker green by combining the 4.8 W/m^2 treatment with 12 W/m^2 weeks 1-3 S.D.

Shelf-life was also affected through combining 12 W/m^2 weeks 1-3 S.D. with 4.8 W/m^2 for the remaining S.D. The onset of general pot deterioration was slower and visual quality through increased number of open flowers throughout shelf-life was improved. The number of distorted flowers per pot at the end of shelf-life was however lower for the lighting treatment 12 W/m^2 weeks 1-3 only than where this treatment was combined with 4.8 W/m^2 for the remaining S.D. period. The main incidence of flower distortion (as illustrated in plate 3, Appendix IV, page 154) in shelf-life could be attributed to the variety Yuba where incidence was higher generally than that for Charm.

Combining the standard supplementary lighting treatments assessed in previous studies therefore impacted quality and production time in different ways. Overall, the best quality can be achieved through supplementary lighting throughout the S.D. period since visual quality in terms of number of flowers and colour of foliage is greater for all treatments providing lighting throughout S.D.

Combining a lower intensity for early S.D. with a higher intensity at the end of the S.D. had the additional benefit of enhancing petal colour and hence visual quality both at marketing and during shelf-life. Deterioration was also apparently slower for this treatment during shelf-life.

Combining high intensity for early S.D. only with a lower intensity for the remaining S.D. period provides the quality benefits of lighting throughout S.D. as discussed above. This provides a vast improvement in quality in comparison with lighting at 12 W/m^2 weeks 1-3 S.D. and still has the production time advantage of lighting at high intensity at the start of S.D. only.

2. The influence of standard supplementary lighting treatments on the winter quality of new varieties.

Full treatment means are recorded in Appendix I, page 85. The following key observations were noted when pots were suitable for marketing (i.e. marketing stage 3)

2.1 Vegetative development and flower production

a. Effect of standard supplementary lighting treatments on production time of Cerise About Time ($P < 0.001$)

Mean number of days from sticking to marketing stage 3.

4.8 W/m² throughout S.D.	12 W/m² weeks 1-3 S.D.	Unlit
76.8 a	75.0 b	85.1 c

L.S.D. (P=0.05) = 1.77

Means followed by different letters differ significantly at the 5% level.

Both supplementary lighting treatments significantly reduced mean production time. Lighting at 12 W/m² week 1-3 S.D. gave the fastest rate of production, saving a mean of 10.1 days over the three sticking dates in comparison with no supplementary lighting. Lighting at 4.8 W/m² throughout S.D. also gave a mean saving of 8.3 days in comparison with no lighting.

Hence as has previously been observed with both Princess Anne types (Finlay 1993) and American bred varieties (Wilson, 1994a), rate of production of Cerise About Time can be significantly reduced through the use of supplementary lighting during flower initiation.

b. Effect of standard supplementary lighting treatments on plant height of Cerise About Time (N.S.)

Mean plant height (cm)

4.8 W/m² throughout S.D.	12 W/m² weeks 1-3 S.D.	Unlit
16.2	16.2	16.2

Plant height for Cerise About Time was not influenced by the standard supplementary lighting regimes. Uniformity of plant height was also not significantly influenced by the standard supplementary lighting treatments.

c. Effect of standard supplementary lighting treatments on maximum pot spread of Cerise About Time (N.S.)

Mean maximum pot spread (cm)

4.8 W/m² throughout S.D.	12 W/m² weeks 1-3 S.D.	Unlit
33.0	32.4	31.9

The standard supplementary lighting regimes did not significantly influence maximum pot spread.

d. Effect of standard supplementary lighting treatments on minimum pot spread of Cerise About Time (N.S.)

Mean minimum pot spread (cm)

4.8 W/m² throughout S.D.	12 W/m² weeks 1-3 S.D.	Unlit
29.5	30.0	29.5

The standard supplementary lighting regimes did not significantly influence minimum pot spread.

As may be expected from the closeness of maximum and minimum pot spread figures in sections c and d above, uniformity of pot spread was also not influenced by the supplementary lighting treatments.

e. Effect of standard supplementary lighting treatments on number of expanding (N.S) and open ($P < 0.001$) buds of Cerise About Time

Mean number of buds/flowers per pot

	4.8 W/m² throughout S.D.	12 W/m² weeks 1-3 S.D.	Unlit
Stages 1-3	13.0	11.8	10.0
Stages 4+	26.1 a	15.6 b	21.5 c

L.S.D. ($P = 0.05$) = 3.32 stages 4+

Means within rows followed by different letters differ significantly at the 5 % level.

Supplementary lighting at 4.8 W/m² throughout S.D. significantly increased the number of open buds and flowers per pot compared with the unlit control. In contrast lighting at 12 W/m² weeks 1-3 S.D. only, significantly reduced the number of open buds/flowers. This conflicts with results for some American bred varieties (Finlay 1993) where lighting at 12 W/m² weeks 1-3 S.D. only produced comparable numbers of open buds/flowers to unlit treatments. A further contrast with previous studies is that no significant difference was found between treatments in numbers of developing buds (i.e stages 1-3) per pot.

In previous studies (Finlay 1993, Wilson, 1994a, 1994b) as well as in the current trial (section 1.1 above), number of developing buds per pot has been significantly increased by lighting at 4.8 W/m^2 throughout S.D. for American bred varieties compared with 12 W/m^2 weeks 1-3 S.D. alone or unlit treatments.

Neither average of maximum bud stage per pot nor uniformity of flowering (as indicated by standard deviation of average maximum bud stage of Cerise About Time); were significantly influenced by the standard supplementary lighting regimes.

f. Effect of standard supplementary lighting treatments on foliage quality of Cerise About Time (N.S.)

Mean leaf quality score

4.8 W/m^2 throughout S.D.	**12 W/m^2 weeks 1-3 S.D.**	**Unlit**
0.2	0.5	0.2

In agreement with the results from section 1 above, foliage quality score was not significantly influenced by lighting treatment and overall foliage quality was good. It was observed visually that the foliage on plants lit at 4.8 W/m^2 throughout S.D. was darker green at marketing than on those lit at 12 W/m^2 weeks 1-3 of S.D. or unlit treatments.

On the whole, Cerise About Time, as a new variety assessed against the standard supplementary lighting treatments reacted in a similar fashion to the American bred varieties previously studied. That is, both lighting at 4.8 W/m^2 throughout S.D. and at 12 W/m^2 weeks 1-3 S.D. significantly reduced total production time (by a mean of 8.3 to 10.1 days overall) with the latter treatment producing the fastest rate of production.

Visual quality was significantly improved by lighting at 4.8 W/m^2 throughout S.D. as illustrated by increases in numbers of open flowers. Lighting at 12 W/m^2 did not however increase number of buds or flowers in comparison with unlit treatments. Quality of foliage in terms of a darker green colour at marketing also resulted from lighting at 4.8 W/m^2 throughout S.D.

2.2 Shelf-life performance

a. Effect of standard supplementary lighting treatments on pot deterioration during shelf-life of Cerise About Time

Mean pot deterioration score

	4.8 W/m² throughout S.D.	12 W/m² weeks 1-3 S.D.	Unlit
Week 1 (N.S.)	0.0	0.0	0.0
Week 2 (N.S.)	0.8	1.1	1.2
Week 3 (N.S.)	2.6	2.8	3.0

The standard supplementary lighting treatments had no significant influence over pot deterioration score on any of the three assessment stages (i.e. week 1, week 2 or week 3). Change in deterioration score from week to week was not analysed statistically but it is apparent that lighting at 4.8 W/m² throughout S.D. may have given a slight advantage in shelf-life. That is, increase in deterioration score from week to week was lower for this treatment than the other two treatments assessed. All pots had high deterioration scores (maximum score = 3) by the end of the assessment period.

b. Effect of standard supplementary lighting treatments on foliage quality during shelf-life of Cerise About Time

Mean leaf damage score

	4.8 W/m² throughout S.D.	12 W/m² weeks 1-3 S.D.	Unlit
Week 1 (N.S.)	0.3	0.6	0.6
Week 2 (N.S.)	0.6	1.2	1.2
Week 3 (N.S.)	1.0	1.1	1.1

Foliage quality was also not significantly influenced by lighting treatment for any of the three assessments made. Early in the shelf-life period (i.e. week 1 and week 2) however, foliage quality was slightly improved from the lighting treatment 4.8 W/m^2 throughout S.D. This reflects the trend observed for overall pot deterioration above. Overall leaf damage score was low throughout shelf-life for all treatments since score 1 indicates minor damage only.

c. Effect of standard supplementary lighting treatments on number of open flowers in shelf-life of Cerise About Time

Mean number of flowers at stages 4 + per pot

	4.8 W/m^2 throughout S.D.	**12 W/m^2 weeks 1-3 S.D.**	**Unlit**
Week 1 (P = 0.017)	25.6 a	15.9 b	24.7 a
Week 2 (P<0.001)	29.3 a	16.6 b	27.1 a
Week 3 (P<0.001)	28.3 a	15.8 b	24.9 a

L.S.D. (P = 0.05) = 3.02 week 1
3.47 week 2
3.55 week 3

Means within each weekly assessment followed by different letters differ significantly at the 5% level.

Significant differences between lighting treatments recorded during shelf-life reflected differences recorded at marketing (as discussed previously in section 2.1.e, page 42). That is, there were significantly fewer open flowers on pots lit at 12 W/m^2 weeks 1-3 S.D. only. An increase in number of open buds from the week 1 assessment to the week 2 assessment indicates that flowers continued to open during shelf-life for all treatments. By the final assessment (i.e. week 3) however, number of open buds had dropped slightly for all treatments indicating loss of flowers on some pots.

d. Effect of standard supplementary lighting treatments on number of distorted flowers in shelf-life of Cerise About Time

Mean number of distorted flowers per pot

	4.8 W/m² throughout S.D.	12 W/m² weeks 1-3 S.D.	Unlit
Week 1 (N.S.)	0.9	0.4	0.1
Week 2 (N.S.)	0.3	0.3	0.6
Week 3 (N.S.)	0.4	1.0	0.7

Overall only a small number of flowers per pot were distorted on opening during shelf-life assessments. The number of distorted flowers during shelf-life was not influenced by lighting treatment.

2.3 Compost Analysis

Since only one sample of compost was taken per plot, figures were not analysed statistically. Individual treatment results are presented in Appendix II, page 122, but figures were meaned across sticking dates to give the following summaries for Cerise About Time.

Lighting Treatment	pH	Ec (μS)	NO_3-N (mg/l)	NH_4-N (mg/l)	P (mg/l)	K (mg/l)	Mg (mg/l)
4.8 W/m² throughout S.D.	5.37	305	176	1.1	34	86	94
12 W/m² Weeks 1-3 S.D.	5.47	253	137	0.8	34	69	81
Unlit	5.3	249	146	0.5	28	103	65

Overall, the analysis of compost samples after 8 weeks of short days produced similar results for all three treatments, with no indication of excess or deficient levels in any of the treatments. The generally higher irrigation requirement (and therefore frequency of feeding) of pots receiving supplementary lighting is reflected in the increased levels of conductivity, nitrate-nitrogen, ammonicacal-nitrogen, phosphorus and magnesium for lit treatments, particularly 4.8 W/m² throughout S.D.

2.4 Summary: New Varieties

Cerise About Time generally responded to the standard supplementary lighting regimes as may be predicted from the results of previous studies with American bred varieties. Speed of production and visual quality were both enhanced through lighting at 4.8 W/m^2 throughout short days. Speed of production was also enhanced by lighting at 12 W/m^2 weeks 1-3 of short days but this treatment had a negative impact on quality in some cases by significantly reducing number of open flowers at marketing. It was felt however that the quality of this variety may have benefitted from an increase in the long day period which will be a subject to be addressed in future work. It is possible that the response of a plant which is more mature at the start of short days may be different to the lighting treatments, particularly 12 W/m^2 weeks 1-3 S.D.

Rate of deterioration in shelf-life was not significantly influenced by lighting treatment although lighting at 4.8 W/m^2 throughout short days did appear to produce lower deterioration scores both in terms of overall pot quality and foliage quality. Assessment of flowers in shelf-life indicated that the benefits achieved through lighting at 4.8 W/m^2 throughout short days (i.e. in terms of increased number of open buds) was maintained throughout shelf-life.

3. The influence of closer pot spacings on winter quality.

Full treatment means are recorded in Appendix I, page 85. The following key observations were noted when pots were suitable for marketing (i.e. marketing stage 3).

As detailed in materials and methods above (page 13) a standard pot spacing was compared with two closer spacing treatments for the varieties Charm and Yuba under the four supplementary lighting regimes assessed. For Cerise About Time however the standard pot spacing was compared with one closer spacing treatment under the two lighting regimes assessed for this variety. For statistical analysis, it was therefore necessary to group Charm and Yuba together and assess values meaned across varieties, sticking dates and the four lighting treatments. A separate analysis was then conducted on Cerise About time for values meaned across sticking dates only.

Data will therefore be presented in separate tables in the following comparisons.

3.1 Vegetative development and flower production

a. Effect of closer pot spacings for Charm and Yuba ($P < 0.001$) and Cerise About Time ($P < 0.001$) on production time

Mean number of days from sticking to marketing stage 3

Charm & Yuba

12.5 pots/m^2	15 pots/m^2	18 pots/m^2
77.4 a	78.4 b	79.4 c

L.S.D. (P=0.05) = 0.63

Cerise About Time

4.8 W/m^2 throughout S.D.		12 W/m^2 weeks 1-3 S.D.	
12.5 pots/m^2	15 pots/m^2	12.5 pots/m^2	15 pots/m^2
76.8 a	76.9 a	75.0 b	77.1 a

L.S.D. (P= 0.05) = 1.77

Means followed by different letters differ significantly at the 5% level.

Closer pot spacings significantly delayed production of Charm and Yuba meaned across all lighting treatments. As pots were placed progressively closer, the delay increased

Cerise About Time was also significantly delayed by spacing pots at 15 per m^2 under the lighting regime 12 W/m^2 weeks 1-3 S.D. Pots lit at 4.8 W/m^2 throughout S.D. were not however delayed as a result of spacing at 15 pots per m^2 rather than 12.5 pots per m^2.

b. Interaction of supplementary lighting regime and closer pot spacings for Charm and Yuba on production time (N.S.)

Mean number of days from sticking to marketing stage 3

Charm and Yuba

Spacing	4.8 W/m² throughout S.D.	12 W/m² weeks 1-3 S.D. to unlit	12 W/m² weeks 1-3 S.D. to 4.8 W/m²	4.8 W/m² weeks 1-7 S.D. to 12 W/m²
12.5 pots/m²	78.2	77.2	76.3	78.1
15 pots/m²	79.2	78.7	77.9	77.7
18 pots/m²	80.4	79.8	77.6	79.6

It is notable that while the effect of spacing on production time was influenced by supplementary lighting regime for Cerise About Time, there was no significant interaction between these parameters for Charm and Yuba.

c. Effect of closer pot spacings for Charm and Yuba (N.S.) and Cerise About Time (N.S.) on plant height

Mean plant height (cm)

Charm and Yuba

12.5 pots/m²	15 pots/m²	18 pots/m²
17.1	16.9	16.9

Cerise About Time

4.8 W/m² throughout S.D.		12 W/m² weeks 1-3 S.D.	
12.5 pots/m²	15 pots/m²	12.5 pots/m²	15 pots/m²
16.2	16.3	16.2	15.7

Although stretching may be expected by spacing pots closer together, no significant differences were found between mean plant height figures for the spacing treatments assessed. Uniformity of plant heights within pot was also not significantly influenced by the closer spacing treatments.

d. Effects of closer pot spacings for Charm and Yuba (P= 0.002) and Cerise About Time (N.S.) on maximum pot spread

Mean maximum pot spread (cm)

Charm and Yuba

12.5 pots/m^2	15 pots/m^2	18 pots/m^2
32.3 a	31.4 b	30.7 b

L.S.D. (P=0.05) = 0.68

Means followed by different letters differ significantly at the 5% level.

Cerise About Time

4.8 W/m^2 throughout S.D.		12 W/m^2 weeks 1-3 S.D.	
12.5 pots/m^2	15 pots/m^2	12.5 pots/m^2	15 pots/m^2
33.0	32.3	32.4	31.8

Reducing pot spacing from 12.5 pots/m^2 to 15 pots/m^2 significantly reduced the maximum pot spread for the combined data from Charm and Yuba. Reducing spacing further from 15 pots/m^2 to 18 pots/m^2 did not however cause a further significant reduction in maximum spread.

Maximum pot spread for Cerise About Time was also reduced through spacing pots at 15 pots/m^2 (rather that at 12.5 pots/m^2) for both lighting treatments but this difference was not found to be significant.

e. **Effects of closer pot spacings for Charm and Yuba (P= 0.004) and Cerise About Time (N.S.) on minimum pot spread**

Mean minimum pot spread (cm)

Charm and Yuba

12.5 pots/m²	**15 pots/m²**	**18 pots/m²**
29.0 a	28.2 b	27.8 b

L.S.D. (P=0.05) = 0.64

Means followed by different letters differ significantly at the 5% level.

Cerise About Time

4.8 W/m² throughout S.D.		**12 W/m² weeks 1-3 S.D.**	
12.5 pots/m²	**15 pots/m²**	**12.5 pots/m²**	**15 pots/m²**
29.5	28.9	30.0	29.2

Minimum pot spread followed the same trend as described above for maximum pot spread. That is, closer pot spacing resulted in a reduction in minimum pot spread but this difference was only statistically significant for the combined spacing from Charm and Yuba. Reducing spacing again from 15 pots/m² to 18 pots/m² again did not cause a further significant reduction in minimum pot spread.

Uniformity of pot spread was not significantly influenced by spacing.

f. Effects of closer pot spacings on number of developing ($P < 0.01$) and open ($P = 0.003$) buds/flowers for Charm and Yuba and number of developing (N.S.) and open ($P < 0.001$) buds/flowers for Cerise About Time

Mean number of buds/flowers per pot

Charm and Yuba

	12.5 pots/m^2	15 pots/m^2	18 pots/m^2
Stages 1-3	24.5 a	22.1 b	20.9 b
Stages 4+	18.7 a	18.1 a	16.4 b

L.S.D. (P=0.05) = 2.13 Stages 1-3
1.17 Stages 4+

Cerise About Time

	4.8 W/m^2 throughout S.D.		12 W/m^2 weeks 1-3 S.D.	
	12.5 pots/m^2	15 pots/m^2	12.5 pots/m^2	15 pots/m^2
Stages 1-3	13.0	12.0	11.8	9.6
Stages 4+	26.1 a	22.2 b	15.6 c	13.9 c

L.S.D. (P=0.05) = 3.32 stages 4+

Means within rows followed by different letters differ significantly at the 5 % level.

Closer pot spacings significantly reduced the number of buds/flowers in comparison with standard spacing under supplementary lighting. For Charm and Yuba, the number of developing buds was significantly reduced by spacing at 15 pots/m^2 compared with 12.5 pots/m^2. There was however no further significant reduction for spacing even closer at 18 pots/m^2 although the relevant mean figure was reduced. The number of open flowers on Charm and Yuba however was only significantly reduced by spacing at 18 pots/m^2 (i.e. the closest spacing treatment).

Similar trends were observed for Cerise About Time under the two standard supplementary lighting regimes. Differences in numbers of developing buds for this variety were not however significant and the number of open flowers was only significantly reduced by closer spacing (i.e. 15 pots/m^2) in combination with the supplementary lighting treatment 4.8 W/m^2 throughout S.D.

There was no significant interaction between supplementary lighting and spacing for the varieties Charm and Yuba. Hence, the increased light energy supplied via the combined supplementary lighting treatments in comparison with the standard supplementary lighting did not (as hoped) compensate for the increased light competition associated with closer pot spacing.

g. **Effects of closer pot spacings on average of maximum bud stage per pot for Charm and Yuba (P=0.002) and Cerise About Time (N.S.)**

Mean of maximum bud stage per pot

Charm and Yuba

12.5 pots/m^2	15 pots/m^2	18 pots/m^2
7.3 a	7.2 a	7.0 b

L.S.D. (P=0.05) = 0.16

Means followed by different letters differ significantly at the 5% level.

Cerise About Time

4.8 W/m^2 throughout S.D.		12 W/m^2 weeks 1-3 S.D.	
12.5 pots/m^2	15 pots/m^2	12.5 pots/m^2	15 pots/m^2
7.4	7.4	7.7	7.5

Closer pot spacings combined with the four supplementary lighting treatments assessed for Charm and Yuba, significantly reduced average maximum bud stage at marketing stage 3. Only the closest spacing treatment caused a significant response. This reflects the delay in production time resulting from closer spacing (Section 3.1.a, page 48). Cerise About Time was not however significantly influenced by spacing in terms of average maximum bud stage.

h. Effects of closer pot spacings on uniformity of flowering of Charm and Yuba (P=0.002) and Cerise About Time (N.S.)

Uniformity of flowering was assessed in terms of standard deviation of maximum bud stage across the five plants in a pot. A small standard deviation figure indicates a more uniform pot.

Standard deviation of maximum bud stage per pot

Charm and Yuba

12.5 pots/m²	**15 pots/m²**	**18 pots/m²**
1.45 a	1.60 a	1.76 b

L.S.D. (P=0.05) = 0.147

Means followed by different letters differ significantly at the 5% level.

Cerise About Time

4.8 W/m² throughout S.D.		**12 W/m² weeks 1-3 S.D.**	
12.5 pots/m²	**15 pots/m²**	**12.5 pots/m²**	**15 pots/m²**
1.40	1.40	1.25	1.56

Flowering uniformity was significantly reduced by spacing pots at 18 pots/m² but was not reduced at 15 pots/m² compared with 12.5 pots/m² (or standard spacing) for Charm and Yuba. Flowering uniformity of Cerise About Time was also not significantly influenced by spacing at 15 pots/m² compared with 12.5 pots/m², the standard deviation of maximum bud stage was however slightly higher for this closer spacing treatment when combined with lighting at 12 W/m² weeks 1-3 S.D.

i. **Effects of closer pot spacings on foliage quality of Charm and Yuba (N.S.) and Cerise About Time (N.S.)**

Mean leaf quality score

Charm and Yuba

12.5 pots/m^2	15 pots/m^2	18 pots/m^2
0.8	0.8	0.8

Cerise About Time

4.8 W/m^2 throughout S.D.		12 W/m^2 weeks 1-3 S.D.	
12.5 pots/m^2	15 pots/m^2	12.5 pots/m^2	15 pots/m^2
0.2	0.4	0.5	0.5

Closer pot spacings did not, as anticipated, significantly reduce leaf quality, assessed as severity of leaf damage/disease. There were also no obvious differences in leaf colour due to closer spacing treatments.

3.2 Shelf-life performance

a. Effect of closer pot spacings for Charm and Yuba, and Cerise About Time on pot deterioration during shelf-life

Mean pot deterioration score

Charm and Yuba

	12.5 pots/m²	15 pots/m²	18 pots/m²
Week 1 (N.S.)	0.4	0.4	0.4
Week 2 (N.S.)	1.2	1.1	1.2
Week 3 (N.S.)	2.2	2.1	2.0

Cerise About Time

	4.8 W/m² throughout S.D.		12 W/m² weeks 1-3 S.D.	
	12.5 pots/m²	15 pots/m²	12.5 pots/m²	15 pots/m²
Week 1 (N.S.)	0.0	0.0	0.0	0.3
Week 2 (N.S.)	0.8	0.7	1.1	1.1
Week 3 (N.S.)	2.6	2.8	2.8	2.7

Closer pot spacings did not significantly influence the rate of pot deterioration during shelf-life.

b. Effect of closer pot spacings for Charm and Yuba, and Cerise About Time on foliage quality during shelf-life

Mean leaf damage score

Charm and Yuba

	12.5 pots/m^2	15 pots/m^2	18 pots/m^2
Week 1 (N.S.)	1.0	1.0	1.0
Week 2 (N.S.)	1.3	1.3	1.3
Week 3 (N.S.)	1.5	1.4	1.4

Cerise About Time

	4.8 W/m^2 throughout S.D.		12 W/m^2 weeks 1-3 S.D.	
	12.5 pots/m^2	15 pots/m^2	12.5 pots/m^2	15 pots/m^2
Week 1 (N.S.)	0.3	0.8	0.6	0.7
Week 2 (N.S.)	0.6	0.9	1.1	0.8
Week 3 (N.S.)	1.0	1.0	1.1	1.0

Closer pot spacings did not significantly influence foliage quality during shelf-life.

c. Effect of closer pot spacings for Charm and Yuba, and Cerise About Time on number of open flowers during shelf-life

Mean number of flowers at stages 4+ per pot

Charm and Yuba

	12.5 pots/m^2	15 pots/m^2	18 pots/m^2
Week 1 (P = 0.013)	19.8 a	18.8 ab	18.2 b
Week 2 (P = 0.023)	21.0 a	19.8 ab	19.3 b
Week 3 (P = 0.041)	21.0 a	19.9 ab	19.4 b

L.S.D. (P = 0.05) = 1.31 week 1
1.50 week 2
1.54 week 3

Cerise About Time

	4.8 W/m^2 throughout S.D.		12 W/m^2 weeks 1-3 S.D.	
	12.5 pots/m^2	15 pots/m^2	12.5 pots/m^2	15 pots/m^2
Week 1 (P<0.001)	25.6 a	23.4 a	15.9 b	13.0 b
Week 2 (P<0.001)	29.3 a	25.2 b	16.6 c	14.4 c
Week 3 (P<0.001)	28.3 a	23.9 b	15.8 c	14.4 c

L.S.D. (P = 0.05) =3.02 week 3
3.47 week 2
3.55 week 3

Means within each weekly assessment followed by different letters differ significantly at the 5% level.

Number of open buds per pot throughout shelf-life reflected trends noted from marketing records. That is, results for Charm and Yuba indicate a progressive decrease in number of open buds as spacing density increases. Some opening of buds (as indicated by an increase in the number of buds at stages 4+) was recorded for all treatments during shelf-life.

For the variety Cerise About Time, number of open buds per pot was only significantly decreased by closer spacing in combination with the lighting treatment 4.8 W/m^2 throughout S.D. It should be noted however that the closest spacing treatment for Cerise About Time was 15 pots/m^2, compared with 18 pots/m^2 for Charm and Yuba. Changes in number of open buds per pot from week to week indicated some opening of buds for all treatments with perhaps the greatest increase resulting from lighting at 4.8 W/m^2 throughout S.D combined with standard spacing (12.5 pots/m^2).

d. Interaction between closer pot spacings and sticking date for Cerise About Time on number of open flowers during shelf-life

There was no significant interaction between closer pot spacing and sticking date for Charm and Yuba. The following therefore represents data for Cerise About Time only.

Mean number of flowers at stages 4+ per pot

	4.8 W/m² throughout S.D.		12 W/m² weeks 1-3 S.D.	
	12.5 pots/m²	15 pots/m²	12.5 pots/m²	15 pots/m²
Week 1 Assessment				
Week 40	15.0 a	11.3 ac	16.7 a	12.7 a
Week 45	28.7 bd	24.3 b	13.7 a	7.8 c
Week 50	33.0 d	34.7 d	17.3 a	18.7 a
Week 2 Assessment				
Week 40	26.0 a	17.0 bc	20.3 ab	17.0 bc
Week 45	29.0 ad	23.3 a	12.0 c	7.7 c
Week 50	33.0 d	35.3 d	17.3 bc	18.7 b
Week 3 Assessment				
Week 40	24.0 a	16.3 b	19.0 ab	17.0 b
Week 45	29.0 ad	22.3 bd	11.3 bc	7.3 c
Week 50	32.0 d	33.0 d	17.0 b	19.0 ab

L.S.D. (P = 0.05) = 5.24 week 1
6.02 week 2
6.15 week 3

Means within each weekly assessment followed by different letters differ significantly at the 5% level.

While there was no significant difference between spacing treatments combined with lighting at 12 W/m² weeks 1-3 S.D. for data meaned across sticking weeks (section c above), differences were observed for individual sticking weeks. In particular, closer spacing (15 pots/m²) combined with 12 W/m² resulted in significantly fewer open buds per pot for plants stuck in week 45 for the first two weeks of shelf-life. Overall, although not always statistically significant, pots stuck in week 40 and week 45 (and therefore developing flowers in the poorest ambient light levels) had lower numbers of open flowers per pot, due to closer pot spacing, throughout shelf-life.

Differences in number of open buds per pot due to spacing combined with lighting at 4.8 W/m^2 throughout S.D., were generally as observed for the meaned data above (section c). It is again apparent however that closer pot spacing had a greater impact on number of open buds during shelf-life for the earlier sticking dates (i.e. week 40 and week 45) when flower development occurred under poorer ambient light levels.

e. **Effect of closer pot spacings for Charm and Yuba, and Cerise About Time on number of distorted flowers during shelf-life**

Mean number of distorted flowers per pot

Charm and Yuba

	12.5 pots/m^2	**15 pots/m^2**	**18 pots/m^2**
Week 1 (N.S.)	4.5	3.6	4.1
Week 2 (N.S.)	4.0	4.1	4.3
Week 3 (N.S.)	3.1	3.3	3.2

Cerise About Time

	4.8 W/m^2 throughout S.D.		**12 W/m^2 weeks 1-3 S.D.**	
	12.5 pots/m^2	**15 pots/m^2**	**12.5 pots/m^2**	**15 pots/m^2**
Week 1 (N.S.)	0.9	0.9	0.4	0.6
Week 2 (N.S.)	0.3	1.2	0.3	0.2
Week 3 (N.S.)	0.4	1.3	1.0	0.1

The number of distorted flowers developing during shelf-life was not significantly influenced by spacing treatment.

3.3 Compost Analyses

Since only one sample of compost was taken per plot, figures were not analysed statistically. Individual treatment results are presented in Appendix II, page 122, but figures were meaned across lighting treatments and sticking dates to give the following summaries.

Spacing Treatment	pH	Ec (μS)	NO_3-N (mg/l)	NH_4-N (mg/l)	P (mg/l)	K (mg/l)	Mg (mg/l)
Variety: Charm							
12.5 pots/m^2	5.27	238	143	3.0	22	89	64
15 pots/m^2	5.28	247	145	1.4	21	92	65
18 pots/m^2	5.21	241	143	4.0	23	99	63
Variety: Yuba							
12.5 pots/m^2	5.49	212	117	1.9	26	68	64
15 pots/m^2	5.54	200	109	0.9	22	70	57
18 pots/m^2	5.54	205	117	0.8	22	78	58
Variety: Cerise About Time							
12.5 pots/m^2	5.35	300	168	1.0	35	96	92
15 pots/m^2	5.33	290	161	4.3	35	96	88

Closer spacing treatments did not appear to effect the analytical results of compost samples meaned across sticking week and lighting treatments.

3.4 Summary: Closer Pot Spacing

In agreement with observations made on closer pot spacings in the HDC funded trial PC92 (Wilson, 1994), it would appear that closer pot spacings may successfully be combined with supplementary lighting regimes as a means of reducing the cost of lighting per pot. The financial benefits (Appendix III, page 131) however need to be balanced against the physiological effects of closer spacing. Total production time will be slightly increased (by approximately 1-2 days) and in addition, quality will be reduced due to a less spread out plant with fewer open flowers and poorer uniformity of flowering. The majority of these changes, although statistically significant, are generally small, particularly if the 15 pots/m^2 spacing is considered rather than 18 pots/m^2. It should be emphasized that all closer spacing treatments were combined with supplementary lighting for at least part of the S.D. period. In addition, comments received from growers viewing plants stuck in weeks 45 and 50 indicated that they were small overall. Closer spacings would clearly have a greater impact on quality for plants growing more vigorously. It is hoped that this will be pursued further through future studies.

By combining the spacing treatments with all the supplementary lighting treatments, it was possible to investigate whether increasing the light input to the crop may reduce the negative impact which was found between the four lighting regimes assessed and spacing treatment. It was not however possible to compare closer spacings on unlit crops where a significant interaction may be more likely to occur. This again will hopefully be pursued in future studies.

4. The influence of wider spacing for unlit pots on winter quality

Full treatment means are recorded in Appendix I, page 85. The following key observations were noted when pots were suitable for marketing (i.e marketing stage 3)

4.1 Vegetative development and flower production

For the purposes of statistical analyses, Charm and Yuba were grouped together for one analysis and Cerise About Time formed a separate analysis. The following results are therefore grouped into separate variety types in order to separate the individual probability and L.S.D. figures.

a. Effect of wider spacing for unlit pots on production time

Mean number of days from sticking to marketing stage 3

	Standard Spacing	Wider Spacing
Charm (N.S.)	81.3	81.7
Yuba (N.S.)	84.7	83.8
Cerise About Time ($P<0.001$)	85.1 a	80.9 b

L.S.D. ($P= 0.05$) = 1.77

Mean values within rows followed by different letters differ significantly at the 5% level.

Moving pots to final spacing directly from pot thick after one week of short days (i.e. wider spacing) had no significant influence on the production time of Charm and Yuba. The production time of Cerise About Time was however significantly reduced (by a mean of 4.2 days) through the wider spacing treatment. It is clear from the individual treatment means in Table 1 (Appendix I, pages 86-88) that differences in production time for Cerise About Time were greatest for pots stuck in week 45 where the production time for unlit pots was also the longest.

b. Effect of wider spacing for unlit pots on plant height

Mean plant height (cm)

	Standard Spacing	Wider Spacing
Charm (N.S.)	15.8	14.5
Yuba (N.S.)	17.2	16.7
Cerise About Time (N.S.)	16.2	15.5

Although there were no significant differences in plant height between the two spacing treatments for each variety, the mean plant height from the wider spacing treatment was slightly shorter throughout. This is reflected in the individual treatment means in Table 2, Appendix I, (pages 89 to 91) where in general wider spaced pots were also shorter. There was no significant interaction between sticking date and wider spacing treatment.

c. Effect of wider spacing for unlit pots on maximum pot spread

Maximum plant spread (cm)

	Standard Spacing	Wider Spacing
Charm (N.S.)	31.1	30.0
Yuba (N.S.)	31.2	32.1
Cerise About Time (N.S.)	31.9	31.3

There were no significant differences between the two spacing treatments in terms of maximum pot spread. There was also no significant interaction between sticking date and wider spacing.

d. Effect of wider spacing for unlit pots on minimum pot spread

Minimum pot spread (cm)

	Standard Spacing	Wider Spacing
Charm (N.S.)	27.6	27.1
Yuba (N.S.)	28.3	28.1
Cerise About Time (N.S.)	29.5	29.0

Minimum pot spread was not significantly influenced by the wider spacing treatment which agrees with maximum pot spread results. There was also no significant interaction between sticking week and the wider spacing treatment. It is not surprising therefore that uniformity of pot spread was also not influenced by the wider spacing treatment.

e. Effect of wider spacing for unlit pots on number of expanding and open buds

Number of buds/flowers per pot

	Standard Spacing	Wider Spacing
Charm		
Stages 1-3 (N.S.)	19.9	16.0
Stages 4+ (N.S.)	11.7	12.1
Yuba		
Stages 1-3 (N.S.)	20.4	17.2
Stages 4+ (N.S.)	14.2	15.8
Cerise About Time		
Stages 1-3 (N.S.)	10.0	9.2
Stages 4+ (N.S.)	21.5	20.7

Neither the number of developing buds (i.e. bud stages 1-3) nor the number of open buds/flowers (i.e. bud stages 4+) were significantly influenced by the wider spacing treatment. This is reflected by the individual treatment means in Table 6, Appendix I, pages 101 to 103. There was no significant interaction between sticking date and the wider spacing treatment. Uniformity of flowering was also not influenced by the wider spacing treatment.

f. Effect of wider spacing for unlit pots on foliage quality

Mean leaf damage score

	Standard Spacing	Wider Spacing
Charm (N.S.)	0.5	0.4
Yuba (N.S.)	1.2	1.0
Cerise About Time (N.S.)	0.2	0.4

The wider spacing treatment had no significant influence on the foliage quality of the three varieties assessed. There was also no significant interaction between the wider spacing treatment and sticking date.

4.2 Shelf-life Performance

a. Effect of wider spacing for unlit pots on pot deterioration during shelf-life

Mean pot deterioration score

	Standard Spacing	Wider Spacing
Charm		
Week 1 (N.S.)	0.0	1.3
Week 2 (N.S.)	1.2	1.3
Week 3 (N.S.)	2.3	2.1
Yuba		
Week 1 (N.S.)	0.9	1.2
Week 2 (N.S.)	1.4	1.2
Week 3 (N.S.)	2.7	2.1
Cerise About Time		
Week 1 (N.S.)	0.0	0.3
Week 2 (N.S.)	1.2	1.3
Week 3 (N.S.)	3.0	2.2

The wider spacing treatment did not significantly influence overall pot deterioration in shelf-life. All varieties deteriorated at a similar rate as indicated by the increase in deterioration score from week to week.

b. Effect of wider spacing for unlit pots on foliage quality during shelf-life

Mean leaf damage score

	Standard Spacing	Wider Spacing
Charm		
Week 1 (N.S.)	0.6	0.6
Week 2 (N.S.)	1.0	1.0
Week 3 (N.S.)	1.0	1.0
Yuba		
Week 1 (N.S.)	1.8	1.9
Week 2 (N.S.)	1.5	1.9
Week 3 (N.S.)	2.1	2.0
Cerise About Time		
Week 1 (N.S.)	0.6	0.3
Week 2 (N.S.)	1.2	0.8
Week 3 (N.S.)	1.1	0.9

Foliage quality, as indicated by the leaf damage score, was not significantly influenced by the wider spacing treatment. Leaf damage score generally increased with length of time in shelf-life although changes from week to week were small overall.

c. Effect of wider spacing for unlit pots on number of open flowers in shelf-life

Mean number of flowers at stages 4+ per pot

	Standard Spacing	Wider Spacing
Charm		
Week 1 (N.S.)	14.0	13.1
Week 2 (N.S.)	16.0	14.3
Week 3 (N.S.)	15.4	14.4
Yuba		
Week 1 (P = 0.017)	17.4 a	13.0 b
Week 2 (N.S.)	19.6	16.7
Week 3 (N.S.)	18.9	16.6
Cerise About Time		
Week 1 (P <0.001)	24.7 a	20.3 b
Week 2 (P<0.001)	27.1 a	21.8 b
Week 3 (N.S.)	24.9	21.7

L.S.D. (P = 0.05) = 3.02 week 1
3.47 week 2

Mean values within rows followed by by different letters differ significantly at the 5% level.

In agreement with the number of open buds recorded at marketing stage 3 above (section 4.1.e, page 65), there was no significant difference in number of open buds during shelf-life for Charm due to the wider spacing treatment. There was also little change in the number of open buds of Charm from week to week in shelf-life.

Although there were apparently more open buds on Yuba at the start of shelf-life (week 1) due to the standard spacing treatment, there were no significant differences due to wider spacing over subsequent weeks. It should be noted that overall Yuba was more difficult to maintain in shelf-life with a heavy infestation of sciarid lavae particularly on the pots in shelf-life which were stuck in week 40. It was therefore necessary to dispose of a large number of pots before completion of shelf-life records and hence the data may be unreliable due to the small sample size remaining.

There were also significantly fewer open buds during shelf-life associated with the wider spacing treatment with the variety Cerise About Time. This difference occurred in the first two shelf-life assessments (i.e. weeks 1 and 2) but not in the final assessment (week 3).

d. Interaction of sticking date and wider spacing for unlit pots on number of open flowers in shelf-life

Mean number of flowers at stages 4+ per pot

	Standard Spacing	Wider Spacing
Charm - Stick Week 40		
Week 1 (N.S.)	10.7	10.7
Week 2 (N.S.)	12.3	11.7
Week 3 (N.S.)	12.7	11.7
Charm - Stick Week 45		
Week 1 (N.S.)	12.7	10.7
Week 2 (N.S.)	13.0	10.3
Week 3 (N.S.)	13.0	11.0
Charm - Stick Week 50		
Week 1 (N.S.)	18.7	18.0
Week 2 (N.S.)	22.7	21.0
Week 3 (N.S.)	20.7	20.7
Yuba - Stick Week 40		
Week 1 (N.S.)	15.0	11.3
Week 2 (N.S.)	17.0	14.0
Week 3 (N.S.)	20.0	14.3
Yuba - Stick Week 45		
Week 1 (N.S.)	14.0	10.3
Week 2 (N.S.)	16.0	13.0
Week 3 (N.S.)	16.0	13.0
Yuba - Stick Week 50		
Week 1 (N.S.)	23.3	17.3
Week 2 (N.S.)	25.7	23.0
Week 3 (N.S.)	20.7	22.3
Cerise About Time - Stick Week 40		
Week 1 ($P<0.001$)	23.0 a	15.7 b
Week 2 ($P<0.01$)	24.0 a	20.0 b
Week 3 (N.S.)	21.0	18.7
Cerise About Time - Stick Week 45		
Week 1 ($P<0.001$)	20.3 a	14.7 b
Week 2 ($P<0.001$)	23.0 a	14.7 b
Week 3 (N.S.)	19.7	14.7
Cerise About Time - Stick Week 50		
Week 1 ($P<0.001$)	30.7 c	30.7 c
Week 2 ($P<0.001$)	34.3 c	30.7 c
Week 3 (N.S.)	34.0	31.7

LSD. ($P=0.05$) = 5.24 week 1
6.02 week 2

Mean values within rows followed by different letters differ significantly at the 5% level.

A significant interaction was noted between number of open buds during shelf-life and sticking date for the variety Cerise About Time. In agreement with the data meaned across sticking dates in section c above (page 68), pots stuck in week 40 and week 45 had significantly fewer open buds from the wider spacing treatment at both the week 1 and week 2 shelf-life assessments. There was, however, no significant difference between the two treatments for pots suck in week 50 at any of the shelf-life assessments.

e. Effect of wider spacing for unlit pots on number of distorted flowers in shelf-life

Mean number of distorted flowers per pot

	Standard Spacing	**Wider Spacing**
Charm		
Week 1 (N.S.)	2.0	2.7
Week 2 (N.S.)	1.6	2.8
Week 3 (N.S.)	1.0	2.0
Yuba		
Week 1 (N.S.)	3.6	5.2
Week 2 (N.S.)	2.5	3.9
Week 3 (N.S.)	2.2	3.4
Cerise About Time		
Week 1 (N.S.)	0.1	1.1
Week 2 (N.S.)	0.6	0.7
Week 3 (N.S.)	0.7	0.3

The wider spacing treatment had no significant influence on the number of distorted flowers during shelf-life.

4.3 Compost Analyses

Since only one sample of compost was taken per plot, figures were not analysed statistically. Individual treatment results are presented in Appendix II, page 122, but figures were meaned across sticking dates to give the following summaries for the three varieties.

Spacing Treatment	pH	Ec (μS)	NO_3-N (mg/l)	NH_4-N (mg/l)	P (mg/l)	K (mg/l)	Mg (mg/l)
Charm							
Standard	5.3	218	130	0.4	22	79	57
Wide	5.4	189	111	0.4	19	76	50
Yuba							
Standard	5.4	179	98	0.6	21	62	51
Wide	5.5	184	107	0.6	20	67	50
Cerise About Time							
Standard	5.3	249	146	0.5	28	103	65
Wide	5.4	231	125	0.8	29	70	70

There was no apparent consistent trend in nutrient levels due to the wider spacing treatment. The majority of the figures were very similar for the two spacings for each variety. There were some differences in conductivity (Ec) and nitrate-nitrogen (NO_3-N) figures but while they are higher for the standard spacing for Charm and Cerise About Time, the opposite occurred for Yuba.

4.4 Summary: Wider Spacing for Unlit Pots

Overall, the wider spacing treatment had very little impact on the three varieties either at marketing or during shelf-life. The aim of this treatment was to improve pot quality by increasing space and therefore light through adapting current practices. That is instead of moving pots from pot thick to intermediate spacing and then final spacing, pots were kept closer together (i.e. pot thick) for the first week of short days and then moved directly to final spacing.

Hence, for the second week of short days, pots in the wider spacing treatment should have received more light during at least part of the period of bud initiation. This had little impact overall, however, and did not improve visual quality as indicated by the number of developing and open buds/flowers and foliage quality results. Foliage colour was also not apparently influenced by this treatment.

Slight differences in number of open flowers recording during shelf-life was also in favour of the standard spacing treatment. There was therefore clearly no benefit from this particular treatment over the winter period for the three varieties assessed. This may in part be because plants grown without supplementary lighting at standard spacing were generally quite small and may not have been suffering a great deal from light competition with their neighbours. In such a situation, wider spacing may not be expected to be beneficial. Furthermore, the nature of the wider spaicng treatment meant that pots were actually spaced closer together than the standard spacing during the first week of short days. If this had created light competition early on, it may have detracted from any benefits acheived through then later placing the pots at a wider spaicng.

5. The influence of negative DIF combined with supplementary lighting on winter quality

Full treatment means are recorded in Appendix I, page 85. The following key observations were noted when pots were suitable for marketing (i.e. marketing stage 3).

5.1 Vegetative development and flower production

As discussed above (section 3, page 47), results from Charm and Yuba were analysed separately from Cerise About Time for statistics. The varieties will therefore be presented accordingly in the following tables. Length of production time and number of developing (i.e. stages 1-3) and open (i.e. stages 4+) buds/flowers were not significantly influenced by the negative DIF treatment combined with lighting at 12 W/m^2 for the first three weeks of S.D. The main effects of this treatment are described below.

a. Effect of negative DIF combined with supplementary lighting on plant height of Charm and Yuba (P = 0.007) and Cerise About Time (N.S.)

Charm and Yuba

standard temperature	negative DIF
16.9 a	16.1 b

L.S.D. (P = 0.05) = 0.586

Cerise About Time

standard temperature	negative DIF
15.9	15.5

Means followed by different letters differ significantly at the 5% level.

For data meaned across the three sticking dates and the two varieties Charm and Yuba, plants grown in standard temperature regimes using standard chemical plant growth regulators were significantly taller than those grown using DIF alone to control plant height. For Cerise About Time, there was no significant difference between plant height achieved using standard chemical plant growth regulators and standard temperature and using negative DIF to control height.

b. Interaction between sticking date and negative DIF combined with supplementary lighting on plant height of Charm and Yuba (P = 0.001) and Cerise About Time (N.S.)

Mean plant height (cm)

Charm and Yuba

stick week	standard temperature	negative DIF
40	16.6 a	17.4 a
45	17.4 a	15.1 b
50	16.8 a	15.8 b

L.S.D. (P = 0.05) = 1.02

Cerise About Time

stick week	standard temperature	negative DIF
40	16.3	16.5
45	15.0	14.6
50	16.6	15.3

Means followed by different letters differ significantly at the 5% level.

A significant interaction was recorded between sticking date and the negative DIF regime on plant height. That is, negative DIF was insufficient for plants stuck in week 40 to achieve equivalent height control to that using B-nine on plants grown under a standard temperature regime. For plants stuck in week 45 and 50 however, plants grown using negative DIF were the shortest. This would coincide with the falling external temperatures and hence greater ability to keep compartment temperatures low throughout the day.

c. **Effect of negative DIF combined with supplementary lighting on uniformity of plant height of Charm and Yuba ($P < 0.001$) and Cerise About time ($P = 0.043$)**

Standard deviation of plant height

Charm and Yuba

standard temperature	negative DIF
1.74 a	1.37 b

L.S.D. ($P = 0.05$) = 0.170

Cerise About Time

standard temperature	negative DIF
1.61 a	1.31 b

Means within rows followed by different letters differ significantly at the 5% level.

All varieties were significantly more uniform, in terms of height differences between the five plants in a pot, where negative DIF had been used.

d. Effect of negative DIF combined with supplementary lighting on maximum pot spread of Charm and Yuba (P = 0.017) and Cerise About Time (N.S.)

Mean maximum pot spread (cm)

Charm and Yuba

standard temperature	negative DIF
30.9 a	30.0 b

L.S.D. (P = 0.05) = 0.747

Cerise About Time

standard temperature	negative DIF
32.1	32.2

Means followed by different letters differ significantly at the 5% level.

Negative DIF was significantly more effective at reducing maximum pot spread of Charm and Yuba than standard temperature combined with treatment with daminozide to control plant height. For Cerise About Time however comparable maximum pot spread was acheived with both regimes.

Minimum pot spread however was not significantly influenced by negative DIF for any of the varieties assessed.

e. **Effect of negative DIF combined with supplementary lighting on uniformity of flowering for Charm and Yuba (P = 0.21) and Cerise About Time (N.S.)**

Standard deviation of maximum bud stage per pot

Charm and Yuba

standard temperature	negative DIF
1.72 a	1.52 b

L.S.D. (P = 0.05) = 0.16

Cerise About Time

standard temperature	negative DIF
1.40	1.35

Means followed by different letters differ significantly at the 5% level.

The uniformity of flower development across the five plants in a pot was improved for Charm and Yuba with negative DIF.

5.2 Shelf-life performance

There were no significant differences recorded between pots grown at standard temperature (i.e. 18/18 °C day/night) and those grown under the negative DIF regime (16/20 °C day/night) when combined with lighting at 12 W/m^2 weeks 1-3 S.D. only. All treatments and varieties showed signs of deterioration (as indicated by deterioration score in Table 9, Appendix I, pages 110 to 112) as length of time in shelf-life increased and flowers continued to open (as indicated by the number of flowers at stages 4 and over in Table 11, Appendix I, pages 116 to 118). There were however no obvious differences in rate of change of these parameters related to treatments imposed.

5.3 Compost Analyses

Since only one sample of compost was taken per plot, figures were not analysed statistically. Individual treatment results are presented in Appendix II, page 122, but figures were meaned across sticking dates to give the following summaries for the three varieties.

Temperature Regime	pH	Ec (μS)	NO_3-N (mg/l)	NH_4-N (mg/l)	P (mg/l)	K (mg/l)	Mg (mg/l)
Variety: Charm							
Standard	5.26	227	133	3.1	22	93	59
Negative DIF	5.14	263	153	0.8	23	120	63
Variety: Yuba							
Standard	5.62	193	108	1.9	23	62	59
Negative DIF	5.39	254	146	2.1	27	105	74
Variety: Cerise About Time							
Standard	5.42	275	151	2.8	35	83	85
Negative DIF	5.28	370	199	2.0	44	125	118

Mean compost analysis figures indicate that higher levels of major nutrients remained in pots grown in a DIF regime than under standard temperature control. This may be a reflection of the reduced rate of growth overall due to the lower daytime temperatures.

5.4 Summary: Negative DIF combined with lighting at 12 W/m^2 weeks 1-3 S.D.

Negative DIF was clearly successful at controlling plant height when combined with supplementary lighting at 12 W/m^2 weeks 1-3 S.D. Looking at interactions between sticking date and negative DIF treatment it is apparent that for earlier sticking dates, when it is difficult to achieve compartment temperatures as low as 16 °C throughout the day time, there may be the requirement for a reduced input from chemical plant growth regulators. Negative DIF was however sufficiently effective in controlling the height of plants from later sticking dates under the environmental conditions of the winter 1994/95 period that additional chemical plant growth regulation was unnecessary.

The negative DIF treatment had the additional benefit of improving pot uniformity in terms of height of plants in a pot and stage of maturity of flowers. Other quality parameters such as number of buds/flowers and extent of leaf damage were not significantly affected by the negative DIF treatment. Foliage colour was lighter as a result of the negative DIF treatment which had been noted in previous trials. Foliage colour does however improve after removing plants from the negative DIF regime.

These findings are largely in agreement with the HDC funded trial on DROP treatments at HRI Efford over the winter 1993/94 period (Wilson, 1994b). That is, control of plant height may be achieved through the manipulation of temperature regimes when using standard supplementary lighting regimes with little impact on the benefits achieved using lights. Negative DIF over the winter 1994/95 period was more successfully at controlling plant height than temperature DROP was over the winter 1993/94 period.

6. Economic evaluation

A full breakdown of the calculations used to assign a cost to each treatment is presented in Appendix III, page 131. Costs were calculated for each combination of lighting and spacing treatment assessed. In addition, two different sets of assumptions regarding capital costs, electricity charges, etc. were compared to give both a comparison with original costings calculated in the final report for PC13b (Finlay, 1993) and figures updated for current charges. A summary of the costings is presented in Table 1, page 80.

It is immediately clear from the summary table that the assumptions made on common costs such as capital for lamps etc. are very important to the final figure. In this example costs were approximately 23% lower for the updated assumptions. This equates to 2.0 to 6.1 p/pot lower cost depending on the lighting and spacing treatment in question. This underlines the importance of calculating costs according to individual circumstances since even the updated assumed figures are averages for the UK and will vary in each case.

Lighting treatments as expected also influenced cost. The most expensive treatments, unsurprisingly, are those where lights are used throughout short days. Combining the 4.8 W/m^2 regime with the 12 W/m^2 regime (i.e. for lighting treatments 3 and 4) produced similar total costs regardless of whether the higher intensity lighting was giving at the start or the end of short days. The cost of providing the combined lighting treatments was on average 33% higher than for providing 4.8 W/m^2 lighting throughout short days.

Increasing the density of pots from 12.5 pots/m^2 to 15 pots/m^2 decreased the cost of lighting by approximately 17%, regardless of lighting regime. This equates to savings of 1.6 to 4.7 p/pot, depending on lighting treatment and basic cost assumptions. Increasing the density of pots even further from 12.5 pots/m^2 to 18 pots/m^2, reduced the cost of lighting by 31% or 3.0 to 8.3 p/pot depending on lighting treatment and basic cost assumptions.

It should be stressed that all of the costs presented represent the cost of providing the supplementary lighting alone. Individual costs for labour, materials etc. would be constant, regardless of lighting treatment, and should be added onto the appropriate lighting cost (calculated as mentioned above, according to individual circumstances). The quality benefits resulting from lighting treatments, weighted against the slight negative impact of closer spacing would have to be balanced against the price premium that may be achieved for enhanced quality over the winter period. Increase in the speed of production (and hence number of pots produced per m^2 annually) through the use of supplementary lighting, enhanced shelf-life quality (for some treatments) and the maintenance of a position within the market place on a year-round basis are other positive aspects to be considered against the increased cost of production. Energy savings on heating will also result from using supplementary lighting since the radiant energy emitted from lamps will reduce the amount of heating required to achieve set point temperatures.

Table 1 Overall cost of treatments

	Cost (p/pot) Capital		Running		Total	
1. 4.8 W/m² throughout S.D. (i.e. 10 weeks)						
Standard spacing (24 pots/m² wks 1-2, 12.5 pots/m² wks 3+)	7.7*	*(6.6)°*	12.1*	*(8.6)°*	19.8*	*(15.2)°*
Close spacing 1 (30 pots/m² wks 1-2, 15 pots/m² wks 3+)	6.4	*(5.5)*	10.1	*(7.1)*	16.5	*(12.6)*
Close spacing 2 (36 pots/m² wks 1-2, 18 pots/m² wks 3+)	5.3	*(4.6)*	8.3	*(5.9)*	13.6	*(10.5)*
2. 12 W/m² weeks 1-3 S.D.						
Standard spacing (24 pots/m² wks 1-2, 12.5 pots/m² wks 3+)	4.5	*(3.9)*	7.2	*(5.1)*	11.7	*(9.0)*
Close spacing 1 (30 pots/m² wks 1-2, 15 pots/m² wks 3+)	3.6	*(3.2)*	5.8	*(4.2)*	9.4	*(7.4)*
Close spacing 2 (36 pots/m² wks 1-2, 18 pots/m² wks 3+)	3.0	*(2.6)*	5.3	*(3.4)*	8.3	*(6.0)*
3. 12 W/m² weeks 1-3 S.D. to 4.8 W/m² weeks 4-9 S.D.						
Standard spacing (24 pots/m² wks 1-2, 12.5 pots/m² wks 3+)	10.2	*(8.8)*	16.2	*(11.5)*	26.4	*(20.3)*
Close spacing 1 (30 pots/m² wks 1-2, 15 pots/m² wks 3+)	8.4	*(7.3)*	13.3	*(9.5)*	21.7	*(16.8)*
Close spacing 2 (36 pots/m² wks 1-2, 18 pots/m² wks 3+)	7.0	*(6.0)*	11.1	*(7.8)*	18.1	*(13.8)*
4. 4.8 W/m² weeks 1-7 S.D. to 12 W/m² weeks 8-9 S.D.						
Standard spacing (24 pots/m² wks 1-2, 12.5 pots/m² wks 3+)	10.2	*(8.8)*	16.1	*(11.4)*	26.3	*(20.2)*
Close spacing 1 (30 pots/m² wks 1-2, 15 pots/m² wks 3+)	8.5	*(7.3)*	13.5	*(9.4)*	22.0	*(16.7)*
Close spacing 2 (36 pots/m² wks 1-2, 18 pots/m² wks 3+)	7.1	*(6.1)*	11.1	*(7.9)*	18.2	*(14.0)*

*Represents figures based on assumptions of capital costs, running costs and interest rates calculated for the 1991/92 HDC funded work.

° Represents figures based on assumptions of capital costs, running costs and interest rates current in early 1995. (see page 133 for further details of costings).

DISCUSSION

Comparisons of standard and 'combined' supplementary lighting regimes has indicated that while high intensity lighting during bud initiation only, increases rate of production, it does not enhance quality. Supplying a similar amount of supplementary light (i.e. 12 W/m^2) at the end of short days did improve quality in terms of enhanced petal colour for Charm. However the combined lighting treatment which supplied 12 W/m^2 at the end of short days, also supplied lighting at 4.8 W/m^2 during weeks 1-7 of short days. It is therefore not clear how much of the quality improvement achieved would have been achieved through lighting at 12 W/m^2 at the end of short days only. The enhanced petal colour achieved through lighting at 12 W/m^2 at the end of short days, also lasted into the shelf-life period when colour quickly faded from the petals of the other treatments assessed. Since shelf-life is becoming an increasingly important consideration for pot plants, with the multiples now providing shelf life guarantees in some cases, this enhanced visual pleasure in shelf-life may prove important.

By combining the standard lighting treatment of 12 W/m^2 weeks 1-3 of short days with lighting at 4.8 W/m^2 for the remaining short day period (i.e. the second combined lighting treatment), significant improvements in quality were achieved in comparison with lighting at 12 W/m^2 weeks 1-3 S.D. alone. In comparison with lighting at 4.8 W/m^2 throughout short days however, the higher intensity lighting during bud initiation (provided by the combined treatment), did not significantly improve plant quality. The speed of production was significantly improved by a mean of 1.9 days overall for this combined lighting treatment in comparison with lighting at 4.8 W/m^2 throughout short days. This equates to savings of 0 to 4.5 days on individual treatment means with the greatest reductions occurring for plants stuck in week 45 and grown during the lowest period of background solar radiation levels. A smaller mean decrease of 1.3 days overall was achieved through this combined lighting treatment in comparison with lighting at 12 W/m^2 during weeks 1-3 of short days only. This equates to savings of 0 to 5.1 days on individual treatment means, again the greater savings on individual treatment means were produced by this treatment for pots stuck in week 45.

When examining the economic costings, it can be seen that the combined lighting treatments are 33% higher (for providing the lighting alone) than the most expensive of the standard treatments (i.e. lighting at 4.8 W/m^2 throughout short days). It is possible that the treatment which combines lighting at 4.8 W/m^2 during weeks 1-7 of short days with 12 W/m^2 for remaining short days, may be able to justify these additional costs due to the potential for being able to meet the terms of shelf-life guarantees (or at least provide a stronger marketing position where such guarantees are in operation). The combined lighting treatment of 12 W/m^2 during weeks 1-3 of short days to 4.8 W/m^2 for remaining short days did not however produce a significant improvement in quality in comparison with the less expensive treatment of 4.8 W/m^2 throughout

short days. There was some indication that pot deterioration was slightly slower as a result of this combined lighting treatment but it seems unlikely that this small difference would justify the increase in cost. The reductions in rate of production time would therefore have to be assessed for their value to individual cases to determine if the extra cost of this particular combined lighting treatment may be justified.

Assessment of Cerise About Time under standard lighting treatments reflects the results discussed above. That is, better quality was achieved through lighting at 4.8 W/m^2 throughout short days than at 12 W/m^2 for weeks 1-3 of short days only. Unfortunately it was not possible under the scope of this trial to assess this variety under the combined lighting treatments discussed above, but results indicate that it responds in a similar way to the American bred varieties tested in previous work. Since petal colour was generally paler than expected for this variety under the treatments assessed it is likely that the combined lighting treatment of 4.8 W/m^2 during weeks 1-7 of short days followed by 12 W/m^2 for the remaining short days may be particularly beneficial for Cerise About Time.

In agreement with observations in earlier studies, it is apparent that when supplementary lighting is supplied, closer pot spacings may be achieved with only a small penalty in terms of quality and speed of production. The potential for employing closer spacings will depend on the vigour of the variety and individual growing environments as well as the marketing specification in question since plant spread in particular is effected and apparently directly related to pot spacings (within the limits of extremes). Given comments mentioned previously on vigour of the plants in the current trial, it will be useful to continue investigating spacing over different winter periods (and hence background environmental conditions) when plant vigour may vary.

The wider spacing treatment for unlit pots provided no consistent improvements in plant quality compared with standard spacing. This treatment clearly did not, as hoped, provide any of the benefits associated with any of the supplementary lighting treatments assessed.

Reductions in plant height were successfully achieved using negative DIF in combination with supplementary lighting at 12 W/m^2 during weeks 1-3 of short days, without any obvious penalties in terms of pot quality. This result reinforces the findings of previous studies (Wilson, 1994b) where a temperature DROP combined with the same lighting regime produced reductions in plant height. The negative DIF treatment was however more effective than the DROP treatment assessed previously and may prove a useful substitute for chemical plant growth regulators during periods of the winter when it is possible to achieve the required lower temperature within the glasshouse. During periods of the winter when these lower temperatures are difficult to achieve throughout the day, reductions in inputs of chemical plant growth regulators at least would still be possible.

CONCLUSIONS

This study has illustrated that :

- Combinations of the standard supplementary lighting regimes identified in previous trials may successfully be used to produce benefits in terms of either quality or rate of production, depending on the combination in question. Specific benefits need to be assessed against the extra cost of providing these treatments.

- Concentrating supplementary lighting over the period of flower initiation alone is insufficient to produce any benefits in terms of plant quality. Lighting during the later stages of short days is clearly necessary to achieve quality benefits.

- The variety Cerise About Time benefits from the standard supplementary lighting regimes in a similar way to that noted for both Princess Anne types and American bred varieties.

- Closer pot spacing does provide a means of reducing costs per pot for supplementary lighting and may be achieved with minimal disadvantages in terms of quality and rate of production. Pot quality at the closest spacing treatment assessed was still superior to that of standard spacing where no supplementary lighting was provided.

- Increasing pot spacing during the second week of short days only (i.e. the wider spacing treatment) was insufficient to reproduce the types of benefits achieved through supplementary lighting.

- Negative DIF may successfully be combined with supplementary lighting at 12 W/m^2 during weeks 1-3 of short days to reduce plant height with no impact on the benefit of this lighting treatment.

RECOMMENDATIONS FOR FURTHER WORK

Marketing of pot mums over the winter period is becoming increasingly competitive against other pot plants such as begonias and hence the requirement for top grade quality as well as good postharvest life are becoming of greater importance.

Results from the above trial as well as from the HDC funded trial PC 104 (on AYR spray chrysanthemums) conducted at HRI Efford over the winter 1994/95 period have indicated the value of concentrating supplementary lighting at the end of the short day period alone. Results have indicated that such a treatment may benefit the flower quality in particular and prolong visual pleasure during shelf-life. Such a treatment would have the added benefit of reducing the cost of supplementary lighting per pot in terms of running costs and also capital costs since more crops could be treated with the same set of lamps. Intensity and length of lighting period are both subjects which require investigation in relation to lighting at the end of short days alone.

Alternative methods of further improving winter quality should also be persued. Research on spray chrysanthemums in Holland has indicated that delaying maturity through increasing daylength during the short day period may enhance quality through increasing the total period of assimilation for each crop. This research has concentrated on the use of supplementary lighting to produce the extended daylengths since natural daylength during the winter period falls below even the 11 hours photoperiod normally given during the generative phase of growth. It may also be possible to achieve quality benefits by increasing photoperiod through the use of tungsten lighting which would be more economical than supplementary lighting. Extended daylengths should therefore be compared using both the standard supplementary lighting regimes already in commercial use in the UK as well as under ambient daylight conditions (i.e. no supplementary lighting) using tungsten lighting.

It would also be valuable to continue with observations on closer pot spacings on pots receiving lighting as well as those grown in natural daylight. The interaction of closer spacing with plant vigour due to varietal differences as well environmental conditions can therefore be examined.

APPENDIX I

TABLES OF TREATMENT MEANS

Table 1a: **The Influence of Supplementary Lighting, Spacing and Negative DIF Treatments on Length of Production Time**

Variety: Charm

Number of days from sticking to marketing stage 3

Lighting Treatment	Sticking Week	Spacing a	Spacing b	Spacing c	Spacing d	Mean
1	40	73.2	76.4	76.1		75.2
	45	80.3	80.2	82.0		80.8
	50	77.5	77.6	80.4		78.5
Mean		*77.0*	*78.1*	*79.5*		*78.2*
2	40	74.0	76.7	76.1		75.6
	45	78.6	74.6	82.9		78.7
	50	75.7	76.0	77.0		76.2
Mean		*76.1*	*75.8*	*78.7*		*76.8*
3	40	73.7	75.5	75.0		74.7
	45	75.9	79.6	77.8		77.8
	50	75.2	75.7	76.7		75.9
Mean		*74.9*	*76.9*	*76.5*		*76.1*
4	40	75.2	75.2	78.9		76.4
	45	78.7	79.5	81.4		79.9
	50	77.8	76.8	77.0		77.2
Mean		*77.2*	*77.2*	*79.1*		*77.8*
5	40	76.1	77.0	81.7		78.3
	45	77.1	81.2	81.3		79.9
	50	76.6	77.3	77.3		77.1
Mean		*76.6*	*78.5*	*80.1*		*78.4*
6	40	77.0			80.3	78.7
	45	84.0			84.2	84.1
	50	82.9			80.6	81.8
Mean		*81.3*			*81.7*	*81.5*

Lighting Treatments:

1. 4.8 W/m^2 throughout S.D. (18/18°C)
2. 12 W/m^2 weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m^2 weeks 1-3 S.D. to 4.8 W/m^2 to marketing (18/18°C)
4. 4.8 W/m^2 weeks 1-7 S.D. to 12 W/m^2 to marketing (18/18°C)
5. 12 W/m^2 weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit (18/18°C)

Spacing Treatments:

a. 24 pots/m^2 weeks 1-2 S.D. to 12.5 pots/m^2 weeks 3 + S.D.
b. 30 pots/m^2 weeks 1-2 S.D. to 15 pots/m^2 weeks 3 + S.D.
c. 36 pots/m^2 weeks 1-2 S.D. to 18 pots/m^2 weeks 3 + S.D.
d. 24 pots/m^2 weeks 1 S.D. to 12.5 pots/m^2 weeks 2 + S.D.

Table 1b: **The Influence of Supplementary Lighting, Spacing and Negative DIF Treatments on Length of Production Time**

Variety: Yuba

Number of days from sticking to marketing stage 3

Lighting Treatment	Sticking Week	Spacing a	Spacing b	Spacing c	Spacing d	Mean
1	40	78.5	79.9	81.9		80.1
	45	82.5	83.0	83.0		82.8
	50	77.0	77.8	78.8		77.9
Mean		*79.3*	*80.2*	*81.2*		*80.3*
2	40	77.4	81.1	80.9		79.8
	45	81.7	81.9	83.5		82.4
	50	75.8	76.3	78.6		76.9
Mean		*78.3*	*79.8*	*81.0*		*79.7*
3	40	77.5	77.6	77.4		77.5
	45	79.6	81.7	81.8		81.0
	50	75.7	77.2	77.0		76.6
Mean		*77.6*	*78.8*	*78.7*		*78.4*
4	40	80.3	78.2	79.7		79.4
	45	80.3	78.5	81.5		80.1
	50	76.5	78.1	79.0		77.9
Mean		*79.0*	*78.3*	*80.1*		*79.1*
5	40	75.8	78.9	80.1		78.3
	45	78.8	80.7	82.3		80.6
	50	76.3	79.4	79.5		78.4
Mean		*77.0*	*79.7*	*80.6*		*79.1*
6	40	86.1			82.5	84.3
	45	83.8			86.1	85.0
	50	80.5			82.8	81.7
Mean		*83.5*			*83.8*	*83.7*

Lighting Treatments:

1. 4.8 W/m^2 throughout S.D. (18/18°C)
2. 12 W/m^2 weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m^2 weeks 1-3 S.D. to 4.8 W/m^2 to marketing (18/18°C)
4. 4.8 W/m^2 weeks 1-7 S.D. to 12 W/m^2 to marketing (18/18°C)
5. 12 W/m^2 weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit (18/18°C)

Spacing Treatments:

a. 24 pots/m^2 weeks 1-2 S.D. to 12.5 pots/m^2 weeks 3 + S.D.
b. 30 pots/m^2 weeks 1-2 S.D. to 15 pots/m^2 weeks 3 + S.D.
c. 36 pots/m^2 weeks 1-2 S.D. to 18 pots/m^2 weeks 3 + S.D.
d. 24 pots/m^2 weeks 1 S.D. to 12.5 pots/m^2 weeks 2 + S.D.

Table 1c: **The Influence of Supplementary Lighting, Spacing and Negative DIF Treatments on Length of Production Time**

Variety: Cerise About Time

Number of days from sticking to marketing stage 3

Lighting Treatment	Sticking Week	Spacing a	Spacing b	Spacing c	Spacing d	Mean
1	40	76.1	76.2			76.2
	45	80.1	79.3			79.7
	50	74.3	75.2			74.8
Mean		*76.8*	*76.9*			*76.9*
2	40	74.0	75.8			74.9
	45	78.9	81.4			80.2
	50	72.0	74.1			73.1
Mean		*75.0*	*77.1*			*76.1*
3	40					
	45					
	50					
Mean						
4	40					
	45					
	50					
Mean						
5	40	71.0	75.4			73.2
	45	78.0	81.2			79.6
	50	74.5	75.0			74.8
Mean		*75.0*	*77.2*			*75.9*
6	40	85.2			80.5	82.9
	45	90.1			82.0	86.1
	50	80.1			80.3	80.2
Mean		*85.1*			*80.9*	*83.1*

Lighting Treatments:

1. 4.8 W/m^2 throughout S.D. (18/18°C)
2. 12 W/m^2 weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m^2 weeks 1-3 S.D. to 4.8 W/m^2 to marketing (18/18°C)
4. 4.8 W/m^2 weeks 1-7 S.D. to 12 W/m^2 to marketing (18/18°C)
5. 12 W/m^2 weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit (18/18°C)

Spacing Treatments:

a. 24 pots/m^2 weeks 1-2 S.D. to 12.5 pots/m^2 weeks 3 + S.D.
b. 30 pots/m^2 weeks 1-2 S.D. to 15 pots/m^2 weeks 3 + S.D.
c. 36 pots/m^2 weeks 1-2 S.D. to 18 pots/m^2 weeks 3 + S.D.
d. 24 pots/m^2 weeks 1 S.D. to 12.5 pots/m^2 weeks 2 + S.D.

Table 2a: **The Influence of Supplementary Lighting, Spacing and Negative DIF Treatments on Plant Height**

Variety: Charm

Plant height (cm)

Lighting Treatment	Sticking Week	Spacing a	Spacing b	Spacing c	Spacing d	Mean
1	40	14.5	15.9	14.8		15.1
	45	16.4	15.9	17.0		16.4
	50	14.7	15.4	14.8		15.0
Mean		*15.2*	*15.7*	*15.5*		*15.5*
2	40	15.5	15.5	14.8		15.3
	45	17.5	16.3	15.8		16.5
	50	17.0	16.7	15.0		16.2
Mean		*16.7*	*16.2*	*15.2*		*16.0*
3	40	16.3	15.5	17.6		16.5
	45	18.1	17.5	18.1		17.9
	50	16.4	15.6	15.2		15.7
Mean		*16.9*	*16.2*	*17.0*		*16.7*
4	40	16.0	15.4	15.5		15.6
	45	16.5	15.2	16.1		15.9
	50	14.1	15.0	14.6		14.6
Mean		*15.5*	*15.2*	*15.4*		*15.4*
5	40	16.7	14.1	14.5		15.1
	45	14.2	14.1	12.7		13.7
	50	14.9	13.8	16.2		15.0
Mean		*15.3*	*14.0*	*14.5*		*14.6*
6	40	14.1			13.4	13.8
	45	15.8			15.8	15.8
	50	17.6			14.0	15.8
Mean		*15.8*			*14.4*	*15.1*

Lighting Treatments:

1. 4.8 W/m^2 throughout S.D. (18/18°C)
2. 12 W/m^2 weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m^2 weeks 1-3 S.D. to 4.8 W/m^2 to marketing (18/18°C)
4. 4.8 W/m^2 weeks 1-7 S.D. to 12 W/m^2 to marketing (18/18°C)
5. 12 W/m^2 weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit (18/18°C)

Spacing Treatments:

a. 24 pots/m^2 weeks 1-2 S.D. to 12.5 pots/m^2 weeks 3 + S.D.
b. 30 pots/m^2 weeks 1-2 S.D. to 15 pots/m^2 weeks 3 + S.D.
c. 36 pots/m^2 weeks 1-2 S.D. to 18 pots/m^2 weeks 3 + S.D.
d. 24 pots/m^2 weeks 1 S.D. to 12.5 pots/m^2 weeks 2 + S.D.

Table 2b: **The Influence of Supplementary Lighting, Spacing and Negative DIF Treatments on Plant Height**

Variety: Yuba

Plant height (cm)

Lighting Treatment	Sticking Week	Spacing a	Spacing b	Spacing c	Spacing d	Mean
1	40	17.3	17.5	19.9		18.2
	45	18.7	17.6	17.7		18.0
	50	16.2	17.4	17.2		16.9
Mean		*17.4*	*17.5*	*18.3*		*17.7*
2	40	18.1	17.8	18.2		18.0
	45	18.8	17.8	18.2		18.3
	50	18.4	17.2	16.5		17.4
Mean		*18.4*	*17.6*	*17.6*		*17.9*
3	40	20.6	19.7	17.7		19.3
	45	18.4	18.3	18.5		18.4
	50	18.4	18.5	17.3		18.1
Mean		*19.1*	*18.8*	*17.8*		*18.6*
4	40	18.3	18.5	18.9		18.6
	45	18.0	18.8	19.6		18.8
	50	16.6	17.1	17.5		17.1
Mean		*17.6*	*18.1*	*18.7*		*18.2*
5	40	20.5	19.2	19.4		19.7
	45	16.9	16.7	16.0		16.5
	50	15.7	16.9	17.3		16.6
Mean		*17.7*	*17.6*	*17.6*		*17.6*
6	40	17.0			16.9	17.0
	45	17.2			18.1	17.7
	50	17.3			15.0	16.2
Mean		*17.2*			*16.7*	*17.0*

Lighting Treatments:

1. 4.8 W/m^2 throughout S.D. (18/18°C)
2. 12 W/m^2 weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m^2 weeks 1-3 S.D. to 4.8 W/m^2 to marketing (18/18°C)
4. 4.8 W/m^2 weeks 1-7 S.D. to 12 W/m^2 to marketing (18/18°C)
5. 12 W/m^2 weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit (18/18°C)

Spacing Treatments:

a. 24 pots/m^2 weeks 1-2 S.D. to 12.5 pots/m^2 weeks 3 + S.D.
b. 30 pots/m^2 weeks 1-2 S.D. to 15 pots/m^2 weeks 3 + S.D.
c. 36 pots/m^2 weeks 1-2 S.D. to 18 pots/m^2 weeks 3 + S.D.
d. 24 pots/m^2 weeks 1 S.D. to 12.5 pots/m^2 weeks 2 + S.D.

Table 2c: **The Influence of Supplementary Lighting, Spacing and Negative DIF Treatments on Plant Height**

Variety: Cerise About Time

Plant height (cm)

Lighting Treatment	Sticking Week	Spacing a	Spacing b	Spacing c	Spacing d	Mean
1	40	16.0	16.9			16.5
	45	17.0	15.8			16.4
	50	15.6	16.3			16.0
Mean		*16.2*	*16.3*			*16.3*
2	40	16.2	16.4			16.3
	45	15.9	14.0			15.0
	50	16.6	16.6			16.6
Mean		*16.2*	*15.7*			*16.0*
3	40					
	45					
	50					
Mean						
4	40					
	45					
	50					
Mean						
5	40	17.2	15.7			16.5
	45	14.8	14.4			14.6
	50	15.3	15.3			15.3
Mean		*15.8*	*15.1*			*15.5*
6	40	16.8			14.8	15.8
	45	15.6			14.6	15.1
	50	16.1			17.2	16.7
Mean		*16.2*			*15.5*	*15.9*

Lighting Treatments:

1. 4.8 W/m^2 throughout S.D. (18/18°C)
2. 12 W/m^2 weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m^2 weeks 1-3 S.D. to 4.8 W/m^2 to marketing (18/18°C)
4. 4.8 W/m^2 weeks 1-7 S.D. to 12 W/m^2 to marketing (18/18°C)
5. 12 W/m^2 weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit (18/18°C)

Spacing Treatments:

a. 24 pots/m^2 weeks 1-2 S.D. to 12.5 pots/m^2 weeks 3 + S.D.
b. 30 pots/m^2 weeks 1-2 S.D. to 15 pots/m^2 weeks 3 + S.D.
c. 36 pots/m^2 weeks 1-2 S.D. to 18 pots/m^2 weeks 3 + S.D.
d. 24 pots/m^2 weeks 1 S.D. to 12.5 pots/m^2 weeks 2 + S.D.

Table 3a: **The Influence of Supplementary Lighting, Spacing and Negative DIF Treatments on Maximum Pot Spread**

Variety: Charm

Maximum pot spread (cm)

Lighting Treatment	Sticking Week	Spacing a	Spacing b	Spacing c	Spacing d	Mean
1	40	34.0	34.1	30.6		32.9
	45	32.7	31.5	31.7		32.0
	50	29.8	31.1	30.0		30.3
Mean		*32.2*	*32.2*	*30.8*		*31.7*
2	40	30.9	31.0	29.2		30.4
	45	32.4	29.9	28.4		30.2
	50	30.8	29.0	28.1		29.3
Mean		*31.4*	*30.0*	*28.6*		*30.0*
3	40	34.3	30.9	33.0		32.7
	45	32.1	30.4	32.4		31.6
	50	29.6	29.8	29.6		29.7
Mean		*32.0*	*30.4*	*31.7*		*31.3*
4	40	32.2	31.5	29.5		31.1
	45	34.3	32.1	32.0		32.8
	50	30.2	30.1	28.8		29.7
Mean		*32.2*	*31.2*	*30.1*		*31.2*
5	40	33.0	29.7	29.2		30.6
	45	29.9	30.0	28.4		29.4
	50	28.4	27.5	28.9		28.3
Mean		*30.4*	*29.1*	*28.8*		*29.4*
6	40	31.2			29.8	30.5
	45	30.9			31.4	31.2
	50	31.3			28.7	30.0
Mean		*31.1*			*30.0*	*30.6*

Lighting Treatments:

1. 4.8 W/m^2 throughout S.D. (18/18°C)
2. 12 W/m^2 weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m^2 weeks 1-3 S.D. to 4.8 W/m^2 to marketing (18/18°C)
4. 4.8 W/m^2 weeks 1-7 S.D. to 12 W/m^2 to marketing (18/18°C)
5. 12 W/m^2 weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit (18/18°C)

Spacing Treatments:

a. 24 pots/m^2 weeks 1-2 S.D. to 12.5 pots/m^2 weeks 3 + S.D.
b. 30 pots/m^2 weeks 1-2 S.D. to 15 pots/m^2 weeks 3 + S.D.
c. 36 pots/m^2 weeks 1-2 S.D. to 18 pots/m^2 weeks 3 + S.D.
d. 24 pots/m^2 weeks 1 S.D. to 12.5 pots/m^2 weeks 2 + S.D.

Table 3b: **The Influence of Supplementary Lighting, Spacing and Negative DIF Treatments on Maximum Pot Spread**

Variety: Yuba

Maximum pot spread (cm)

Lighting Treatment	Sticking Week	Spacing a	Spacing b	Spacing c	Spacing d	Mean
1	40	34.6	32.8	33.4		33.6
	45	33.1	31.0	31.4		31.8
	50	30.7	31.2	30.2		30.7
Mean		*32.8*	*31.7*	*31.7*		*32.0*
2	40	32.9	32.1	32.1		32.4
	45	32.2	30.5	32.0		31.6
	50	31.8	31.9	31.2		31.6
Mean		*32.3*	*31.5*	*31.8*		*31.9*
3	40	33.9	35.7	31.9		33.8
	45	33.6	30.6	30.1		31.4
	50	32.1	30.6	29.1		30.6
Mean		*33.2*	*32.3*	*30.4*		*31.9*
4	40	32.2	32.0	31.5		31.9
	45	33.4	33.7	31.4		32.8
	50	30.7	30.8	30.9		30.8
Mean		*32.1*	*32.2*	*31.3*		*31.8*
5	40	35.8	31.1	30.5		32.5
	45	30.1	30.6	29.4		30.0
	50	28.9	29.5	28.8		29.1
Mean		*31.6*	*30.4*	*29.6*		*30.5*
6	40	32.5			32.1	32.3
	45	30.4			32.6	31.5
	50	30.8			31.7	31.3
Mean		*31.2*			*32.1*	*31.7*

Lighting Treatments:

1. 4.8 W/m^2 throughout S.D. (18/18°C)
2. 12 W/m^2 weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m^2 weeks 1-3 S.D. to 4.8 W/m^2 to marketing (18/18°C)
4. 4.8 W/m^2 weeks 1-7 S.D. to 12 W/m^2 to marketing (18/18°C)
5. 12 W/m^2 weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit (18/18°C)

Spacing Treatments:

a. 24 pots/m^2 weeks 1-2 S.D. to 12.5 pots/m^2 weeks 3 + S.D.
b. 30 pots/m^2 weeks 1-2 S.D. to 15 pots/m^2 weeks 3 + S.D.
c. 36 pots/m^2 weeks 1-2 S.D. to 18 pots/m^2 weeks 3 + S.D.
d. 24 pots/m^2 weeks 1 S.D. to 12.5 pots/m^2 weeks 2 + S.D.

Table 3c: **The Influence of Supplementary Lighting, Spacing and Negative DIF Treatments on Maximum Pot Spread**

Variety: Cerise About Time

Maximum pot spread (cm)

Lighting Treatment	Sticking Week	Spacing a	Spacing b	Spacing c	Spacing d	Mean
1	40	33.9	34.0			34.0
	45	33.6	32.3			33.0
	50	31.7	30.5			31.1
Mean		*33.1*	*32.3*			*32.7*
2	40	33.2	31.8			32.5
	45	31.6	31.0			31.3
	50	32.5	32.7			32.6
Mean		*32.4*	*31.8*			*32.1*
3	40					
	45					
	50					
Mean						
4	40					
	45					
	50					
Mean						
5	40	35.9	33.7			34.8
	45	32.1	30.7			31.4
	50	30.4	30.5			30.5
Mean		*32.8*	*31.6*			*32.2*
6	40	33.4			31.9	32.7
	45	31.3			31.0	31.2
	50	31.1			32.1	31.6
Mean		*31.9*			*31.7*	*31.8*

Lighting Treatments:

1. 4.8 W/m^2 throughout S.D. (18/18°C)
2. 12 W/m^2 weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m^2 weeks 1-3 S.D. to 4.8 W/m^2 to marketing (18/18°C)
4. 4.8 W/m^2 weeks 1-7 S.D. to 12 W/m^2 to marketing (18/18°C)
5. 12 W/m^2 weeks 1-3 S.D. to unlit (i6/20°C)
6. Unlit (18/18°C)

Spacing Treatments:

a. 24 pots/m^2 weeks 1-2 S.D. to 12.5 pots/m^2 weeks 3 + S.D.
b. 30 pots/m^2 weeks 1-2 S.D. to 15 pots/m^2 weeks 3 + S.D.
c. 36 pots/m^2 weeks 1-2 S.D. to 18 pots/m^2 weeks 3 + S.D.
d. 24 pots/m^2 weeks 1 S.D. to 12.5 pots/m^2 weeks 2 + S.D.

Table 4a: **The Influence of Supplementary Lighting, Spacing and Negative DIF Treatments on Minimum Pot Spread**

Variety: Charm

Minimum pot spread (cm)

Lighting Treatment	Sticking Week	Spacing a	Spacing b	Spacing c	Spacing d	Mean
1	40	29.7	31.2	27.9		29.6
	45	30.5	28.0	28.1		28.9
	50	26.8	27.8	27.3		27.3
Mean		*29.0*	*29.0*	*27.8*		*28.6*
2	40	28.1	26.9	25.9		27.0
	45	29.9	27.5	26.1		27.8
	50	28.2	25.9	26.4		26.8
Mean		*28.7*	*26.8*	*26.1*		*27.2*
3	40	30.7	27.5	30.1		29.4
	45	29.1	28.5	29.1		28.9
	50	26.5	26.7	27.6		26.9
Mean		*28.8*	*27.6*	*28.9*		*28.4*
4	40	28.9	27.8	27.4		28.0
	45	31.0	29.9	29.3		30.1
	50	27.0	27.7	26.6		27.1
Mean		*29.0*	*28.5*	*27.8*		*28.4*
5	40	29.9	26.2	25.9		27.3
	45	28.0	27.1	25.7		26.9
	50	25.7	24.8	26.6		25.7
Mean		*27.9*	*26.0*	*26.1*		*26.6*
6	40	27.7			27.0	27.4
	45	27.5			28.2	27.9
	50	27.5			26.3	26.9
Mean		*27.6*			*27.2*	*27.4*

Lighting Treatments:

1. 4.8 W/m^2 throughout S.D. (18/18°C)
2. 12 W/m^2 weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m^2 weeks 1-3 S.D. to 4.8 W/m^2 to marketing (18/18°C)
4. 4.8 W/m^2 weeks 1-7 S.D. to 12 W/m^2 to marketing (18/18°C)
5. 12 W/m^2 weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit (18/18°C)

Spacing Treatments:

a. 24 pots/m^2 weeks 1-2 S.D. to 12.5 pots/m^2 weeks 3 + S.D.
b. 30 pots/m^2 weeks 1-2 S.D. to 15 pots/m^2 weeks 3 + S.D.
c. 36 pots/m^2 weeks 1-2 S.D. to 18 pots/m^2 weeks 3 + S.D.
d. 24 pots/m^2 weeks 1 S.D. to 12.5 pots/m^2 weeks 2 + S.D.

Table 4b: **The Influence of Supplementary Lighting, Spacing and Negative DIF Treatments on Minimum Pot Spread**

Variety: Yuba

Minimum pot spread (cm)

Lighting Treatment	Sticking Week	Spacing a	Spacing b	Spacing c	Spacing d	Mean
1	40	30.9	30.0	30.8		30.6
	45	29.7	27.5	26.5		27.9
	50	28.0	27.4	27.7		27.7
Mean		*29.5*	*28.3*	*28.3*		*28.7*
2	40	28.9	29.2	28.3		28.8
	45	29.6	27.5	28.1		28.4
	50	27.1	27.9	27.1		27.4
Mean		*28.5*	*28.2*	*27.8*		*28.2*
3	40	30.2	31.2	30.1		30.5
	45	30.1	27.8	27.1		28.3
	50	28.6	26.7	26.4		27.2
Mean		*29.6*	*28.6*	*27.9*		*28.7*
4	40	29.3	28.9	27.4		28.5
	45	29.5	30.0	28.7		29.4
	50	29.3	27.6	28.3		28.4
Mean		*29.4*	*28.8*	*28.1*		*28.8*
5	40	31.8	27.5	27.6		29.0
	45	28.4	27.9	26.7		27.7
	50	27.5	26.7	26.6		26.9
Mean		*29.2*	*27.4*	*27.0*		*27.9*
6	40	29.8			28.1	29.0
	45	27.6			28.0	27.8
	50	27.6			28.2	27.9
Mean		*28.3*			*28.1*	*28.2*

Lighting Treatments:

1. 4.8 W/m^2 throughout S.D. (18/18°C)
2. 12 W/m^2 weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m^2 weeks 1-3 S.D. to 4.8 W/m^2 to marketing (18/18°C)
4. 4.8 W/m^2 weeks 1-7 S.D. to 12 W/m^2 to marketing (18/18°C)
5. 12 W/m^2 weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit (18/18°C)

Spacing Treatments:

a. 24 pots/m^2 weeks 1-2 S.D. to 12.5 pots/m^2 weeks 3 + S.D.
b. 30 pots/m^2 weeks 1-2 S.D. to 15 pots/m^2 weeks 3 + S.D.
c. 36 pots/m^2 weeks 1-2 S.D. to 18 pots/m^2 weeks 3 + S.D.
d. 24 pots/m^2 weeks 1 S.D. to 12.5 pots/m^2 weeks 2 + S.D.

Table 4c: **The Influence of Supplementary Lighting, Spacing and Negative DIF Treatments on Minimum Pot Spread**

Variety: Cerise About Time

Minimum pot spread (cm)

Lighting Treatment	Sticking Week	Spacing a	Spacing b	Spacing c	Spacing d	Mean
1	40	30.8	30.6			30.7
	45	29.4	28.4			28.9
	50	28.4	27.7			28.1
Mean		*29.5*	*28.9*			*29.2*
2	40	30.4	29.3			29.9
	45	30.2	28.9			29.6
	50	29.3	29.5			29.4
Mean		*30.0*	*29.2*			*29.6*
3	40					
	45					
	50					
Mean						
4	40					
	45					
	50					
Mean						
5	40	32.6	30.7			31.7
	45	28.6	27.7			28.2
	50	27.8	27.4			27.6
Mean		*29.7*	*28.6*			*29.2*
6	40	30.9			28.7	29.8
	45	29.1			29.4	29.3
	50	28.6			28.9	28.8
Mean		*29.5*			*29.0*	*29.3*

Lighting Treatments:

1. 4.8 W/m^2 throughout S.D. (18/18°C)
2. 12 W/m^2 weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m^2 weeks 1-3 S.D. to 4.8 W/m^2 to marketing (18/18°C)
4. 4.8 W/m^2 weeks 1-7 S.D. to 12 W/m^2 to marketing (18/18°C)
5. 12 W/m^2 weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit (18/18°C)

Spacing Treatments:

a. 24 pots/m^2 weeks 1-2 S.D. to 12.5 pots/m^2 weeks 3 + S.D.
b. 30 pots/m^2 weeks 1-2 S.D. to 15 pots/m^2 weeks 3 + S.D.
c. 36 pots/m^2 weeks 1-2 S.D. to 18 pots/m^2 weeks 3 + S.D.
d. 24 pots/m^2 weeks 1 S.D. to 12.5 pots/m^2 weeks 2 + S.D.

Table 5a: The Influence of Supplementary Lighting, Spacing and Negative DIF Treatments on the Number of Developing Buds

Variety: Charm

Number of buds at stages 1-3 per pot

Lighting Treatment	Sticking Week	Spacing a	Spacing b	Spacing c	Spacing d	Mean
1	40	25.1	24.9	20.5		23.5
	45	26.6	23.1	21.8		23.8
	50	38.5	36.6	31.0		35.4
Mean		*30.1*	*28.2*	*24.4*		*27.6*
2	40	14.0	12.7	11.5		12.7
	45	16.7	9.4	8.8		11.6
	50	23.4	25.0	24.0		24.1
Mean		*18.0*	*15.7*	*14.8*		*16.1*
3	40	24.1	16.8	16.7		19.2
	45	25.9	20.2	21.6		22.6
	50	29.1	28.7	30.3		29.4
Mean		*26.4*	*21.9*	*22.9*		*23.7*
4	40	21.2	22.7	14.7		19.5
	45	27.9	24.3	21.4		24.5
	50	38.8	29.2	41.2		36.4
Mean		*29.3*	*25.4*	*25.8*		*26.8*
5	40	12.8	13.9	8.3		11.7
	45	14.7	11.8	7.0		11.2
	50	22.9	21.8	26.6		23.8
Mean		*16.8*	*15.8*	*14.0*		*15.6*
6	40	15.3			11.6	13.5
	45	14.6			12.8	13.7
	50	29.9			23.7	26.8
Mean		*19.9*			*16.0*	*18.0*

Lighting Treatments:

1. 4.8 W/m^2 throughout S.D. (18/18°C)
2. 12 W/m^2 weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m^2 weeks 1-3 S.D. to 4.8 W/m^2 to marketing (18/18°C)
4. 4.8 W/m^2 weeks 1-7 S.D. to 12 W/m^2 to marketing (18/18°C)
5. 12 W/m^2 weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit (18/18°C)

Spacing Treatments:

a. 24 pots/m^2 weeks 1-2 S.D. to 12.5 pots/m^2 weeks 3 + S.D.
b. 30 pots/m^2 weeks 1-2 S.D. to 15 pots/m^2 weeks 3 + S.D.
c. 36 pots/m^2 weeks 1-2 S.D. to 18 pots/m^2 weeks 3 + S.D.
d. 24 pots/m^2 weeks 1 S.D. to 12.5 pots/m^2 weeks 2 + S.D.

Table 5b: **The Influence of Supplementary Lighting, Spacing and Negative DIF Treatments on the Number of Developing Buds**

Variety: Yuba

Number of buds at stages 1-3 per pot

Lighting Treatment	Sticking Week	Spacing a	Spacing b	Spacing c	Spacing d	Mean
1	40	15.2	13.3	12.8		13.8
	45	23.2	20.5	20.6		21.4
	50	26.7	27.8	31.0		28.5
Mean		*21.7*	*20.5*	*21.5*		*21.2*
2	40	13.4	13.3	11.9		12.9
	45	14.5	11.0	12.5		12.7
	50	33.7	32.4	24.4		30.2
Mean		*20.5*	*18.9*	*16.3*		*18.6*
3	40	15.2	15.0	8.6		12.9
	45	26.9	23.0	17.6		22.5
	50	33.1	26.6	28.6		29.4
Mean		*25.1*	*21.5*	*18.3*		*21.6*
4	40	17.5	15.1	15.4		16.0
	45	21.3	26.2	24.0		23.8
	50	35.7	33.5	30.4		33.2
Mean		*24.8*	*24.9*	*23.3*		*24.3*
5	40	15.4	10.2	12.9		12.8
	45	14.1	14.4	10.9		13.1
	50	24.8	20.8	21.4		22.3
Mean		*18.1*	*15.1*	*15.1*		*16.1*
6	40	16.6			14.5	15.6
	45	19.6			13.8	16.7
	50	25.1			23.3	24.2
Mean		*20.4*			*17.2*	*18.8*

Lighting Treatments:

1. 4.8 W/m^2 throughout S.D. (18/18°C)
2. 12 W/m^2 weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m^2 weeks 1-3 S.D. to 4.8 W/m^2 to marketing (18/18°C)
4. 4.8 W/m^2 weeks 1-7 S.D. to 12 W/m^2 to marketing (18/18°C)
5. 12 W/m^2 weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit (18/18°C)

Spacing Treatments:

a. 24 pots/m^2 weeks 1-2 S.D. to 12.5 pots/m^2 weeks 3 + S.D.
b. 30 pots/m^2 weeks 1-2 S.D. to 15 pots/m^2 weeks 3 + S.D.
c. 36 pots/m^2 weeks 1-2 S.D. to 18 pots/m^2 weeks 3 + S.D.
d. 24 pots/m^2 weeks 1 S.D. to 12.5 pots/m^2 weeks 2 + S.D.

Table 5c: The Influence of Supplementary Lighting, Spacing and Negative DIF Treatments on the Number of Developing Buds

Variety: Cerise About Time

Number of buds at stages 1-3 per pot

Lighting Treatment	Sticking Week	Spacing a	Spacing b	Spacing c	Spacing d	Mean
1	40	14.9	11.1			13.0
	45	9.9	10.8			10.4
	50	14.2	14.2			14.2
Mean		*13.0*	*12.0*			*12.5*
2	40	13.4	12.0			12.7
	45	9.1	6.8			8.0
	50	12.8	9.9			11.4
Mean		*11.8*	*9.6*			*10.7*
3	40					
	45					
	50					
Mean						
4	40					
	45					
	50					
Mean						
5	40	19.4	8.9			14.2
	45	5.6	6.4			6.0
	50	12.3	13.0			12.7
Mean		*12.4*	*9.4*			*11.0*
6	40	8.7			10.7	9.7
	45	10.9			6.7	8.8
	50	10.4			10.3	10.4
Mean		*10.0*			*9.2*	*9.6*

Lighting Treatments:

1. 4.8 W/m^2 throughout S.D. (18/18°C)
2. 12 W/m^2 weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m^2 weeks 1-3 S.D. to 4.8 W/m^2 to marketing (18/18°C)
4. 4.8 W/m^2 weeks 1-7 S.D. to 12 W/m^2 to marketing (18/18°C)
5. 12 W/m^2 weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit (18/18°C)

Spacing Treatments:

a. 24 pots/m^2 weeks 1-2 S.D. to 12.5 pots/m^2 weeks 3 + S.D.
b. 30 pots/m^2 weeks 1-2 S.D. to 15 pots/m^2 weeks 3 + S.D.
c. 36 pots/m^2 weeks 1-2 S.D. to 18 pots/m^2 weeks 3 + S.D.
d. 24 pots/m^2 weeks 1 S.D. to 12.5 pots/m^2 weeks 2 + S.D.

Table 6a: **The Influence of Supplementary Lighting, Spacing and Negative DIF Treatments on the Number of Open Flowers**

Variety: Charm

Number of buds at stages 4+ per pot

Lighting Treatment	Sticking Week	Spacing a	Spacing b	Spacing c	Spacing d	Mean
1	40	15.5	15.8	10.5		13.9
	45	12.6	13.9	12.3		12.9
	50	13.0	12.8	14.7		13.5
Mean		*13.7*	*14.2*	*12.5*		*13.4*
2	40	15.0	13.0	12.1		13.4
	45	9.0	8.5	8.1		8.5
	50	14.7	12.1	9.6		12.2
Mean		*12.9*	*11.2*	*9.9*		*11.4*
3	40	15.0	12.8	12.7		13.5
	45	11.5	10.6	11.2		11.1
	50	14.7	17.5	13.4		15.2
Mean		*13.7*	*13.6*	*12.4*		*13.3*
4	40	18.2	20.1	17.6		18.6
	45	13.1	13.9	13.8		13.6
	50	11.7	13.0	9.8		11.5
Mean		*14.3*	*15.7*	*13.7*		*14.6*
5	40	14.3	13.2	10.0		12.5
	45	10.5	10.4	11.2		10.7
	50	13.8	11.2	9.4		11.5
Mean		*12.9*	*11.6*	*10.2*		*11.6*
6	40	13.2			13.4	13.3
	45	10.2			10.6	10.4
	50	11.8			13.2	12.5
Mean		*11.7*			*12.4*	*12.1*

Lighting Treatments:

1. 4.8 W/m^2 throughout S.D. (18/18°C)
2. 12 W/m^2 weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m^2 weeks 1-3 S.D. to 4.8 W/m^2 to marketing (18/18°C)
4. 4.8 W/m^2 weeks 1-7 S.D. to 12 W/m^2 to marketing (18/18°C)
5. 12 W/m^2 weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit (18/18°C)

Spacing Treatments:

a. 24 pots/m^2 weeks 1-2 S.D. to 12.5 pots/m^2 weeks 3 + S.D.
b. 30 pots/m^2 weeks 1-2 S.D. to 15 pots/m^2 weeks 3 + S.D.
c. 36 pots/m^2 weeks 1-2 S.D. to 18 pots/m^2 weeks 3 + S.D.
d. 24 pots/m^2 weeks 1 S.D. to 12.5 pots/m^2 weeks 2 + S.D.

Table 6b: **The Influence of Supplementary Lighting, Spacing and Negative DIF Treatments on the Number of Open Flowers**

Variety: Yuba

Number of buds at stages 4+ per pot

Lighting Treatment	Sticking Week	Spacing a	Spacing b	Spacing c	Spacing d	Mean
1	40	30.0	30.6	23.3		28.0
	45	25.5	22.5	21.2		23.1
	50	20.1	22.9	21.3		21.4
Mean		*25.2*	*25.3*	*21.9*		*24.2*
2	40	22.2	14.2	13.3		16.6
	45	14.7	11.4	10.7		12.3
	50	17.9	16.7	15.9		16.8
Mean		*18.3*	*14.1*	*13.3*		*15.2*
3	40	29.6	27.5	27.7		28.3
	45	20.2	24.1	22.0		22.1
	50	27.9	25.1	19.8		24.3
Mean		*25.9*	*25.6*	*23.2*		*24.9*
4	40	32.4	33.8	28.2		31.5
	45	21.6	18.3	22.7		20.9
	50	22.9	24.3	22.4		23.2
Mean		*25.6*	*25.5*	*24.4*		*25.2*
5	40	16.6	18.7	14.8		16.7
	45	15.3	14.7	14.1		14.7
	50	17.2	20.3	18.6		18.7
Mean		*16.4*	*17.9*	*15.8*		*16.7*
6	40	12.5			16.6	14.6
	45	14.3			12.4	13.4
	50	15.9			18.5	17.2
Mean		*14.2*			*15.8*	*15.1*

Lighting Treatments:

1. 4.8 W/m^2 throughout S.D. (18/18°C)
2. 12 W/m^2 weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m^2 weeks 1-3 S.D. to 4.8 W/m^2 to marketing (18/18°C)
4. 4.8 W/m^2 weeks 1-7 S.D. to 12 W/m^2 to marketing (18/18°C)
5. 12 W/m^2 weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit (18/18°C)

Spacing Treatments:

a. 24 pots/m^2 weeks 1-2 S.D. to 12.5 pots/m^2 weeks 3 + S.D.
b. 30 pots/m^2 weeks 1-2 S.D. to 15 pots/m^2 weeks 3 + S.D.
c. 36 pots/m^2 weeks 1-2 S.D. to 18 pots/m^2 weeks 3 + S.D.
d. 24 pots/m^2 weeks 1 S.D. to 12.5 pots/m^2 weeks 2 + S.D.

Table 8a: The Influence of Supplementary Lighting, Spacing and Negative DIF Treatments on Foliage Quality

Variety: Charm

Leaf damage score

Lighting Treatment	Sticking Week	Spacing a	Spacing b	Spacing c	Spacing d	Mean
1	40	0.3	0.1	0.2		0.2
	45	0.1	0.2	0.3		0.2
	50	0.6	0.2	0.0		0.3
Mean		*0.3*	*0.2*	*0.2*		*0.2*
2	40	0.4	0.6	0.2		0.4
	45	0.3	0.5	0.1		0.3
	50	0.4	0.3	0.3		0.3
Mean		*0.4*	*0.5*	*0.2*		*0.3*
3	40	0.1	0.0	0.5		0.2
	45	0.1	0.2	0.4		0.2
	50	0.9	0.2	0.3		0.5
Mean		*0.4*	*0.1*	*0.4*		*0.3*
4	40	0.3	0.3	0.8		0.5
	45	0.1	0.1	0.0		0.1
	50	0.1	0.4	0.3		0.3
Mean		*0.2*	*0.3*	*0.4*		*0.3*
5	40	0.3	0.4	0.6		0.4
	45	0.2	0.3	0.5		0.3
	50	0.1	0.0	0.2		0.1
Mean		*0.2*	*0.2*	*0.4*		*0.3*
6	40	0.2			0.7	0.5
	45	0.8			0.4	0.6
	50	0.5			0.2	0.4
Mean		*0.5*			*0.4*	*0.5*

Lighting Treatments:

1. 4.8 W/m^2 throughout S.D. (18/18°C)
2. 12 W/m^2 weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m^2 weeks 1-3 S.D. to 4.8 W/m^2 to marketing (18/18°C)
4. 4.8 W/m^2 weeks 1-7 S.D. to 12 W/m^2 to marketing (18/18°C)
5. 12 W/m^2 weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit (18/18°C)

Spacing Treatments:

a. 24 pots/m^2 weeks 1-2 S.D. to 12.5 pots/m^2 weeks 3 + S.D.
b. 30 pots/m^2 weeks 1-2 S.D. to 15 pots/m^2 weeks 3 + S.D.
c. 36 pots/m^2 weeks 1-2 S.D. to 18 pots/m^2 weeks 3 + S.D.
d. 24 pots/m^2 weeks 1 S.D. to 12.5 pots/m^2 weeks 2 + S.D.

Table 8b: **The Influence of Supplementary Lighting, Spacing and Negative DIF Treatments on Foliage Quality**

Variety: Yuba

Leaf damage score

Lighting Treatment	Sticking Week	Spacing a	Spacing b	Spacing c	Spacing d	Mean
1	40	1.1	1.3	2.0		1.5
	45	1.3	1.6	1.5		1.5
	50	1.3	0.9	0.8		1.0
Mean		*1.2*	*1.3*	*1.4*		*1.3*
2	40	1.2	1.8	1.4		1.5
	45	1.7	1.4	1.5		1.5
	50	1.7	1.6	1.6		1.6
Mean		*1.5*	*1.6*	*1.5*		*1.5*
3	40	1.0	1.3	1.2		1.2
	45	1.6	1.4	1.6		1.5
	50	1.0	1.8	1.3		1.4
Mean		*1.2*	*1.5*	*1.4*		*1.4*
4	40	1.2	0.9	1.2		1.1
	45	1.0	1.1	1.5		1.2
	50	1.6	1.0	1.3		1.3
Mean		*1.3*	*1.0*	*1.3*		*1.2*
5	40	0.9	0.9	1.6		1.1
	45	2.1	2.0	2.0		2.0
	50	1.6	1.3	1.6		1.5
Mean		*1.5*	*1.4*	*1.7*		*1.5*
6	40	1.0			1.1	1.1
	45	1.3			1.3	1.3
	50	1.1			0.7	0.9
Mean		*1.1*			*1.0*	*1.1*

Lighting Treatments:

1. 4.8 W/m^2 throughout S.D. (18/18°C)
2. 12 W/m^2 weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m^2 weeks 1-3 S.D. to 4.8 W/m^2 to marketing (18/18°C)
4. 4.8 W/m^2 weeks 1-7 S.D. to 12 W/m^2 to marketing (18/18°C)
5. 12 W/m^2 weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit (18/18°C)

Spacing Treatments:

a. 24 pots/m^2 weeks 1-2 S.D. to 12.5 pots/m^2 weeks 3 + S.D.
b. 30 pots/m^2 weeks 1-2 S.D. to 15 pots/m^2 weeks 3 + S.D.
c. 36 pots/m^2 weeks 1-2 S.D. to 18 pots/m^2 weeks 3 + S.D.
d. 24 pots/m^2 weeks 1 S.D. to 12.5 pots/m^2 weeks 2 + S.D.

Table 8c: The Influence of Supplementary Lighting, Spacing and Negative DIF Treatments on Foliage Quality

Variety: Cerise About Time

Leaf damage score

Lighting Treatment	Sticking Week	Spacing a	Spacing b	Spacing c	Spacing d	Mean
1	40	0.3	0.8			0.6
	45	0.3	0.3			0.3
	50	0.0	0.1			0.1
Mean		*0.2*	*0.4*			*0.3*
2	40	0.9	0.9			0.9
	45	0.1	0.5			0.3
	50	0.4	0.1			0.3
Mean		*0.5*	*0.5*			*0.5*
3	40					
	45					
	50					
Mean						
4	40					
	45					
	50					
Mean						
5	40	0.3	0.5			0.4
	45	0.2	0.4			0.3
	50	0.0	0.0			0.0
Mean		*0.2*	*0.3*			*0.2*
6	40	0.4			0.6	0.5
	45	0.1			0.5	0.3
	50	0.1			0.0	0.1
Mean		*0.2*			*0.4*	*0.3*

Lighting Treatments:

1. 4.8 W/m^2 throughout S.D. (18/18°C)
2. 12 W/m^2 weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m^2 weeks 1-3 S.D. to 4.8 W/m^2 to marketing (18/18°C)
4. 4.8 W/m^2 weeks 1-7 S.D. to 12 W/m^2 to marketing (18/18°C)
5. 12 W/m^2 weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit (18/18°C)

Spacing Treatments:

a. 24 pots/m^2 weeks 1-2 S.D. to 12.5 pots/m^2 weeks 3 + S.D.
b. 30 pots/m^2 weeks 1-2 S.D. to 15 pots/m^2 weeks 3 + S.D.
c. 36 pots/m^2 weeks 1-2 S.D. to 18 pots/m^2 weeks 3 + S.D.
d. 24 pots/m^2 weeks 1 S.D. to 12.5 pots/m^2 weeks 2 + S.D.

Table 9a: **The Influence of Supplementary Lighting, Spacing and Negative DIF Treatments on Pot Deterioration in Shelf-Life**

Variety: Charm

Mean pot deterioration score

Lighting Treatment	Sticking Week	Spacing a w1	w2	w3	Spacing b w1	w2	w3	Spacing c w1	w2	w3	Spacing d w1	w2	w3	Mean w1	w2	w3
1	40	0.0	1.0	3.0	0.0	1.0	2.3	0.0	1.0	2.7				0.0	1.0	2.7
	45	0.0	1.0	2.0	0.0	1.0	2.0	0.0	1.0	2.0				0.0	1.0	2.0
	50	0.0	1.0	2.0	0.0	1.0	2.0	0.0	1.0	2.0				0.0	1.0	2.0
Mean		*0.0*	*1.0*	*2.3*	*0.0*	*1.0*	*2.1*	*0.0*	*1.0*	*2.2*				*0.0*	*1.0*	*2.2*
2	40	0.0	1.0	3.0	0.0	1.0	3.0	0.0	1.0	3.0				0.0	1.0	3.0
	45	0.7	1.7	2.0	0.0	1.0	2.0	0.0	1.0	2.0				0.2	1.2	2.0
	50	0.0	1.0	2.0	0.0	1.0	2.0	0.0	1.0	2.0				0.0	1.0	2.0
Mean		*0.2*	*1.2*	*2.3*	*0.0*	*1.0*	*2.3*	*0.0*	*1.0*	*2.3*				*0.1*	*1.1*	*2.3*
3	40	0.0	1.0	3.0	0.0	1.0	3.0	0.0	1.0	3.0				0.0	1.0	3.0
	45	0.0	1.0	2.0	0.0	1.0	2.0	0.0	1.0	2.0				0.0	1.0	2.0
	50	0.0	1.0	2.0	0.0	1.0	2.0	0.0	1.0	2.0				0.0	1.0	2.0
Mean		*0.0*	*1.0*	*2.3*	*0.0*	*1.0*	*2.3*	*0.0*	*1.0*	*2.3*				*0.0*	*1.0*	*2.3*
4	40	0.0	0.0	2.3	0.0	0.7	2.7	0.0	1.0	2.0				0.0	0.6	2.3
	45	0.0	0.3	2.0	0.0	0.3	1.3	0.0	1.0	2.0				0.0	0.5	1.8
	50	0.0	1.0	2.0	0.0	1.0	2.0	0.0	1.0	2.0				0.0	1.0	2.0
Mean		*0.0*	*0.4*	*2.1*	*0.0*	*0.7*	*2.0*	*0.0*	*1.0*	*2.0*				*0.0*	*0.7*	*2.0*
5	40	0.0	2.0	3.0	0.3	1.7	2.3	0.0	2.0	2.3				0.1	1.9	2.5
	45	0.0	1.3	2.3	0.0	1.3	2.0	0.0	1.0	2.0				0.0	1.2	2.1
	50	0.0	1.3	2.0	0.0	1.3	2.0	0.0	1.0	2.0				0.0	1.2	2.0
Mean		*0.0*	*1.5*	*2.4*	*0.1*	*1.4*	*2.1*	*0.0*	*1.3*	*2.1*				*0.0*	*1.4*	*2.2*
6	40	0.0	1.7	3.0							0.0	1.7	2.3	0.0	1.7	2.7
	45	0.0	1.0	2.0							0.3	1.3	2.0	0.2	1.2	2.0
	50	0.0	1.0	2.0							0.0	1.0	2.0	0.0	1.0	2.0
Mean		*0.0*	*1.2*	*2.3*							*0.1*	*1.3*	*2.1*	*0.1*	*1.3*	*2.2*

Lighting Treatments:

1. 4.8 W/m^2 throughout S.D. (18/18°C)
2. 12 W/m^2 weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m^2 weeks 1-3 S.D. to 4.8 W/m^2 to marketing (18/18°C)
4. 4.8 W/m^2 weeks 1-7 S.D. to 12 W/m^2 to marketing (18/18°C)
5. 12 W/m^2 weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit (18/18°C)

Spacing Treatments:

a. 24 pots/m^2 weeks 1-2 S.D. to 12.5 pots/m^2 weeks 3 + S.D.
b. 30 pots/m^2 weeks 1-2 S.D. to 15 pots/m^2 weeks 3 + S.D.
c. 36 pots/m^2 weeks 1-2 S.D. to 18 pots/m^2 weeks 3 + S.D.
d. 24 pots/m^2 weeks 1 S.D. to 12.5 pots/m^2 weeks 2 + S.D.

Date of Assessment:

w1. One week after removing sleeves.
w2. Two weeks after removing sleeves.
w3. Three weeks after removing sleeves.

Table 9b: The Influence of Supplementary Lighting, Spacing and Negative DIF Treatments on Pot Deterioration in Shelf-Life

Variety: Yuba

Mean pot deterioration score

Lighting Treatment	Sticking Week	Spacing a w1	w2	w3	Spacing b w1	w2	w3	Spacing c w1	w2	w3	Spacing d w1	w2	w3	Mean w1	w2	w3
1	40	0.3	1.0	2.7	0.3	0.7	1.7	0.3	1.0	2.3				0.3	0.9	2.2
	45	0.7	-	-	0.7	1.0	2.0	1.0	1.3	2.0				0.8	1.2	2.0
	50	1.0	1.3	2.0	0.7	1.7	2.3	0.7	1.0	1.7				0.8	1.3	2.0
Mean		*0.7*	*1.2*	*2.4*	*0.6*	*1.1*	*2.0*	*0.7*	*1.1*	*2.0*				*0.6*	*1.1*	*2.1*
2	40	0.7	2.3	-	1.0	1.0	2.3	1.0	3.0	-				0.9	2.1	2.3
	45	1.0	1.0	2.0	1.0	1.3	2.3	1.0	-	-				1.0	1.2	2.2
	50	1.0	1.7	2.3	1.0	2.0	2.0	1.0	1.7	2.0				1.0	1.8	2.1
Mean		*0.9*	*1.7*	*2.2*	*1.0*	*1.4*	*2.2*	*1.0*	*2.4*	*2.0*				*1.0*	*1.7*	*2.2*
3	40	0.7	1.0	2.0	0.7	2.0	3.0	1.0	1.0	1.5				0.8	1.3	2.2
	45	0.7	1.0	2.0	1.0	1.0	1.7	1.0	1.0	2.0				0.9	1.0	1.9
	50	1.0	2.0	2.0	1.0	2.0	-	0.7	1.3	2.0				0.9	1.8	2.0
Mean		*0.8*	*1.3*	*2.0*	*0.9*	*1.7*	*2.4*	*0.9*	*1.1*	*1.8*				*0.9*	*1.4*	*2.0*
4	40	1.0	1.7	1.5	0.3	1.0	2.3	0.3	1.7	1.0				0.5	1.5	1.6
	45	0.3	1.5	2.5	0.3	0.7	1.0	0.7	0.7	1.7				0.4	1.0	1.7
	50	1.0	2.0	-	1.0	1.0	2.0	1.0	1.3	2.0				1.0	1.4	2.0
Mean		*0.8*	*1.7*	*2.0*	*0.5*	*0.9*	*1.8*	*0.7*	*1.2*	*1.6*				*0.6*	*1.3*	*1.8*
5	40	0.0	0.3	3.0	1.3	1.3	2.0	2.0	2.0	2.0				1.1	1.2	2.3
	45	1.0	1.5	2.5	1.0	1.3	2.5	1.0	1.3	2.3				1.0	1.4	2.4
	50	1.0	2.0	2.3	1.0	1.0	2.3	1.0	1.0	2.0				1.0	1.3	2.2
Mean		*0.7*	*1.3*	*2.6*	*1.1*	*1.2*	*2.3*	*1.3*	*1.4*	*2.1*				*1.0*	*1.3*	*2.3*
6	40	1.0	2.0	3.0							1.7	1.7	2.0	1.4	1.9	2.5
	45	0.7	-	3.0							1.0	1.0	2.3	0.9	1.0	2.7
	50	1.0	1.0	2.0							1.0	1.0	2.0	1.0	1.0	2.0
Mean		*0.9*	*1.5*	*2.7*							*1.2*	*1.2*	*2.1*	*1.1*	*1.3*	*2.4*

Lighting Treatments:

1. 4.8 W/m² throughout S.D. (18/18°C)
2. 12 W/m² weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m² weeks 1-3 S.D. to 4.8 W/m² to marketing (18/18°C)
4. 4.8 W/m² weeks 1-7 S.D. to 12 W/m² to marketing (18/18°C)
5. 12 W/m² weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit (18/18°C)

Spacing Treatments:

a. 24 pots/m² weeks 1-2 S.D. to 12.5 pots/m² weeks 3 + S.D.
b. 30 pots/m² weeks 1-2 S.D. to 15 pots/m² weeks 3 + S.D.
c. 36 pots/m² weeks 1-2 S.D. to 18 pots/m² weeks 3 + S.D.
d. 24 pots/m² weeks 1 S.D. to 12.5 pots/m² weeks 2 + S.D.

Date of Assessment:

w1. One week after removing sleeves.
w2. Two weeks after removing sleeves.
w3. Three weeks after removing sleeves.

Table 9c: The Influence of Supplementary Lighting, Spacing and Negative DIF Treatments on Pot Deterioration in Shelf-Life

Variety: Cerise About Time

Mean pot deterioration score

Lighting Treatment	Sticking Week	Spacing a w1	w2	w3	Spacing b w1	w2	w3	Spacing c w1	w2	w3	Spacing d w1	w2	w3	Mean w1	w2	w3
1	40	0.0	0.0	2.7	0.0	0.0	3.0							0.0	0.0	2.9
	45	0.0	1.0	2.0	0.0	1.0	2.3							0.0	1.0	2.2
	50	0.0	1.3	3.0	0.0	1.0	3.0							0.0	1.2	3.0
Mean		*0.0*	*0.8*	*2.6*	*0.0*	*0.7*	*2.8*							*0.0*	*0.7*	*2.7*
2	40	0.0	1.3	2.5	1.0	1.0	3.0							0.5	1.2	2.8
	45	0.0	1.0	3.0	0.0	1.0	2.0							0.0	1.0	2.5
	50	0.0	1.0	3.0	0.0	1.3	3.0							0.0	1.2	3.0
Mean		*0.0*	*1.1*	*2.8*	*0.3*	*1.1*	*2.7*							*0.2*	*1.1*	*2.8*
3	40															
	45															
	50															
Mean																
4	40															
	45															
	50															
Mean																
5	40	1.0	1.0	3.0	1.0	1.0	3.0							1.0	1.0	3.0
	45	0.0	1.3	2.7	0.0	1.0	2.0							0.0	1.2	2.4
	50	0.0	1.0	3.0	0.0	1.0	3.0							0.0	1.0	3.0
Mean		*0.3*	*1.1*	*2.9*	*0.3*	*1.0*	*2.7*							*0.3*	*1.1*	*2.8*
6	40	0.0	1.0	3.0							0.3	1.0	2.0	0.2	1.0	2.5
	45	0.0	0.0	3.0							0.0	1.0	2.0	0.0	0.5	2.5
	50	0.0	1.3	3.0							0.7	2.0	2.7	0.4	1.7	2.9
Mean		*0.0*	*0.8*	*3.0*							*0.3*	*1.3*	*2.2*	*0.2*	*1.1*	*2.6*

Lighting Treatments:

1. 4.8 W/m^2 throughout S.D. (18/18°C)
2. 12 W/m^2 weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m^2 weeks 1-3 S.D. to 4.8 W/m^2 to marketing (18/18°C)
4. 4.8 W/m^2 weeks 1-7 S.D. to 12 W/m^2 to marketing (18/18°C)
5. 12 W/m^2 weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit (18/18°C)

Spacing Treatments:

a. 24 pots/m^2 weeks 1-2 S.D. to 12.5 pots/m^2 weeks 3 + S.D.
b. 30 pots/m^2 weeks 1-2 S.D. to 15 pots/m^2 weeks 3 + S.D.
c. 36 pots/m^2 weeks 1-2 S.D. to 18 pots/m^2 weeks 3 + S.D.
d. 24 pots/m^2 weeks 1 S.D. to 12.5 pots/m^2 weeks 2 + S.D.

Date of Assessment:

w1. One week after removing sleeves.
w2. Two weeks after removing sleeves.
w3. Three weeks after removing sleeves.

Table 10a: **The Influence of Supplementary Lighting, Spacing and Negative DIF Treatments on Foliage Quality in Shelf-Life**

Variety: Charm

Mean leaf damage score

Lighting Treatment	Sticking Week	Spacing a w1	w2	w3	Spacing b w1	w2	w3	Spacing c w1	w2	w3	Spacing d w1	w2	w3	Mean w1	w2	w3
1	40	0.3	1.0	1.0	1.0	1.0	1.0	0.3	0.3	1.0				0.5	0.8	1.0
	45	0.0	1.0	1.0	0.7	0.7	0.7	0.3	0.3	0.3				0.3	0.7	0.7
	50	0.7	1.0	1.0	0.7	0.7	1.0	0.7	1.0	1.3				0.7	0.9	1.1
Mean		*0.3*	*1.0*	*1.0*	*0.8*	*0.8*	*0.9*	*0.4*	*0.5*	*0.9*				*0.5*	*0.8*	*0.9*
2	40	0.3	0.3	1.0	0.0	1.0	1.0	0.0	0.3	1.0				0.1	0.5	1.0
	45	0.7	0.7	0.7	0.7	0.7	0.7	0.3	0.7	0.7				0.6	0.7	0.7
	50	1.0	1.0	1.0	0.3	1.0	1.0	1.0	1.0	1.0				0.8	1.0	1.0
Mean		*0.7*	*0.7*	*0.9*	*0.3*	*0.9*	*0.9*	*0.4*	*0.7*	*0.9*				*0.5*	*0.7*	*0.9*
3	40	0.3	1.0	1.0	0.0	0.7	0.7	0.3	1.0	1.0				0.2	0.9	0.9
	45	0.3	0.3	0.3	1.0	1.0	1.0	1.0	1.0	1.0				0.8	0.8	0.8
	50	0.7	0.7	1.0	0.7	0.7	0.7	0.7	0.7	1.0				0.7	0.7	0.9
Mean		*0.4*	*0.7*	*0.8*	*0.6*	*0.8*	*0.8*	*0.7*	*0.9*	*1.0*				*0.6*	*0.8*	*0.9*
4	40	0.0	0.3	1.0	0.3	0.7	1.0	0.0	0.7	1.0				0.1	0.6	1.0
	45	0.3	0.3	0.7	0.7	0.7	0.7	0.3	0.3	0.7				0.4	0.4	0.7
	50	0.3	0.7	1.0	0.7	0.7	1.0	0.7	0.7	1.0				0.6	0.7	1.0
Mean		*0.2*	*0.4*	*0.9*	*0.6*	*0.7*	*0.9*	*0.3*	*0.6*	*0.9*				*0.4*	*0.6*	*0.9*
5	40	0.3	1.0	1.0	0.3	0.3	1.0	0.3	0.7	1.0				0.3	0.7	1.0
	45	0.3	0.3	0.7	1.0	1.0	1.7	0.7	1.3	1.3				0.7	0.9	1.2
	50	0.7	1.0	1.0	0.3	0.3	0.7	0.3	0.3	0.7				0.4	0.5	0.8
Mean		*0.4*	*0.8*	*0.9*	*0.5*	*0.5*	*1.1*	*0.4*	*0.8*	*1.0*				*0.5*	*0.7*	*1.0*
6	40	0.3	1.0	1.0							0.3	1.0	1.0	0.3	1.0	1.0
	45	0.7	1.0	1.0							0.7	0.7	0.7	0.7	0.9	0.9
	50	0.7	1.0	1.0							0.7	1.3	1.3	0.7	1.2	1.2
Mean		*0.6*	*1.0*	*1.0*							*0.6*	*1.0*	*1.0*	*0.6*	*1.0*	*1.0*

Lighting Treatments:

1. 4.8 W/m^2 throughout S.D. (18/18°C)
2. 12 W/m^2 weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m^2 weeks 1-3 S.D. to 4.8 W/m^2 to marketing (18/18°C)
4. 4.8 W/m^2 weeks 1-7 S.D. to 12 W/m^2 to marketing (18/18°C)
5. 12 W/m^2 weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit (18/18°C)

Spacing Treatments:

a. 24 pots/m^2 weeks 1-2 S.D. to 12.5 pots/m^2 weeks 3 + S.D.
b. 30 pots/m^2 weeks 1-2 S.D. to 15 pots/m^2 weeks 3 + S.D.
c. 36 pots/m^2 weeks 1-2 S.D. to 18 pots/m^2 weeks 3 + S.D.
d. 24 pots/m^2 weeks 1 S.D. to 12.5 pots/m^2 weeks 2 + S.D.

Date of Assessment:

w1. One week after removing sleeves.
w2. Two weeks after removing sleeves.
w3. Three weeks after removing sleeves.

Table 10b: **The Influence of Supplementary Lighting, Spacing and Negative DIF Treatments on Foliage Quality in Shelf-Life**

Variety: Yuba

Mean leaf damage score

Lighting Treatment	Sticking Week	Spacing a w1	w2	w3	Spacing b w1	w2	w3	Spacing c w1	w2	w3	Spacing d w1	w2	w3	Mean w1	w2	w3
1	40	1.0	1.7	2.0	1.0	1.0	1.0	1.0	1.3	1.0				1.0	1.3	1.3
	45	1.7	-	0.0	1.7	1.7	1.7	2.0	2.0	2.0				1.8	1.9	1.2
	50	2.0	2.0	2.0	0.3	2.3	2.3	1.7	1.7	2.0				1.3	2.0	2.1
Mean		*1.6*	*1.9*	*2.0*	*1.0*	*1.7*	*1.7*	*1.6*	*1.7*	*1.7*				*1.4*	*1.8*	*1.6*
2	40	0.7	2.3	-	2.0	2.0	2.0	1.0	3.0	-				1.2	2.4	2.0
	45	2.0	2.0	2.0	2.0	2.0	2.0	2.0	-	-				2.0	2.0	2.0
	50	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0				2.0	2.0	2.0
Mean		*1.6*	*2.1*	*2.0*	*2.0*	*2.0*	*2.0*	*1.7*	*2.5*	*2.0*				*1.7*	*2.1*	*2.0*
3	40	1.3	1.3	1.0	1.0	2.0	2.0	1.7	1.7	1.5				1.3	1.7	1.5
	45	1.7	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0				1.9	2.0	2.0
	50	2.0	2.5	3.0	2.0	2.0	-	1.3	2.0	2.0				1.8	2.2	2.5
Mean		*1.7*	*1.9*	*2.0*	*1.7*	*2.0*	*2.0*	*1.7*	*1.9*	*1.8*				*1.7*	*2.0*	*2.0*
4	40	2.0	2.3	2.0	0.3	0.3	1.0	0.7	1.7	2.0				1.0	1.4	1.7
	45	1.3	1.5	2.0	1.3	1.7	1.7	1.7	1.7	1.7				1.4	1.6	1.8
	50	2.0	2.0	-	2.0	2.0	2.3	2.0	2.0	2.0				2.0	2.0	2.2
Mean		*1.8*	*1.9*	*2.0*	*1.2*	*1.3*	*1.7*	*1.5*	*1.8*	*1.9*				*1.5*	*1.7*	*1.9*
5	40	0.7	1.3	2.0	1.3	1.7	1.7	1.7	1.5	2.0				1.2	1.5	1.9
	45	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.3				2.0	2.0	2.1
	50	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0				2.0	2.0	2.0
Mean		*1.6*	*1.8*	*2.0*	*1.8*	*1.9*	*1.9*	*1.9*	*1.8*	*2.1*				*1.7*	*1.8*	*2.0*
6	40	1.7	1.0	2.1							1.7	1.7	2.0	1.7	1.4	2.1
	45	1.7	-	2.0							2.0	2.0	2.0	1.9	2.0	2.0
	50	2.0	2.0	2.0							2.0	2.0	2.0	2.0	2.0	2.0
Mean		*1.8*	*1.5*	*2.0*							*1.9*	*1.9*	*2.0*	*1.9*	*1.8*	*2.0*

Lighting Treatments:

1. 4.8 W/m² throughout S.D. (18/18°C)
2. 12 W/m² weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m² weeks 1-3 S.D. to 4.8 W/m² to marketing (18/18°C)
4. 4.8 W/m² weeks 1-7 S.D. to 12 W/m² to marketing (18/18°C)
5. 12 W/m² weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit (18/18°C)

Spacing Treatments:

a. 24 pots/m² weeks 1-2 S.D. to 12.5 pots/m² weeks 3 + S.D.
b. 30 pots/m² weeks 1-2 S.D. to 15 pots/m² weeks 3 + S.D.
c. 36 pots/m² weeks 1-2 S.D. to 18 pots/m² weeks 3 + S.D.
d. 24 pots/m² weeks 1 S.D. to 12.5 pots/m² weeks 2 + S.D.

Date of Assessment:

w1. One week after removing sleeves.
w2. Two weeks after removing sleeves.
w3. Three weeks after removing sleeves.

Table 10c: The Influence of Supplementary Lighting, Spacing and Negative DIF Treatments on Foliage Quality in Shelf-Life

Variety: Cerise About Time

Mean leaf damage score

Lighting Treatment	Sticking Week	Spacing a w1	w2	w3	Spacing b w1	w2	w3	Spacing c w1	w2	w3	Spacing d w1	w2	w3	Mean w1	w2	w3
1	40	0.3	0.7	1.3	1.0	1.0	1.0							0.7	0.9	1.2
	45	0.7	0.7	1.0	1.0	1.3	1.3							0.9	1.0	1.2
	50	0.0	0.3	0.7	0.3	0.3	0.7							0.2	0.3	0.7
Mean		*0.3*	*0.6*	*1.0*	*0.8*	*0.9*	*1.0*							*0.6*	*0.7*	*1.0*
2	40	0.7	1.3	1.0	1.0	1.0	1.0							0.9	1.2	1.0
	45	0.7	1.3	1.7	0.3	0.3	1.0							0.5	0.8	1.4
	50	0.3	0.7	0.7	0.7	1.0	1.0							0.5	0.9	0.9
Mean		*0.6*	*1.1*	*1.1*	*0.7*	*0.8*	*1.0*							*0.6*	*1.0*	*1.1*
3	40															
	45															
	50															
Mean																
4	40															
	45															
	50															
Mean																
5	40	0.0	0.0	1.0	0.0	0.7	0.7							0.0	0.4	0.9
	45	0.7	1.0	1.0	1.0	1.0	1.3							0.9	1.0	1.2
	50	0.0	0.7	1.0	0.7	1.0	1.0							0.4	0.9	1.0
Mean		*0.2*	*0.6*	*1.0*	*0.6*	*0.9*	*1.0*									
6	40	0.7	1.0	1.0							0.3	0.7	1.0	0.5	0.9	1.0
	45	0.3	-	1.0							1.0	0.7	0.7	0.7	0.7	0.9
	50	0.0	1.3	1.3							0.7	1.0	1.0	0.4	1.2	1.2
Mean		*0.3*	*1.2*	*1.1*							*0.7*	*0.8*	*0.9*	*0.5*	*1.0*	*1.0*

Lighting Treatments:

1. 4.8 W/m^2 throughout S.D. (18/18°C)
2. 12 W/m^2 weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m^2 weeks 1-3 S.D. to 4.8 W/m^2 to marketing (18/18°C)
4. 4.8 W/m^2 weeks 1-7 S.D. to 12 W/m^2 to marketing (18/18°C)
5. 12 W/m^2 weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit (18/18°C)

Spacing Treatments:

a. 24 pots/m^2 weeks 1-2 S.D. to 12.5 pots/m^2 weeks 3 + S.D.
b. 30 pots/m^2 weeks 1-2 S.D. to 15 pots/m^2 weeks 3 + S.D.
c. 36 pots/m^2 weeks 1-2 S.D. to 18 pots/m^2 weeks 3 + S.D.
d. 24 pots/m^2 weeks 1 S.D. to 12.5 pots/m^2 weeks 2 + S.D.

Date of Assessment:

w1. One week after removing sleeves.
w2. Two weeks after removing sleeves.
w3. Three weeks after removing sleeves.

Table 11a: **The Influence of Supplementary Lighting, Spacing and Negative DIF Treatments on Number of Open Flowers in Shelf-Life**

Variety: Charm

Mean number of flowers at stages 4+ per pot

Lighting Treatment	Sticking Week	Spacing a w1	w2	w3	Spacing b w1	w2	w3	Spacing c w1	w2	w3	Spacing d w1	w2	w3	Mean w1	w2	w3
1	40	12	13	13	12	14	14	8	14	13				11	14	13
	45	19	20	20	17	19	19	21	21	21				19	20	20
	50	17	19	20	17	17	19	20	-	23				18	18	21
Mean		*16*	*17*	*18*	*15*	*17*	*17*	*16*	*18*	*19*				*16*	*17*	*18*
2	40	13	15	14	11	13	12	10	12	11				11	13	12
	45	10	11	11	10	11	11	9	9	9				10	10	10
	50	16	16	17	16	17	18	16	17	18				16	17	18
Mean		*13*	*14*	*14*	*12*	*14*	*14*	*12*	*13*	*13*				*12*	*13*	*13*
3	40	11	17	16	11	13	12	11	13	13				11	14	14
	45	19	19	19	15	16	16	20	19	17				18	18	18
	50	17	18	18	21	22	22	16	18	19				18	19	20
Mean		*16*	*18*	*18*	*16*	*17*	*17*	*16*	*17*	*16*				*16*	*17*	*17*
4	40	12	16	16	14	18	17	12	19	19				13	18	17
	45	27	26	26	22	23	23	21	23	24				23	24	24
	50	17	19	20	16	16	18	14	15	17				16	17	18
Mean		*19*	*20*	*21*	*17*	*19*	*19*	*16*	*19*	*20*				*17*	*19*	*20*
5	40	12	15	14	12	13	13	10	11	10				11	13	12
	45	15	14	14	13	14	13	12	12	12				13	13	13
	50	18	20	21	15	17	17	15	18	18				16	18	19
Mean		*15*	*16*	*16*	*13*	*15*	*14*	*12*	*14*	*13*				*13*	*15*	*14*
6	40	11	12	13							11	12	12	11	12	13
	45	13	13	13							11	10	11	12	12	12
	50	19	23	21							18	21	21	19	22	21
Mean		*14*	*16*	*16*							*13*	*14*	*15*	*14*	*15*	*15*

Lighting Treatments:

1. 4.8 W/m² throughout S.D. (18/18°C)
2. 12 W/m² weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m² weeks 1-3 S.D. to 4.8 W/m² to marketing (18/18°C)
4. 4.8 W/m² weeks 1-7 S.D. to 12 W/m² to marketing (18/18°C)
5. 12 W/m² weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit (18/18°C)

Spacing Treatments:

a. 24 pots/m² weeks 1-2 S.D. to 12.5 pots/m² weeks 3 + S.D.
b. 30 pots/m² weeks 1-2 S.D. to 15 pots/m² weeks 3 + S.D.
c. 36 pots/m² weeks 1-2 S.D. to 18 pots/m² weeks 3 + S.D.
d. 24 pots/m² weeks 1 S.D. to 12.5 pots/m² weeks 2 + S.D.

Date of Assessment:

w1. One week after removing sleeves.
w2. Two weeks after removing sleeves.
w3. Three weeks after removing sleeves.

Table 11b: **The Influence of Supplementary Lighting, Spacing and Negative DIF Treatments on Number of Open Flowers in Shelf-Life**

Variety: Yuba

Mean number of flowers at stages 4+ per pot

Lighting Treatment	Sticking Week	Spacing a			Spacing b			Spacing c			Spacing d			Mean		
		w1	w2	w3	w1	w2	w3	w1	w2	w3	w1	w2	w3	w1	w2	w3
1	40	20	29	28	12	22	22	15	21	21				16	24	24
	45	25	-	-	22	20	19	24	24	25				24	22	22
	50	25	24	25	31	28	27	32	30	29				29	27	27
Mean		*23*	*27*	*27*	*22*	*23*	*23*	*24*	*25*	*25*				*23*	*24*	*24*
2	40	15	14	-	10	11	12	9	9	-				11	11	12
	45	14	16	15	12	13	13	8	-	-				11	14	14
	50	24	24	24	20	24	23	19	19	21				21	22	23
Mean		*18*	*18*	*20*	*14*	*16*	*16*	*12*	*14*	*21*				*15*	*16*	*16*
3	40	21	23	22	20	20	21	20	21	19				20	21	21
	45	26	27	28	26	24	25	23	23	24				25	25	26
	50	35	31	23	29	28	-	26	20	21				30	26	22
Mean		*27*	*27*	*24*	*25*	*24*	*23*	*23*	*21*	*21*				*25*	*24*	*23*
4	40	23	21	21	26	25	25	25	20	21				25	22	22
	45	31	33	33	29	27	25	30	30	29				30	30	29
	50	28	28	-	32	32	34	27	27	32				29	29	33
Mean		*27*	*27*	*27*	*29*	*28*	*28*	*27*	*26*	*27*				*28*	*27*	*28*
5	40	13	15	14	14	17	18	12	14	14				13	15	15
	45	14	16	19	16	17	17	14	15	15				15	16	17
	50	16	22	22	21	18	20	17	15	16				18	18	19
Mean		*14*	*18*	*18*	*17*	*18*	*18*	*15*	*15*	*15*				*15*	*17*	*17*
6	40	15	17	-							11	14	14	13	16	14
	45	14	-	16							10	13	13	12	13	15
	50	23	26	21							17	23	22	20	24	22
Mean		*17*	*22*	*19*							*13*	*17*	*16*	*15*	*18*	*17*

Lighting Treatments:

1. 4.8 W/m^2 throughout S.D. (18/18°C)
2. 12 W/m^2 weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m^2 weeks 1-3 S.D. to 4.8 W/m^2 to marketing (18/18°C)
4. 4.8 W/m^2 weeks 1-7 S.D. to 12 W/m^2 to marketing (18/18°C)
5. 12 W/m^2 weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit (18/18°C)

Spacing Treatments:

a. 24 pots/m^2 weeks 1-2 S.D. to 12.5 pots/m^2 weeks 3 + S.D.
b. 30 pots/m^2 weeks 1-2 S.D. to 15 pots/m^2 weeks 3 + S.D.
c. 36 pots/m^2 weeks 1-2 S.D. to 18 pots/m^2 weeks 3 + S.D.
d. 24 pots/m^2 weeks 1 S.D. to 12.5 pots/m^2 weeks 2 + S.D.

Date of Assessment:

w1. One week after removing sleeves.
w2. Two weeks after removing sleeves.
w3. Three weeks after removing sleeves.

Table 11c: The Influence of Supplementary Lighting, Spacing and Negative DIF Treatments on Number of Open Flowers in Shelf-Life

Variety: Cerise About Time

Mean number of flowers at stage 4+ per pot

Lighting Treatment	Sticking Week	Spacing a w1	w2	w3	Spacing b w1	w2	w3	Spacing c w1	w2	w3	Spacing d w1	w2	w3	Mean w1	w2	w3
1	40	15	26	24	11	17	16							13	22	20
	45	29	29	29	24	23	22							27	26	26
	50	33	33	32	35	35	32							34	34	32
Mean		*26*	*29*	*28*	*23*	*25*	*23*							*25*	*27*	*26*
2	40	17	20	19	13	17	17							15	19	18
	45	14	12	11	8	8	7							11	10	9
	50	17	17	17	19	19	19							18	18	18
Mean		*16*	*16*	*16*	*13*	*15*	*14*							*15*	*16*	*15*
3	40															
	45															
	50															
Mean																
4	40															
	45															
	50															
Mean																
5	40	12	13	12	15	14	14							14	14	13
	45	14	14	13	14	14	14							14	14	14
	50	18	17	17	18	18	18							18	18	18
Mean		*15*	*15*	*14*	*16*	*15*	*15*							*15*	*15*	*15*
6	40	23	24	21							16	20	19	19	22	20
	45	20	-	20							13	15	15	17	15	17
	50	31	34	34							31	31	32	31	33	33
Mean		*25*	*29*	*25*							*20*	*22*	*22*	*22*	*23*	*23*

Lighting Treatments:

1. 4.8 W/m² throughout S.D. (18/18°C)
2. 12 W/m² weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m² weeks 1-3 S.D. to 4.8 W/m² to marketing (18/18°C)
4. 4.8 W/m² weeks 1-7 S.D. to 12 W/m² to marketing (18/18°C)
5. 12 W/m² weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit (18/18°C)

Spacing Treatments:

a. 24 pots/m² weeks 1-2 S.D. to 12.5 pots/m² weeks 3 + S.D.
b. 30 pots/m² weeks 1-2 S.D. to 15 pots/m² weeks 3 + S.D.
c. 36 pots/m² weeks 1-2 S.D. to 18 pots/m² weeks 3 + S.D.
d. 24 pots/m² weeks 1 S.D. to 12.5 pots/m² weeks 2 + S.D.

Date of Assessment:

w1. One week after removing sleeves.
w2. Two weeks after removing sleeves.
w3. Three weeks after removing sleeves.

Table 12a: The Influence of Supplementary Lighting, Spacing and Negative DIF Treatments on Number of Distorted Flowers in Shelf-Life

Variety: Charm

Mean number of distorted flowers per pot

Lighting Treatment	Sticking Week	Spacing a			Spacing b			Spacing c			Spacing d			Mean		
		w1	w2	w3	w1	w2	w3	w1	w2	w3	w1	w2	w3	w1	w2	w3
1	40	2	5	1	2	8	2	3	4	4				2	6	2
	45	2	3	3	3	2	1	1	3	2				2	3	2
	50	0	0	1	0	1	1	2	-	1				1	1	1
Mean		*1*	*3*	*2*	*2*	*4*	*1*	*2*	*4*	*2*				*2*	*3*	*2*
2	40	2	1	1	5	3	2	2	2	2				3	2	2
	45	2	2	2	1	1	1	0	1	1				1	1	1
	50	2	4	3	1	1	1	2	2	1				2	2	2
Mean		*2*	*2*	*2*	*2*	*2*	*1*	*1*	*2*	*1*				*2*	*2*	*2*
3	40	3	4	3	2	5	2	2	2	1				2	4	2
	45	3	2	1	1	2	1	1	2	2				2	2	1
	50	2	2	2	1	1	1	0	0	0				1	1	1
Mean		*3*	*3*	*2*	*1*	*3*	*1*	*1*	*1*	*1*				*2*	*2*	*1*
4	40	4	7	3	2	6	2	6	5	4				4	6	3
	45	1	1	1	1	2	1	2	2	2				1	2	1
	50	0	0	0	0	1	1	1	2	2				0	1	1
Mean		*2*	*3*	*1*	*1*	*3*	*1*	*3*	*3*	*3*				*2*	*3*	*2*
5	40	2	3	2	4	4	1	4	2	1				3	3	1
	45	3	4	4	2	2	3	1	1	1				2	2	3
	50	2	3	2	6	4	5	4	4	4				4	4	4
Mean		*2*	*3*	*3*	*4*	*3*	*3*	*3*	*2*	*2*				*3*	*3*	*3*
6	40	6	2	0							5	5	3	6	4	2
	45	0	1	1							1	2	1	1	2	1
	50	0	1	2							2	1	2	1	1	2
Mean		*2*	*1*	*1*							*3*	*3*	*2*	*3*	*2*	*2*

Lighting Treatments:

1. 4.8 W/m^2 throughout S.D. (18/18°C)
2. 12 W/m^2 weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m^2 weeks 1-3 S.D. to 4.8 W/m^2 to marketing (18/18°C)
4. 4.8 W/m^2 weeks 1-7 S.D. to 12 W/m^2 to marketing (18/18°C)
5. 12 W/m^2 weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit (18/18°C)

Spacing Treatments:

a. 24 pots/m^2 weeks 1-2 S.D. to 12.5 pots/m^2 weeks 3 + S.D.
b. 30 pots/m^2 weeks 1-2 S.D. to 15 pots/m^2 weeks 3 + S.D.
c. 36 pots/m^2 weeks 1-2 S.D. to 18 pots/m^2 weeks 3 + S.D.
d. 24 pots/m^2 weeks 1 S.D. to 12.5 pots/m^2 weeks 2 + S.D.

Date of Assessment:

w1. One week after removing sleeves.
w2. Two weeks after removing sleeves.
w3. Three weeks after removing sleeves.

Table 12b: The Influence of Supplementary Lighting, Spacing and Negative DIF Treatments on the Number of Distorted Flowers in Shelf-Life

Variety: Yuba

Mean number of distorted flowers per pot

Lighting Treatment	Sticking Week	Spacing a			Spacing b			Spacing c			Spacing d			Mean		
		w1	w2	w3	w1	w2	w3	w1	w2	w3	w1	w2	w3	w1	w2	w3
1	40	20	5	5	23	12	13	16	10	6				20	9	8
	45	4	-	-	8	9	11	6	5	4				6	7	8
	50	0	3	3	1	4	3	0	4	5				0	4	4
Mean		*8*	*4*	*4*	*11*	*8*	*9*	*7*	*6*	*5*				*9*	*6*	*6*
2	40	9	9	-	8	4	3	11	10	-				9	8	3
	45	3	2	1	3	3	4	6	-	-				4	3	4
	50	1	2	3	1	2	4	2	3	2				1	2	3
Mean		*4*	*4*	*2*	*4*	*3*	*4*	*6*	*7*	*2*				*5*	*4*	*3*
3	40	10	9	8	11	9	5	11	8	10				11	9	8
	45	9	10	11	5	8	7	7	6	5				7	8	8
	50	1	3	6	0	2	-	0	8	6				0	4	6
Mean		*7*	*7*	*8*	*5*	*6*	*6*	*6*	*7*	*7*				*6*	*7*	*7*
4	40	22	9	9	5	8	5	14	17	14				14	11	9
	45	4	3	2	0	3	5	2	5	5				2	4	4
	50	2	6	-	1	1	1	0	1	1				1	3	1
Mean		*9*	*6*	*6*	*2*	*4*	*4*	*5*	*8*	*7*				*6*	*6*	*5*
5	40	5	2	2	6	4	2	3	3	3				5	3	2
	45	10	9	7	7	7	8	3	4	4				7	7	6
	50	25	4	3	4	8	5	2	4	4				10	5	4
Mean		*13*	*5*	*4*	*6*	*6*	*5*	*3*	*4*	*4*				*7*	*5*	*4*
6	40	6	3	3							11	7	5	9	5	4
	45	3	-	1							2	2	1	3	2	1
	50	2	3	3							3	3	4	3	3	4
Mean		*4*	*3*	*2*							*5*	*4*	*3*	*5*	*3*	*3*

Lighting Treatments:

1. 4.8 W/m^2 throughout S.D. (18/18°C)
2. 12 W/m^2 weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m^2 weeks 1-3 S.D. to 4.8 W/m^2 to marketing (18/18°C)
4. 4.8 W/m^2 weeks 1-7 S.D. to 12 W/m^2 to marketing (18/18°C)
5. 12 W/m^2 weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit (18/18°C)

Spacing Treatments:

a. 24 pots/m^2 weeks 1-2 S.D. to 12.5 pots/m^2 weeks 3 + S.D.
b. 30 pots/m^2 weeks 1-2 S.D. to 15 pots/m^2 weeks 3 + S.D.
c. 36 pots/m^2 weeks 1-2 S.D. to 18 pots/m^2 weeks 3 + S.D.
d. 24 pots/m^2 weeks 1 S.D. to 12.5 pots/m^2 weeks 2 + S.D.

Date of Assessment:

w1. One week after removing sleeves.
w2. Two weeks after removing sleeves.
w3. Three weeks after removing sleeves.

Table 12c: The Influence of Supplementary Lighting, Spacing and Negative DIF Treatments on Number of Distorted Flowers in Shelf-Life

Variety: Cerise About Time

Mean number of distorted flowers per pot

Lighting Treatment	Sticking Week	Spacing a w1	w2	w3	Spacing b w1	w2	w3	Spacing c w1	w2	w3	Spacing d w1	w2	w3	Mean w1	w2	w3
1	40	2	0	1	1	1	2							2	1	2
	45	1	1	0	1	2	2							1	2	1
	50	0	0	0	0	0	0							0	0	0
Mean		*1*	*0*	*0*	*1*	*1*	*1*							*1*	*1*	*1*
2	40	1	1	3	1	0	0							1	1	2
	45	0	0	0	0	0	0							0	0	0
	50	0	0	0	0	0	0							0	0	0
Mean		*0*	*0*	*1*	*0*	*0*	*0*							*0*	*0*	*1*
3	40															
	45															
	50															
Mean																
4	40															
	45															
	50															
Mean																
5	40	1	1	1	1	1	0									
	45	0	0	0	0	1	1									
	50	0	0	0	0	0	0									
Mean		*0*	*0*	*0*	*0*	*1*	*0*									
6	40	0	1	1							6	2	1	3	2	1
	45	0	-	0							2	0	0	1	0	0
	50	0	0	0							0	0	0	0	0	0
Mean		*0*	*0*	*0*							*3*	*1*	*0*	*1*	*1*	*0*

Lighting Treatments:

1. 4.8 W/m^2 throughout S.D. (18/18°C)
2. 12 W/m^2 weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m^2 weeks 1-3 S.D. to 4.8 W/m^2 to marketing (18/18°C)
4. 4.8 W/m^2 weeks 1-7 S.D. to 12 W/m^2 to marketing (18/18°C)
5. 12 W/m^2 weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit (18/18°C)

Spacing Treatments:

a. 24 pots/m^2 weeks 1-2 S.D. to 12.5 pots/m^2 weeks 3 + S.D.
b. 30 pots/m^2 weeks 1-2 S.D. to 15 pots/m^2 weeks 3 + S.D.
c. 36 pots/m^2 weeks 1-2 S.D. to 18 pots/m^2 weeks 3 + S.D.
d. 24 pots/m^2 weeks 1 S.D. to 12.5 pots/m^2 weeks 2 + S.D.

Date of Assessment:

w1. One week after removing sleeves.
w2. Two weeks after removing sleeves.
w3. Three weeks after removing sleeves.

APPENDIX II

COMPOST ANALYSES

Table 1: Charm - Compost Analyses (Spacing Treatment - 12.5 pots/m² at final spacing)

Treatment	Stick Week	pH	Ec	NO_3-N	NH_4-N	P	K	Mg
1a	40	5.2	251	149	0.7	24	108	65
	45	5.2	208	115	0.6	15	67	51
	50	5.2	249	210	2.0	33	110	98
Mean		*5.2*	*236*	*158*	*1.1*	*24*	*95*	*71*
2a	40	5.2	286	168	0.5	28	139	76
	45	5.2	200	118	0.4	16	82	46
	50	5.5	200	111	18.0	22	29	69
Mean		*5.3*	*229*	*132*	*6.3*	*22*	*83*	*64*
3a	40	5.2	268	160	3.4	26	98	60
	45	5.0	234	140	0.7	18	80	58
	50	5.4	374	215	14.3	35	115	106
Mean		*5.2*	*292*	*172*	*6.1*	*26*	*98*	*75*
4a	40	5.3	233	121	0.5	19	95	55
	45	5.4	220	127	0.6	16	100	41
	50	5.3	169	102	9.4	19	55	50
Mean		*5.3*	*207*	*117*	*3.5*	*18*	*83*	*49*
5a	40	5.3	235	141	0.7	22	131	52
	45	5.0	203	117	0.9	17	112	37
	50	5.5	306	187	0.4	27	48	111
Mean		*5.3*	*248*	*148*	*0.7*	*22*	*97*	*67*
6a	40	5.4	223	135	0.5	21	102	53
	45	5.2	173	102	0.5	14	76	35
	50	5.4	258	154	0.3	31	60	84
Mean		*5.3*	*218*	*130*	*0.4*	*22*	*79*	*57*
6d†	40	5.4	212	130	0.5	18	97	54
	45	5.2	178	104	0.5	17	84	40
	50	5.5	179	99	0.3	22	47	55
Mean		*5.4*	*189*	*111*	*0.4*	*19*	*76*	*50*

Supplementary Lighting Treatments

1. 4.8 W/m² throughout S.D. (18/18°C)
2. 12 W/m² weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m² weeks 1-3 S.D. to 4.8 W/m² (18/18°C)
4. 4.8 W/m² weeks 1-7 S.D. to 12 W/m² (18/18°C)
5. 12 W/m² weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit

†Note: Treatment d = wider spacing treatment for unlit pots

Table 2: **Charm - Compost Analyses**
(Spacing Treatment - 15 pots/m² at final spacing)

Treatment	Stick Week	pH	Ec	NO_3-N	NH_4-N	P	K	Mg
1b	40	5.2	216	131	0.7	18	119	48
	45	5.1	271	161	0.8	16	67	67
	50	5.5	254	158	2.7	22	41	87
Mean		*5.3*	*247*	*150*	*1.4*	*19*	*75*	*67*
2b	40	5.2	262	156	1.0	27	145	65
	45	5.1	229	132	0.4	19	115	43
	50	5.5	193	112	1.1	21	29	65
Mean		*5.2*	*229*	*133*	*0.8*	*22*	*96*	*58*
3b	40	5.3	220	136	0.8	17	130	56
	45	5.1	292	169	0.9	23	91	69
	50	5.6	221	130	4.5	22	31	80
Mean		*5.3*	*244*	*145*	*2.1*	*21*	*84*	*68*
4b	40	5.3	239	149	0.5	21	85	67
	45	5.2	261	158	0.5	17	74	64
	50	5.5	211	120	4.0	19	35	72
Mean		*5.3*	*237*	*142*	*1.7*	*19*	*65*	*68*
5b	40	5.1	294	139	0.8	25	137	70
	45	4.9	242	143	1.4	17	126	44
	50	5.3	311	187	0.3	30	150	79
Mean		*5.1*	*282*	*156*	*0.8*	*24*	*138*	*64*

Supplementary Lighting Treatments

1. 4.8 W/m² throughout S.D. (18/18°C)
2. 12 W/m² weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m² weeks 1-3 S.D. to 4.8 W/m² (18/18°C)
4. 4.8 W/m² weeks 1-7 S.D. to 12 W/m² (18/18°C)
5. 12 W/m² weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit

Table 3: Charm - Compost Analyses
(Spacing Treatment - 18 pots/m² at final spacing)

Treatment	Stick Week	pH	Ec	NO_3-N	NH_4-N	P	K	Mg
1c	40	5.3	233	146	0.8	21	98	64
	45	5.2	224	131	0.7	15	70	52
	50	5.4	392	240	25.0	32	131	102
Mean		*5.3*	*283*	*172*	*8.8*	*23*	*100*	*73*
2c	40	5.2	244	149	0.5	25	134	59
	45	5.0	214	123	0.5	18	110	40
	50	5.4	219	131	5.3	23	56	70
Mean		*5.2*	*226*	*134*	*2.1*	*22*	*100*	*56*
3c	40	5.3	241	117	1.9	43	128	108
	45	5.0	224	129	0.3	21	76	52
	50	5.5	253	156	18.7	28	91	71
Mean		*5.3*	*239*	*134*	*7.0*	*31*	*98*	*77*
4c	40	5.2	240	150	0.7	19	102	59
	45	5.0	189	110	0.6	15	59	40
	50	5.5	174	103	3.0	15	46	51
Mean		*5.2*	*201*	*121*	*1.4*	*16*	*69*	*50*
5c	40	5.1	265	161	0.6	25	154	58
	45	4.8	234	138	0.9	16	127	39
	50	5.3	274	168	0.9	25	96	77
Mean		*5.1*	*258*	*156*	*0.8*	*22*	*126*	*58*

Supplementary Lighting Treatments

1. 4.8 W/m² throughout S.D. (18/18°C)
2. 12 W/m² weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m² weeks 1-3 S.D. to 4.8 W/m² (18/18°C)
4. 4.8 W/m² weeks 1-7 S.D. to 12 W/m² (18/18°C)
5. 12 W/m² weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit

Table 4: Yuba - Compost Analyses
(Spacing Treatment - 12.5 pots/m^2 at final spacing)

Treatment	Stick Week	pH	Ec	NO_3-N	NH_4-N	P	K	Mg
1a	40	5.5	244	132	0.4	32	83	76
	45	5.6	156	81	0.3	20	53	44
	50	5.6	215	132	1.1	21	42	74
Mean		*5.6*	*205*	*115*	*0.6*	*24*	*59*	*65*
2a	40	5.5	202	105	0.4	28	66	63
	45	5.6	214	119	0.9	27	65	65
	50	5.8	176	94	12.0	23	29	65
Mean		*5.6*	*197*	*106*	*4.4*	*26*	*53*	*64*
3a	40	5.5	180	110	0.6	18	74	44
	45	5.5	198	106	0.7	23	66	54
	50	5.3	322	183	0.4	37	121	89
Mean		*5.4*	*233*	*133*	*0.6*	*26*	*87*	*62*
4a	40	5.6	199	95	0.4	33	47	64
	45	5.5	203	117	0.7	17	70	53
	50	5.4	204	109	1.1	30	50	70
Mean		*5.5*	*202*	*107*	*0.7*	*27*	*56*	*62*
5a	40	5.4	274	158	0.8	37	109	84
	45	5.3	199	117	0.7	17	97	48
	50	5.4	284	151	12.1	36	62	108
Mean		*5.4*	*252*	*142*	*4.5*	*30*	*89*	*80*
6a	40	5.3	192	118	0.5	20	107	45
	45	5.4	176	96	1.0	15	52	46
	50	5.6	169	79	0.4	28	26	62
Mean		*5.4*	*179*	*98*	*0.6*	*21*	*62*	*51*
6d†	40	5.4	190	112	0.5	21	90	45
	45	5.4	178	102	0.6	18	66	46
	50	5.6	185	107	0.7	21	46	60
Mean		*5.5*	*184*	*107*	*0.6*	*20*	*67*	*50*

Supplementary Lighting Treatments

1. 4.8 W/m^2 throughout S.D. (18/18°C)
2. 12 W/m^2 weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m^2 weeks 1-3 S.D. to 4.8 W/m^2 (18/18°C)
4. 4.8 W/m^2 weeks 1-7 S.D. to 12 W/m^2 (18/18°C)
5. 12 W/m^2 weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit

†Note: Treatment d = wider spacing treatment for unlit pots

Table 5: Yuba - Compost Analyses
(Spacing Treatment - 15 pots/m² at final spacing)

Treatment	Stick Week	pH	Ec	NO_3-N	NH_4-N	P	K	Mg
1b	40	5.6	171	101	0.7	16	78	42
	45	5.4	170	92	1.0	16	82	36
	50	5.4	220	114	2.1	31	70	70
Mean		*5.5*	*187*	*102*	*1.3*	*21*	*77*	*49*
2b	40	5.5	191	111	0.7	21	86	49
	45	5.8	185	101	0.8	21	48	56
	50	5.7	179	97	0.4	25	37	69
Mean		*5.7*	*185*	*103*	*0.6*	*22*	*57*	*58*
3b	40	5.5	212	84	0.4	22	66	47
	45	5.7	180	95	0.9	18	59	49
	50	5.6	206	100	0.6	29	44	73
Mean		*5.6*	*199*	*93*	*0.6*	*23*	*56*	*56*
4b	40	5.5	181	111	0.4	18	70	50
	45	5.6	227	126	0.9	19	58	65
	50	5.6	137	73	2.8	18	31	43
Mean		*5.6*	*182*	*103*	*1.4*	*18*	*53*	*53*
5b	40	5.3	278	158	0.4	36	127	78
	45	5.3	206	123	0.8	16	106	47
	50	5.6	261	155	0.9	29	95	88
Mean		*5.4*	*248*	*145*	*0.7*	*27*	*109*	*71*

Supplementary Lighting Treatments

1. 4.8 W/m² throughout S.D. (18/18°C)
2. 12 W/m² weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m² weeks 1-3 S.D. to 4.8 W/m² (18/18°C)
4. 4.8 W/m² weeks 1-7 S.D. to 12 W/m² (18/18°C)
5. 12 W/m² weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit

Table 6: Yuba - Compost Analyses
(Spacing Treatment - 18 pots/m² at final spacing)

Treatment	Stick Week	pH	Ec	NO_3-N	NH_4-N	P	K	Mg
1c	40	5.5	184	107	0.4	21	73	51
	45	5.6	210	119	0.9	20	80	51
	50	5.6	240	139	0.2	28	55	87
Mean		*5.6*	*211*	*122*	*0.5*	*23*	*69*	*63*
2c	40	5.5	192	120	0.7	20	91	50
	45	5.6	199	112	0.8	19	83	51
	50	5.6	195	113	0.3	25	56	66
Mean		*5.6*	*195*	*115*	*0.6*	*21*	*77*	*56*
3c	40	5.4	190	113	0.9	20	96	45
	45	5.6	164	93	0.7	14	83	36
	50	5.7	240	137	0.4	30	84	65
Mean		*5.6*	*198*	*114*	*0.7*	*21*	*88*	*49*
4c	40	5.4	164	96	0.4	19	56	45
	45	5.7	151	86	0.6	15	30	47
	50	5.7	160	75	2.3	26	25	59
Mean		*5.6*	*158*	*86*	*1.1*	*20*	*37*	*50*
5c	40	5.4	239	137	1.4	22	121	60
	45	5.3	232	134	0.8	20	120	54
	50	5.5	316	179	1.3	34	110	99
Mean		*5.4*	*262*	*150*	*1.2*	*25*	*117*	*71*

Supplementary Lighting Treatments

1. 4.8 W/m² throughout S.D. (18/18°C)
2. 12 W/m² weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m² weeks 1-3 S.D. to 4.8 W/m² (18/18°C)
4. 4.8 W/m² weeks 1-7 S.D. to 12 W/m² (18/18°C)
5. 12 W/m² weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit

Table 7: Cerise About Time - Compost Analyses (Spacing Treatment - 12.5 pots/m² at final spacing)

Treatment	Stick Week	pH	Ec	NO_3-N	NH_4-N	P	K	Mg
1a	40	5.4	181	108	0.5	22	58	51
	45	5.5	255	151	1.7	25	65	81
	50	5.2	479	269	1.1	54	136	149
Mean		*5.4*	*305*	*176*	*1.1*	*34*	*86*	*94*
2a	40	5.4	262	139	0.4	36	78	81
	45	5.6	229	136	1.2	26	86	64
	50	5.4	268	135	0.8	40	43	99
Mean		*5.4*	*253*	*137*	*0.8*	*34*	*69*	*81*
3a	40							
	45							
	50							
Mean								
4a	40							
	45							
	50							
Mean								
5a	40	5.3	296	157	1.1	38	103	92
	45	5.4	380	204	1.2	47	114	132
	50	5.2	506	278	2.5	47	162	164
Mean		*5.3*	*394*	*213*	*1.6*	*44*	*126*	*129*
6a	40	5.3	211	129	0.4	21	98	52
	45	5.3	198	117	0.7	18	101	40
	50	5.2	337	193	0.5	45	109	102
Mean		*5.3*	*249*	*146*	*0.5*	*28*	*103*	*65*
6d†	40	5.4	202	109	1.2	22	73	54
	45	5.4	258	145	1.0	29	95	69
	50	5.5	232	120	0.3	36	41	87
Mean		*5.4*	*231*	*125*	*0.8*	*29*	*70*	*70*

Supplementary Lighting Treatments

1. 4.8 W/m² throughout S.D. (18/18°C)
2. 12 W/m² weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m² weeks 1-3 S.D. to 4.8 W/m² (18/18°C)
4. 4.8 W/m² weeks 1-7 S.D. to 12 W/m² (18/18°C)
5. 12 W/m² weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit

†Note: Treatment d = wider spacing treatment for unlit pots

Table 8: **Cerise About Time - Compost Analyses**
(Spacing Treatment - 15 pots/m² at final spacing)

Treatment	Stick Week	pH	Ec	NO_3-N	NH_4-N	P	K	Mg
1b	40	5.4	209	127	0.5	22	96	52
	45	5.3	213	127	0.8	19	70	56
	50	5.4	263	144	15.8	36	35	97
Mean		*5.4*	*228*	*133*	*5.7*	*26*	*67*	*68*
2b	40	5.4	224	135	0.5	24	120	53
	45	5.4	287	170	0.7	28	109	75
	50	5.3	379	190	13.1	53	64	140
Mean		*5.4*	*297*	*165*	*4.8*	*35*	*98*	*89*
3b	40							
	45							
	50							
Mean								
4b	40							
	45							
	50							
Mean								
5b	40	5.2	390	181	0.6	58	106	135
	45	5.3	281	166	0.9	28	116	73
	50	5.3	367	205	5.4	45	151	113
Mean		*5.3*	*346*	*184*	*2.3*	*44*	*124*	*107*

Supplementary Lighting Treatments

1. 4.8 W/m² throughout S.D. (18/18°C)
2. 12 W/m² weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m² weeks 1-3 S.D. to 4.8 W/m² (18/18°C)
4. 4.8 W/m² weeks 1-7 S.D. to 12 W/m² (18/18°C)
5. 12 W/m² weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit

APPENDIX III

ECONOMIC APPRAISAL OF LIGHTING TREATMENTS

COST OF SUPPLEMENTARY LIGHTING FOR POT CHRYSANTHEMUMS

The following presents calculations for the costs of the lighting treatments assessed in this trial. There are a number of variables which will affect final costing. These include the lighting regime itself (of which 4 were assessed in this trial), and the density of pot spacing (3 spacings were examined). Calculations have therefore been presented for each of the supplementary lighting x spacing combinations assessed to illustrate how they influence final cost.

The final cost of lighting will also be affected by items such as the capital cost of lamps, electricity charges and interest rates on loans. To illustrate the impact that changes in the cost of these basic items can have on final costs, all calculations have been based on two separate sets of assumptions. The first set is based on costings calculated for the 1991/92 HDC funded work PC13b (Finlay, 1993) and PC13c (Wilson, 1994a). The second set is based on updated figures collected from the Electricity Association and Royal Bank of Scotland. (The latter set of figures are presented in italics to separate them from the former set).

Assumptions

1. Capital cost of 400W SON/T lamp & installation = £160* *or (£150)°*

2. Illuminance 12 W/m² 1 lamp covers 6m²
   4.8 W/m² 1 lamp covers 14m²

3. Annual capital cost per luminaire assuming amortized over 5 years at 14%* *(or 9%°)*

   $\frac{£160}{5\text{ yrs}} + \left(\frac{80}{100} \times 14\%\right) = £43.20$ *or* $\frac{150}{5\ yrs} + \left(\frac{80}{100} \times 9\%\right) = £37.20$

4. Annual capital cost per m²

   at 12 W/m² = $\frac{43.2}{6}$ = £7.20/m²/year *or* $\frac{37.2}{6}$ =*£6.20/m²/year*

   at 4.8 W/m² = $\frac{43.2}{14}$ = £3.09/m²/year *or* $\frac{37.2}{14}$ =*£2.66/m²/year*

5. S.D. lighting for 11 hours/day (07.00 - 18.00)

6. Lighting period - October - February = 20 weeks.

   Trial period = 20 weeks but commercial winter production period = 26 weeks. Hence calculations are based on commercial standard of 26 weeks.

7. Electricity running costs

Standard	7 am - midnight	7.78p/kWhr*	*or 5.50p/kWhr°*
Off-Peak	Midnight - 7 am	2.61p/kWhr*	*or 3.00p/kWhr °*

   Each luminaire requires 0.44 kW per hour i.e. 400 watts per lamp plus 40 watts for starter equipment.

8. Average production time (to marketing stage 3)

   at 12 W/m² weeks 1-3 SD = 75 days (including 14 days in propagation)
   at 4.8 W/m² throughout SD = 77 days (including 14 days in propagation)

* Assumed cost in original costings calculated for the 1991/92 HDC funded work.
° Assumed cost according to average figures in 1995.

A. Capital Cost

Treatment 1 S.D. at 4.8 W/m² throughout

At intermediate spacing (weeks 1-2) and 4.8 W/m², 1m² will service 13 crops at the following densities:

a. 24 pots/m² x 13 crops = 312 pots
b. 30 pots/m² x 13 crops = 390 pots
c. 36 pots/m² x 13 crops = 468 pots

Capital cost per density:

a = $\frac{309}{312}$ = 1.0p/pot *or* $\frac{266}{312}$ = *0.9p/pot*

b = $\frac{309}{390}$ = 0.8p/pot *or* $\frac{266}{390}$ = *0.7p/pot*

c = $\frac{309}{468}$ = 0.7p/pot *or* $\frac{266}{468}$ = *0.6p/pot*

At final spacing (weeks 3-9) and 4.8 W/m², 1m² will service 3.7 crops at the following densities:

a. 12.5 pots/m² x 3.7 crops = 46.3 pots
b. 15 pots/m² x 3.7 crops = 55.5 pots
c. 18 pots/m² x 3.7 crops = 66.6 pots

Capital cost per density:

a = $\frac{309}{46.3}$ = 6.7p/pot *or* $\frac{266}{46.3}$ = *5.7p/pot*

b = $\frac{309}{55.5}$ = 5.6p/pot *or* $\frac{266}{55.5}$ = *4.8p/pot*

c = $\frac{309}{66.6}$ = 4.6p/pot *or* $\frac{266}{66.6}$ = *4.0p/pot*

Total capital cost per density:

a = 1.0 + 6.7 = 7.7p/pot *or* *0.9 + 5.7 = 6.6p/pot*
b = 0.8 + 5.6 = 6.4p/pot *or* *0.7 + 4.8 = 5.5p/pot*
c = 0.7 + 4.6 = 5.3p/pot *or* *0.6 + 4.0 = 4.6p/pot*

Treatment 2 S.D. at 12 W/m² weeks 1-3 only

At intermediate spacing (weeks 1-2) and 12 W/m², 1m² will service 13 crops at the following densities:

a. 24 pots/m² x 13 crops = 312 pots
b. 30 pots/m² x 13 crops = 390 pots
c. 36 pots/m² x 13 crops = 468 pots

Capital cost per density:

a = $\frac{720}{312}$ = 2.3p/pot *or* $\frac{620}{312}$ = *2.0p/pot*

b = $\frac{720}{390}$ = 1.8p/pot *or* $\frac{620}{390}$ = *1.6p/pot*

c = $\frac{720}{468}$ = 1.5p/pot *or* $\frac{620}{468}$ = *1.3p/pot*

At final spacing (week 3) and 12 W/m², 1m² will service 26 crops at the following densities:

a. 12.5 pots/m² x 26 crops = 325 pots
b. 15 pots/m² x 26 crops = 390 pots
c. 18 pots/m² x 26 crops = 468 pots

Capital cost per density:

a = $\frac{720}{325}$ = 2.2p/pot *or* $\frac{620}{325}$ = *1.9p/pot*

b = $\frac{720}{390}$ = 1.8p/pot *or* $\frac{620}{390}$ = *1.6p/pot*

c = $\frac{720}{468}$ = 1.5p/pot *or* $\frac{620}{468}$ = *1.3p/pot*

Total capital cost per density:

a = 2.3 + 2.2 = 4.5p/pot *or* *2.0 + 1.9 = 3.9p/pot*
b = 1.8 + 1.8 = 3.6p/pot *or* *1.6 + 1.6 = 3.2p/pot*
c = 1.5 + 1.5 = 3.0p/pot *or* *1.3 + 1.3 = 2.6p/pot*

Treatment 3 S.D. at 12 W/m² for weeks 1-3 followed by 4.8 W/m² weeks 4-9

At intermediate spacing (weeks 1-2) and 12 W/m², 1m² will service 13 crops at the following densities:

a. 24 pots/m² x 13 crops = 312 pots
b. 30 pots/m² x 13 crops = 390 pots
c. 36 pots/m² x 13 crops = 468 pots

Capital cost per density:

a = $\frac{720}{312}$ = 2.3p/pot *or* $\frac{620}{312}$ = *2.0p/pot*

b = $\frac{720}{390}$ = 1.8p/pot *or* $\frac{620}{390}$ = *1.6p/pot*

c = $\frac{720}{468}$ = 1.5p/pot *or* $\frac{620}{468}$ = *1.3p/pot*

At final spacing (week 3) and 12 W/m², 1m² will service 26 crops at the following densities:

a. 12.5 pots/m² x 26 crops = 325 pots
b. 15 pots/m² x 26 crops = 390 pots
c. 18 pots/m² x 26 crops = 468 pots

Capital cost per density:

a = $\frac{720}{325}$ = 2.2p/pot *or* $\frac{620}{325}$ = *1.9p/pot*

b = $\frac{720}{390}$ = 1.8p/pot *or* $\frac{620}{390}$ = *1.6p/pot*

c = $\frac{720}{468}$ = 1.5p/pot *or* $\frac{620}{468}$ = *1.3p/pot*

At final spacing (weeks 4-9) and 4.8 W/m², 1m² will service 4.3 crops at the following densities:

a. 12.5 pots/m² x 4.3 crops = 53.8 pots
b. 15 pots/m² x 4.3 crops = 64.5 pots
c. 18 pots/m² x 4.3 crops = 77.4 pots

Capital cost per density:

a = $\frac{309}{53.8}$ = 5.7p/pot *or* $\frac{266}{53.8}$ = *4.9p/pot*

b = $\frac{309}{64.5}$ = 4.8p/pot *or* $\frac{266}{64.5}$ = *4.1p/pot*

c = $\frac{309}{77.4}$ = 4.0p/pot *or* $\frac{266}{77.4}$ = *3.4p/pot*

Total capital cost per density:

a = 2.3 + 2.2 + 5.7 = 10.2p/pot *or* *2.0 + 1.9 + 4.9 = 8.8p/pot*

b = 1.8 + 1.8 + 4.8 = 8.4p/pot *or* *1.6 + 1.6 + 4.1 = 7.3p/pot*

c = 1.5 + 1.5 + 4.0 = 7.0p/pot *or* *1.3 + 1.3 + 3.4 = 6.0p/pot*

Treatment 4 S.D. at 4.8 W/m² weeks 1-7 followed by 12 W/m² weeks 8-9

At intermediate spacing (weeks 1-2) and 4.8 W/m², 1m² will service 13 crops at the following densities:

a. 24 pots/m² x 13 crops = 312 pots
b. 30 pots/m² x 13 crops = 390 pots
c. 36 pots/m² x 13 crops = 468 pots

Capital cost per density:

a = $\frac{309}{312}$ = 1.0p/pot *or* $\frac{266}{312}$ = *0.9p/pot*

b = $\frac{309}{390}$ = 0.8p/pot *or* $\frac{266}{390}$ = *0.7p/pot*

c = $\frac{309}{468}$ = 0.7p/pot *or* $\frac{266}{468}$ = *0.6p/pot*

At final spacing (week 3) and 4.8 W/m², 1m² will service 26 crops at the following densities:

a. 12.5 pots/m² x 26 crops = 325 pots
b. 15 pots/m² x 26 crops = 390 pots
c. 18 pots/m² x 26 crops = 468 pots

Capital cost per density:

a = $\frac{309}{325}$ = 1.0p/pot *or* $\frac{266}{325}$ = *0.8p/pot*

b = $\frac{309}{390}$ = 0.8p/pot *or* $\frac{266}{390}$ = *0.7p/pot*

c = $\frac{309}{468}$ = 0.7p/pot *or* $\frac{266}{468}$ = *0.6p/pot*

At final spacing (weeks 4-7) 1m² will service 6.5 crops at the following densities:

a. 12.5 pots/m² x 6.5 crops = 81.3 pots
b. 15 pots/m² x 6.5 crops = 97.5 pots
c. 18 pots/m² x 6.5 crops = 117 pots

Capital cost per density:

a = $\frac{309}{81.3}$ = 3.8p/pot *or* $\frac{266}{81.3}$ = *3.3p/pot*

b = $\frac{309}{97.5}$ = 3.2p/pot *or* $\frac{266}{97.5}$ = *2.7p/pot*

c = $\frac{309}{117}$ = 2.6p/pot *or* $\frac{266}{117}$ = *2.3p/pot*

At final spacing (weeks 8-9) 1m² will service 13 crops at the following densities:

a. 12.5 pots/m² x 13 crops = 162.5 pots
b. 15 pots/m² x 13 crops = 195.0 pots
c. 18 pots/m² x 13 crops = 234.0 pots

Capital cost per density:

a = $\frac{720}{162.5}$ = 4.4p/pot *or* $\frac{620}{162.5}$ = *3.8p/pot*

b = $\frac{720}{195.0}$ = 3.7p/pot *or* $\frac{620}{195.0}$ = *3.2p/pot*

c = $\frac{720}{234.0}$ = 3.1p/pot *or* $\frac{620}{234.0}$ = *2.6p/pot*

Total capital cost per density:

a = 1.0 + 1.0 + 3.8 + 4.4 = 10.2p/pot
or *0.9 + 0.8 + 3.3 + 3.8 = 8.8p/pot*

b = 0.8 + 0.8 + 3.2 + 3.7 = 8.5p/pot
or *0.7 + 0.7 + 2.7 + 3.2 = 7.3p/pot*

c = 0.7 + 0.7 + 2.6 + 3.1 = 7.1p/pot
or 0.6 + 0.6 + 2.3 + 2.6 = 6.1p/pot

B. Running Cost

Treatment 1 S.D. at 4.8 W/m² throughout

i) Based on costings used in the 1991/92 HDC funded work (PC13b):

2 weeks at intermediate spacing plus 7 weeks at final spacing

At intermediate spacing for 2 weeks (4.8 W/m²) =

$$\frac{0.44 \text{ kW} \times 11 \text{ hrs} \times 14 \text{ days} \times 7.78\text{p/kWhr}}{14\text{m}^2} = 37.7\text{p/m}^2$$

Running cost per density:

a = $\frac{37.7}{24}$ = 1.6p/pot

b = $\frac{37.7}{30}$ = 1.3p/pot

c = $\frac{37.7}{36}$ = 1.0p/pot

At final spacing for 7 weeks (4.8 W/m²) =

$$\frac{0.44 \text{ kW} \times 11 \text{ hrs} \times 49 \text{ days} \times 7.78\text{p/kWhr}}{14\text{m}^2} = 131.8\text{p/m}^2$$

Running cost per density:

a = $\frac{131.8}{12.5}$ = 10.5p/pot

b = $\frac{131.8}{15}$ = 8.8p/pot

c = $\frac{131.8}{18}$ = 7.3p/pot

Total Running Cost per Density:

a = 1.6 + 10.5 = 12.1p/pot
b = 1.3 + 8.8 = 10.1p/pot
c = 1.0 + 7.3 = 8.3p/pot

or

ii) Based on average figures current in 1995:

At intermediate spacing for 2 weeks (4.8 W/m²) =

$$\frac{0.44\ kW \times 11\ hrs \times 14\ days \times 5.50p/kWhr}{14m^2} = 26.6p/m^2$$

Running cost per density:

$a = \frac{26.6}{24} = 1.1p/pot$

$b = \frac{26.6}{30} = 0.9p/pot$

$c = \frac{26.6}{36} = 0.7p/pot$

At final spacing for 7 weeks (4.8 W/m²) =

$$\frac{0.44\ kW \times 11\ hrs \times 49\ days \times 5.50p/kWhr}{14m^2} = 93.2p/m^2$$

Running cost per density:

$a = \frac{93.2}{12.5} = 7.5p/pot$

$b = \frac{93.2}{15} = 6.2p/pot$

$c = \frac{93.2}{18} = 5.2p/pot$

Total Running Cost per Density:

$a = 1.1 + 7.5 = 8.6p/pot$
$b = 0.9 + 6.2 = 7.1p/pot$
$c = 0.7 + 5.2 = 5.9p/pot$

Treatment 2 S.D. at 12 W/m² weeks 1-3 only

2 weeks at intermediate spacing , plus 1 week at final spacing under lighting, and 6 weeks at final spacing unlit

i) Based on costings used in the 1991/92 HDC funded work (PC13b):

At intermediate spacing for 2 weeks (12 W/m²) =

$$\frac{0.44 \text{ kW} \times 11 \text{ hrs} \times 14 \text{ days} \times 7.78\text{p/kWhr}}{6\text{m}^2} = 87.9\text{p/m}^2$$

Running cost per density:

a = $\frac{87.9}{24}$ = 3.7p/pot

b = $\frac{87.9}{30}$ = 2.9p/pot

c = $\frac{87.9}{36}$ = 2.4p/pot

At final spacing for 1 week (12 W/m²) =

$$\frac{0.44 \text{ kW} \times 11 \text{ hrs} \times 7 \text{ days} \times 7.78\text{p/kWhr}}{6\text{m}^2} = 43.9\text{p/m}^2$$

Running cost per density:

a = $\frac{43.9}{12.5}$ = 3.5p/pot

b = $\frac{43.9}{15}$ = 2.9p/pot

c = $\frac{43.9}{18}$ = 2.4p/pot

Total Running Cost per Density:

a = 3.7 + 3.5 = 7.2p/pot
b = 2.9 + 2.9 = 5.8p/pot
c = 2.4 + 2.4 = 4.8p/pot

or

i) Based on average figures current in 1995:

At intermediate spacing for 2 weeks (12 W/m²) =

$$\frac{0.44\ kW \times 11\ hrs \times 14\ days \times 5.50p/kWhr}{6m^2} = 62.1p/m^2$$

Running cost per density:

$$a = \frac{62.1}{24} = 2.6p/pot$$

$$b = \frac{62.1}{30} = 2.1p/pot$$

$$c = \frac{62.1}{36} = 1.7p/pot$$

At final spacing for 1 week (12 W/m²) =

$$\frac{0.44\ kW \times 11\ hrs \times 7\ days \times 5.50p/kWhr}{6m^2} = 31.1p/m^2$$

Running cost per density:

$$a = \frac{31.1}{12.5} = 2.5p/pot$$

$$b = \frac{31.1}{15} = 2.1p/pot$$

$$c = \frac{31.1}{18} = 1.7p/pot$$

Total Running Cost per Density:

$$a = 2.6 + 2.5 = 5.1p/pot$$
$$b = 2.1 + 2.1 = 4.2p/pot$$
$$c = 1.7 + 1.7 = 3.4p/pot$$

Treatment 3 S.D. at 12 W/m² weeks 1-3 followed by 4.8 W/m² weeks 4-10

2 weeks at intermediate spacing at 12 W/m², 1 week at final spacing at 12 W/m², 6 weeks at final spacing at 4.8 W/m²

i) Based on costings used in the 1991/92 HDC funded work (PC13b):

At intermediate spacing for 2 weeks (12 W/m²) =

$$\frac{0.44\ \text{kW} \times 11\ \text{hrs} \times 14\ \text{days} \times 7.78\text{p/kWhr}}{6\text{m}^2} = 87.9\text{p/m}^2$$

Running cost per density:

a = $\frac{87.9}{24}$ = 3.7p/pot

b = $\frac{87.9}{30}$ = 2.9p/pot

c = $\frac{87.9}{36}$ = 2.4p/pot

At final spacing for 1 week (12 W/m²) =

$$\frac{0.44\ \text{kW} \times 11\ \text{hrs} \times 7\ \text{days} \times 7.78\text{p/kWhr}}{6\text{m}^2} = 43.9\text{p/m}^2$$

Running cost per density:

a = $\frac{43.9}{12.5}$ = 3.5p/pot

b = $\frac{43.9}{15}$ = 2.9p/pot

c = $\frac{43.9}{18}$ = 2.4p/pot

At final spacing for 6 weeks (4.8 W/m²) =

$$\frac{0.44\ \text{kW} \times 11\ \text{hrs} \times 42\ \text{days} \times 7.78\text{p/kWhr}}{14\text{m}^2} = 113.0\text{p/m}^2$$

Running cost per density:

a = $\frac{113.0}{12.5}$ = 9.0p/pot

b = $\frac{113.0}{15}$ = 7.5p/pot

c = $\frac{113.0}{18}$ = 6.3p/pot

Total Running Cost per Density:

a = 3.7 + 3.5 + 9.0 = 16.2p/pot
b = 2.9 + 2.9 + 7.5 = 13.3p/pot
c = 2.4 + 2.4 + 6.3 = 11.1p/pot

or

ii) Based on average figures current in 1995:

At intermediate spacing for 2 weeks (12 W/m²) =

$$\frac{0.44\ kW \times 11\ hrs \times 14\ days \times 5.50p/kWhr}{6m^2} = 62.1p/m^2$$

Running cost per density:

a = $\frac{62.1}{24}$ = *2.6p/pot*

b = $\frac{62.1}{30}$ = *2.1p/pot*

c = $\frac{62.1}{36}$ = *1.7p/pot*

At final spacing for 1 week (12 W/m²) =

$$\frac{0.44\ kW \times 11\ hrs \times 7\ days \times 5.50p/kWhr}{6m^2} = 31.1p/m^2$$

Running cost per density:

a = $\frac{31.1}{12.5}$ = *2.5p/pot*

b = $\frac{31.1}{15}$ = *2.1p/pot*

c = $\frac{31.1}{18}$ = *1.7p/pot*

At final spacing for 6 weeks (4.8 W/m²) =

$$\frac{0.44\ kW \times 11\ hrs \times 42\ days \times 5.50p/kWhr}{14m^2} = 79.9p/m^2$$

Running cost per density:

a = $\frac{79.9}{12.5}$ = *6.4p/pot*

b = $\frac{79.9}{15}$ = *5.3p/pot*

c = $\frac{79.9}{18}$ = *4.4p/pot*

Total Running Cost per Density:

a	=	2.6 + 2.5 + 6.4	=	11.5p/pot
b	=	2.1 + 2.1 + 5.3	=	9.5p/pot
c	=	1.7 + 1.7 + 4.4	=	7.8p/pot

Treatment 4 S.D. at 4.8 W/m² weeks 1-7 followed by 12 W/m² weeks 8-9

2 weeks at intermediate spacing at 4.8 W/m², 5 weeks at final spacing at 4.8 W/m², 2 weeks at final spacing at 12 W/m²

i) Based on costings used in the 1991/92 HDC funded work (PC13b):

At intermediate spacing for 2 weeks (4.8 W/m²) =

$$\frac{0.44 \text{ kW} \times 11 \text{ hrs} \times 14 \text{ days} \times 7.78\text{p/kWhr}}{14\text{m}^2} = 37.7\text{p/m}^2$$

Running cost per density:

a = $\frac{37.7}{24}$ = 1.6p/pot

b = $\frac{37.7}{30}$ = 1.3p/pot

c = $\frac{37.7}{36}$ = 1.0p/pot

At final spacing for 5 weeks (4.8 W/m²) =

$$\frac{0.44 \text{ kW} \times 11 \text{ hrs} \times 35 \text{ days} \times 7.78\text{p/kWhr}}{14\text{m}^2} = 94.1\text{p/m}^2$$

Running cost per density:

a = $\frac{94.1}{12.5}$ = 7.5p/pot

b = $\frac{94.1}{15}$ = 6.3p/pot

c = $\frac{94.1}{18}$ = 5.2p/pot

At final spacing for 2 weeks (12 W/m²) =

$$\frac{0.44 \text{ kW} \times 11 \text{ hrs} \times 14 \text{ days} \times 7.78\text{p/kWhr}}{6\text{m}^2} = 87.9\text{p/m}^2$$

Running cost per density:

a = $\frac{87.9}{12.5}$ = 7.0p/pot

b = $\frac{87.9}{15}$ = 5.9p/pot

c = $\frac{87.9}{18}$ = 4.9p/pot

Total Running Cost per Density:

a = 1.6 + 7.5 + 7.0 = 16.1p/pot
b = 1.3 + 6.3 + 5.9 = 13.5p/pot
c = 1.0 + 5.2 + 4.9 = 11.1p/pot

or

ii) Based on average figures current in 1995:

At intermediate spacing for 2 weeks (4.8 W/m²) =

$$\frac{0.44\ kW \times 11\ hrs \times 14\ days \times 5.50p/kWhr}{14m^2} = 26.6p/m^2$$

Running cost per density:

a = $\frac{26.6}{24}$ = *1.1p/pot*

b = $\frac{26.6}{30}$ = *0.9p/pot*

c = $\frac{26.6}{36}$ = *0.7p/pot*

At final spacing for 5 weeks (4.8 W/m²) =

$$\frac{0.44\ kW \times 11\ hrs \times 35\ days \times 5.50p/kWhr}{14m^2} = 66.6p/m^2$$

Running cost per density:

a = $\frac{66.6}{12.5}$ = *5.3p/pot*

b = $\frac{66.6}{15}$ = *4.4p/pot*

c = $\frac{66.6}{18}$ = *3.7p/pot*

At final spacing for 2 weeks (12 W/m²) =

$$\frac{0.44\ kW \times 11\ hrs \times 14\ days \times 5.50p/kWhr}{6m^2} = 62.1p/m^2$$

Running cost per density:

$$a = \frac{62.1}{12.5} = 5.0p/pot$$

$$b = \frac{62.1}{15} = 4.1p/pot$$

$$c = \frac{62.1}{18} = 3.5p/pot$$

Total Running Cost per Density:

$$a = 1.1 + 5.3 + 5.0 = 11.4p/pot$$
$$b = 0.9 + 4.4 + 4.1 = 9.4p/pot$$
$$c = 0.7 + 3.7 + 3.5 = 7.9p/pot$$

Table 1 Overall cost of treatments

	Capital		Cost (p/pot) Running		Total	
1. 4.8 W/m² throughout S.D. (i.e. 10 weeks)						
Standard spacing (24 pots/m² wks 1-2, 12.5 pots/m² wks 3+)	7.7*	*(6.6)°*	12.1*	*(8.6)°*	19.8*	*(15.2)°*
Close spacing 1 (30 pots/m² wks 1-2, 15 pots/m² wks 3+)	6.4	*(5.5)*	10.1	*(7.1)*	16.5	*(12.6)*
Close spacing 2 (36 pots/m² wks 1-2, 18 pots/m² wks 3+)	5.3	*(4.6)*	8.3	*(5.9)*	13.6	*(10.5)*
2. 12 W/m² weeks 1-3 S.D.						
Standard spacing (24 pots/m² wks 1-2, 12.5 pots/m² wks 3+)	4.5	*(3.9)*	7.2	*(5.1)*	11.7	*(9.0)*
Close spacing 1 (30 pots/m² wks 1-2, 15 pots/m² wks 3+)	3.6	*(3.2)*	5.8	*(4.2)*	9.4	*(7.4)*
Close spacing 2 (36 pots/m² wks 1-2, 18 pots/m² wks 3+)	3.0	*(2.6)*	5.3	*(3.4)*	8.3	*(6.0)*
3. 12 W/m² weeks 1-3 S.D. to 4.8 W/m² weeks 4-9 S.D.						
Standard spacing (24 pots/m² wks 1-2, 12.5 pots/m² wks 3+)	10.2	*(8.8)*	16.2	*(11.5)*	26.4	*(20.3)*
Close spacing 1 (30 pots/m² wks 1-2, 15 pots/m² wks 3+)	8.4	*(7.3)*	13.3	*(9.5)*	21.7	*(16.8)*
Close spacing 2 (36 pots/m² wks 1-2, 18 pots/m² wks 3+)	7.0	*(6.0)*	11.1	*(7.8)*	18.1	*(13.8)*
4. 4.8 W/m² weeks 1-7 S.D. to 12 W/m² weeks 8-9 S.D.						
Standard spacing (24 pots/m² wks 1-2, 12.5 pots/m² wks 3+)	10.2	*(8.8)*	16.1	*(11.4)*	26.3	*(20.2)*
Close spacing 1 (30 pots/m² wks 1-2, 15 pots/m² wks 3+)	8.5	*(7.3)*	13.5	*(9.4)*	22.0	*(16.7)*
Close spacing 2 (36 pots/m² wks 1-2, 18 pots/m² wks 3+)	7.1	*(6.1)*	11.1	*(7.9)*	18.2	*(14.0)*

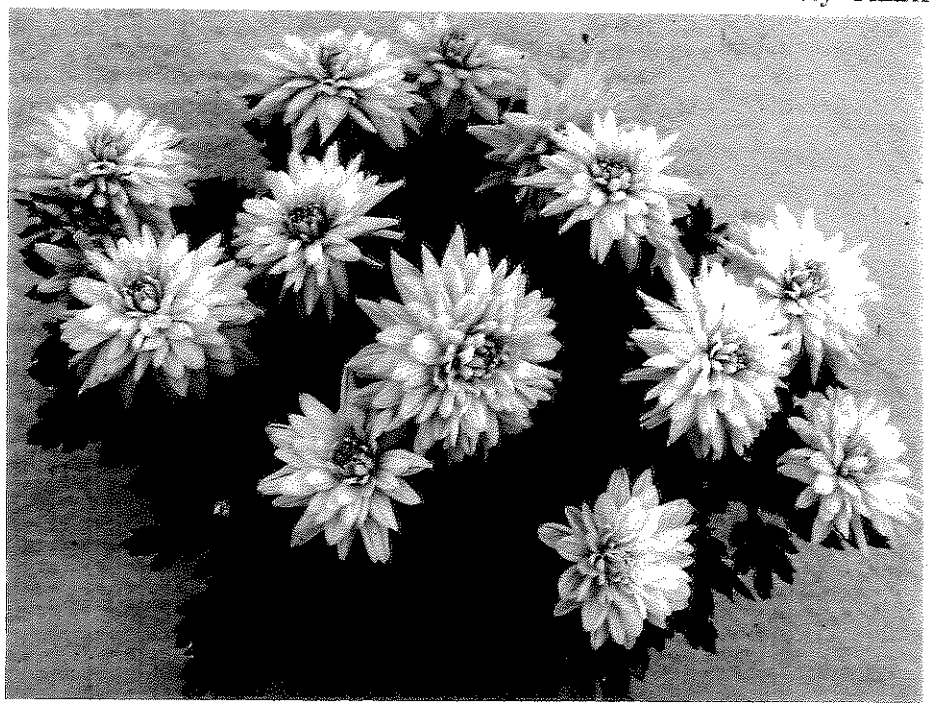
* Based on costings calculated in the 1991/92 HDC funded work (PC13b)
° Based on figures current in 1995.

APPENDIX IV

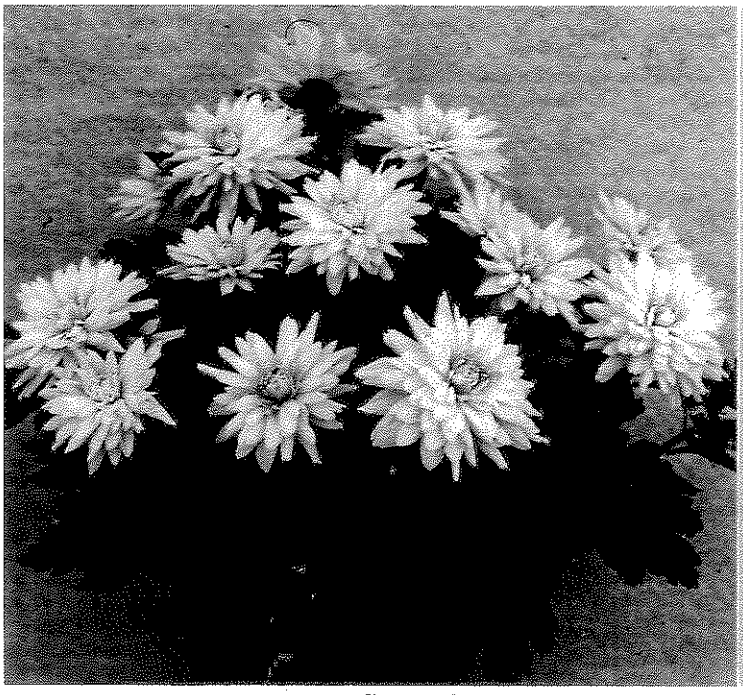
PHOTOGRAPHIC RECORDS

Plate 1

Illustration of deterioration scores for shelf-life assessments for the variety Charm



Score 1



Score 2

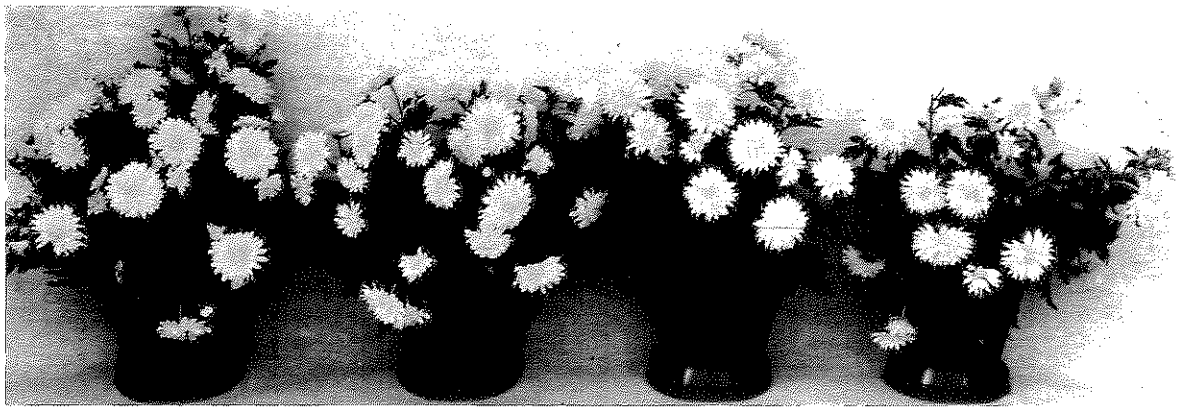
Score 3

Key

Score 1 = Minor overall deterioration
Score 2 = Moderate overall deterioration
Score 3 = Severe overall deterioration

Plate 2

Illustration of deterioration scores for shelf-life assessments for the variety Yuba



Score 0 Score 1 Score 2 Score 3

Illustration of distorted flowers developing in shelf-life for the variety Yuba

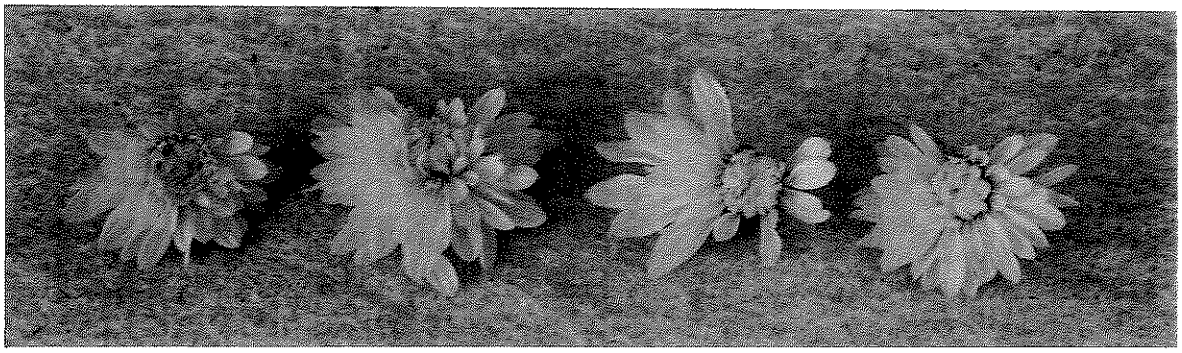


Illustration of petal fade during shelf-life for the variety Cerise About Time

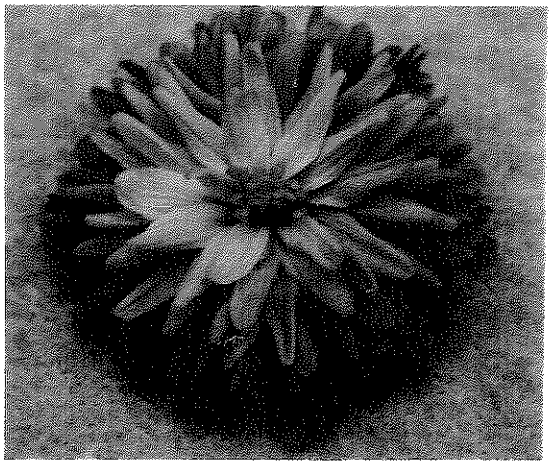
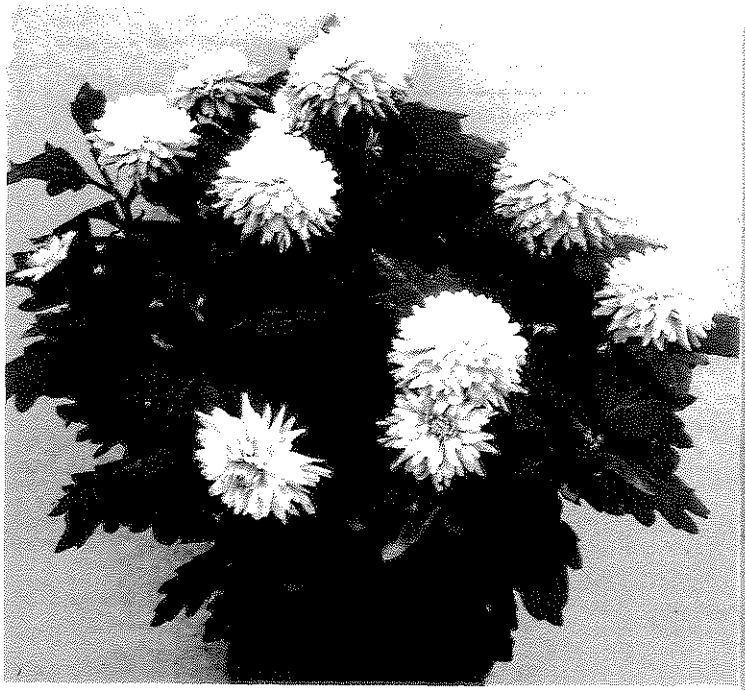


Plate 3

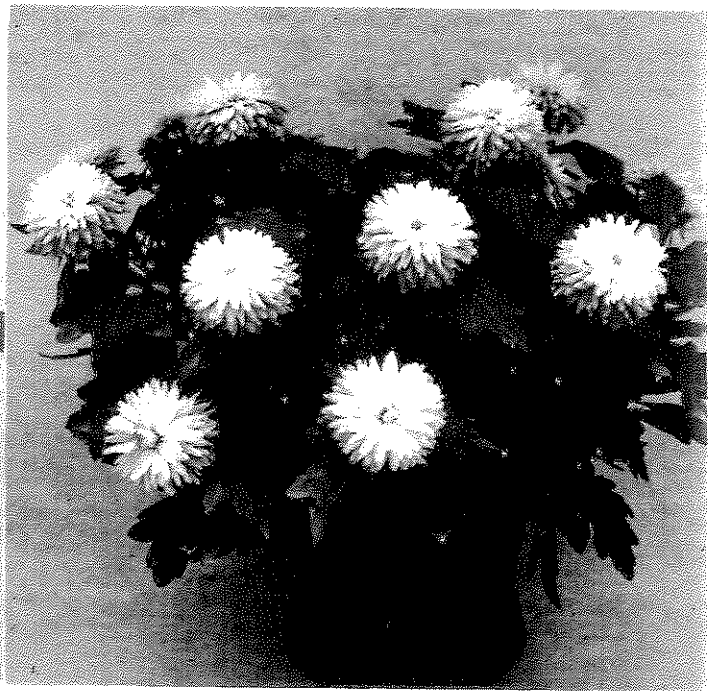
Illustration of deterioration scores for shelf-life assessments for the variety Cerise About Time

Score 0

Score 1



Score 2



Score 3

Key

Score 0 = No overall deterioration
Score 1 = Minor overall deterioration
Score 2 = Moderate overall deterioration
Score 3 = Severe overall deterioration

Plate 4

Illustration of leaf damage scores for assessments at marketing and during shelf-life

Variety: Cerise About Time

Score 0 Score 1

Variety: Yuba

Score 0 Score 1 Score 2

Key

Score 0 = No leaf damage
Score 1 = Minor leaf damage (particularly of lower leaves)
Score 2 = Moderate leaf damage (particularly of lower leaves)

Plate 5

Treatment comparisons for the variety Charm

i) **Supplementary lighting treatments**

4.8 W/m² throughout SD	12 W/m² weeks 1-3 SD only	12 W/m² weeks 1-3 SD to 4.8 W/m²	4.8 W/m² weeks 1-7 SD to 12 W/m²

ii) **Closer spacing treatments**

12.5 pots/m² final spacing	15 pots/m² final spacing	18 pot/m² final spacing

iii) **Negative DIF combined with lighting at 12 W/m² weeks 1-3 SD only**

Standard temperature regime — Negative DIF temperature Regime

Plate 6

Treatment comparisons for the variety Yuba

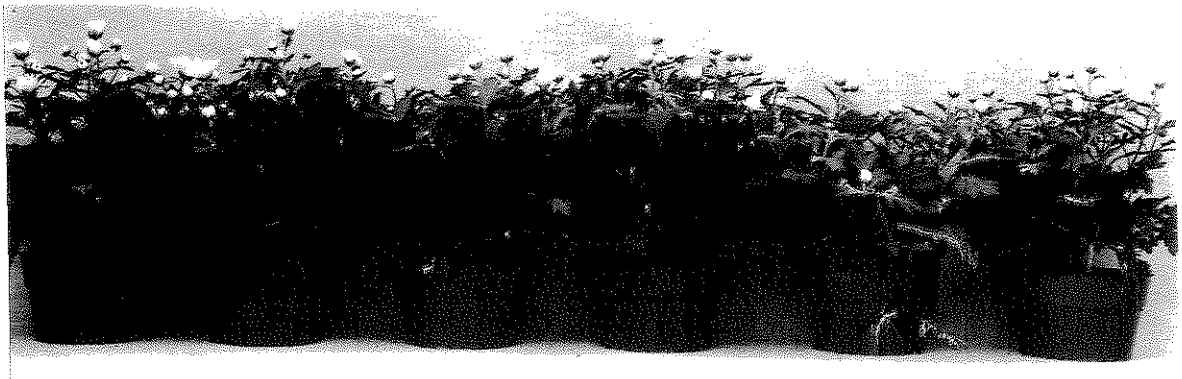
i) **Supplementary lighting treatments**

4.8 W/m² throughout SD	12 W/m² weeks 1-3 SD only	12 W/m² weeks 1-3 SD to 4.8 W/m²	4.8 W/m² weeks 1-7 SD to 12 W/m²

ii) **Closer spacing treatments**

12.5 pots/m² final spacing	15 pots/m² final spacing	18 pot/m² final spacing

iii) **Negative DIF combined with lighting at 12 W/m² weeks 1-3 SD only**



Standard temperature regime	Negative DIF temperature Regime

Plate 7

Treatment comparisons for the variety Cerise About Time

i) **Supplementary lighting treatments**

4.8 W/m² throughout SD

12 W/m² weeks 1-3 SD only

No Supplementary Lighting

ii) **Closer spacing treatments**

12.5 pots/m² final spacing

15 pots/m² final spacing

iii) **Negative DIF combined with lighting at 12 W/m² weeks 1-3 SD only**

Standard temperature regime

Negative DIF temperature regime

APPENDIX V

CROP DIARIES

WEEK 40 STUCK PLANTS

DATE	OPERATION
06/10/94	Cuttings stuck. Cyclic lighting on.
06/10/94	Mycotal 1.0 g/l and Vertilec 2.0 g/l, preventative insecticide.
20/10/94	Pots moved to treatments at intermediate spacing (treatment d, kept at pot thick). Cyclic lighting off.
23/10/94	Malathion 1.8 mls/l, preventative insecticide.
27/10/94	Yuba and Cerise About Time plants pinched.
27/10/94	Treatment d, spacing pots moved to 12.5 pots/m^2 spacing.
28/10/94	Charm plants pinched in DIF treatment only.
30/10/94	Malathion 1.8 mls/l, preventative insecticide.
01/11/94	Charm plants pinched all remaining treatments.
03/11/94	Standard and close spacing treatments moved to final spacing.
06/11/94	Thiodan 2 mls/l, preventative insecticide.
10/11/94	Pots moved from 12 W/m^2 to unlit or 4.8 W/m^2 for lighting treatments 2 and 3 respectively.
11/11/94	B-Nine 1.5 g/l, all plots except DIF treatments, chemical plant growth regulation.
13/11/94	Malathion 1.8 mls/l, preventative insecticide.
20/11/94	Dichlorvos 1 ml/l, preventative insecticide.
24/11/94	Pots moved from 12 W/m^2 to unlit or 4.8 W/m^2 for lighting treatments 2 and 3 respectively.
27/11/94	Thiodan 2 mls/l, preventative insecticide.
30/11/94	Zineb 2g/l, preventative fungicide.
04/12/94	Malathion 1.8 mls/l, preventative insecticide.
08/12/94	Treatment 4 pots moved to 12 W/m^2.

WEEK 45 STUCK PLANTS

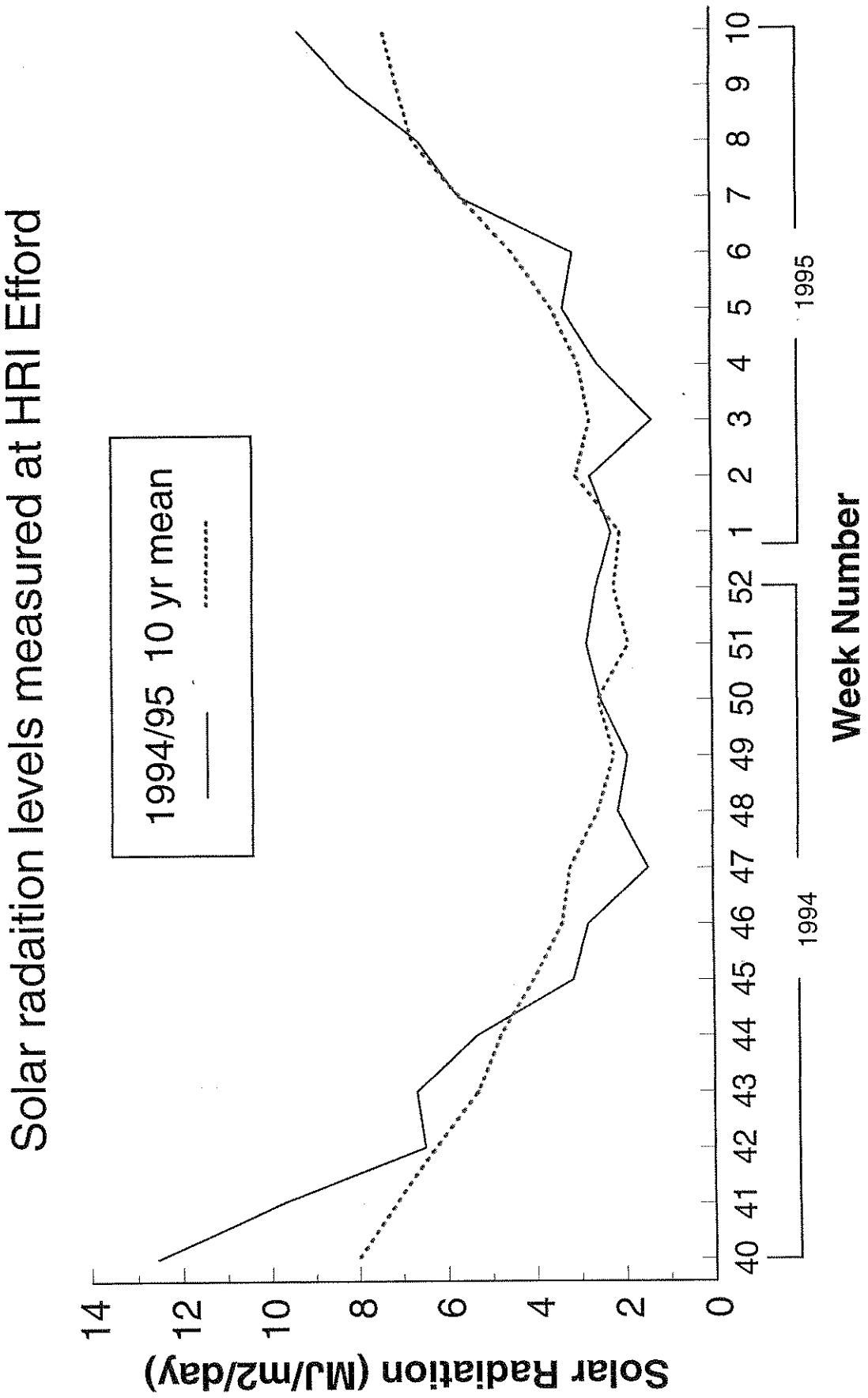
DATE	OPERATION
10/11/94	Cuttings stuck. Cyclic lighting on.
10/11/94	Mycotal 1.0 g/l and Vertilec 2.0 g/l, preventative insecticide.
24/11/94	Pots moved to treatments at intermediate spacing (treatment d, kept at pot thick). Cyclic lighting off.
27/11/94	Malathion 1.8 mls/l, preventative insecticide.
30/11/94	Zineb 2g/l, preventative fungicide.
01/12/94	Treatment d, spaced plants moved to 12.5 pots/m^2 spacing.
04/12/94	Malathion 1.8mls/l, preventative insecticide.
06/12/94	Yuba and Cerise About Time plants pinched.
08/12/94	Charm plants pinched.
08/12/94	Standard and close spacing pots moved to final spacing.
11/12/94	Malathion 1.8 mls/l, preventative insecticide.
15/12/94	Pots moved from 12 W/m^2 to unlit or 4.8 W/m^2 for lighting treatments 2 and 3 respectively.
18/12/94	Thiodan 2 mls/l, preventative insecticide.
23/12/94	B-Nine 1.5 g/l on all Yuba and Cerise About Time pots and Charm treatment 3 only, plant growth regulation.
24/12/94	Malathion 1.8 mls/l, preventative insecticide.
30/12/94	B-Nine 1.5 g/l Charm remaining treatments, plant growth regulation.
01/01/95	Dichlorvos 1 ml/l, preventative insecticide.
08/01/95	Thiodan 2 mls/l, preventative insecticide.
12/01/94	Treatment 4 pots moved to 12 W/m^2.
20/01/95	Nemasys drench, 1 pack per 1000 pots.

WEEK 50 STUCK PLANTS

DATE	OPERATION
15/12/94	Cuttings stuck. Cyclic lighting on.
15/12/94	Mycotal 1.0 g/l and Vertilec 2.0 g/l, preventative insecticide.
27/12/94	Rovral drench 0.5 g/l, preventative fungicide.
30/12/94	Pots moved to treatments at intermediate spacing (treatment d, kept at pot thick). Cyclic lighting off.
01/01/95	Malathion 1.8 mls/l, preventative insecticide.
06/01/95	Treatment d, spacing pots moved to 12.5 pots/m^2.
08/01/95	Thiodan 2 mls/l, preventative insecticide.
11/01/95	Yuba and Cerise About Time plants pinched.
12/01/95	Standard and close spacing pots moved to final spacing.
15/01/95	Malathion 1.8 mls/l, preventative insecticide.
16/01/95	Charm plants pinched.
19/01/95	Pots moved from 12 W/m^2 to unlit or 4.8 W/m^2 for lighting treatments 2 and 3 respectively.
20/01/95	Nemasys drench, 1 pack per 1000 pots.
22/01/95	Dichlorvos 1ml/l, preventative insecticide.
26/01/95	B-Nine 1.5 g/l on all Yuba and Cerise About Time pots and Charm treatment 3 only, plant growth regulation.
29/01/95	Thiodan 2mls/l, preventative insecticide.
30/01/95	B-Nine 1.5 g/l Charm remaining treatments, plant growth regulation.
05/02/95	Malathion 1.8 mls/l, preventative insecticide.
12/02/95	Dichlorvos 1 ml/l, preventative insecticide.
16/02/95	Treatment 4 pots moved to 12 W/m^2.

APPENDIX VI

SOLAR RADIATION LEVELS


Solar radaition levels measured at HRI Efford
1994/95
10 yr mean
Solar Radiation (MJ/m2/day)
0
2
4
6
8
10
12
14
40 41 42 43 44 45 46 47 48 49 50 51 52 1 2 3 4 5 6 7 8 9 10
1994
1995
Week Number

APPENDIX VII

COPY OF CONTRACT TERMS AND CONDITIONS

Contract between HRI (hereinafter called the "Contractor") and the Horticultural Development Council (hereinafter called the "Council") for a research/development project.

1. TITLE OF PROJECT

Contract No: PC92a

CHRYSANTHEMUMS: THE INFLUENCE OF COMBINED SUPPLEMENTARY LIGHTING REGIMES AND POT SPACINGS ON THE QUALITY AND ECONOMICS OF THE WINTER PRODUCTION OF POT CHRYSANTHEMUMS

2. BACKGROUND AND COMMERCIAL OBJECTIVE

Supplementary lighting has become a recognised technique for improving the production of pot chrysanthemums during the winter period when solar radiation levels are below the minimum required for satisfactory growth.

Trial work initially at Lee Valley EHS and latterly at HRI Efford has clearly demonstrated that high intensity supplementary lighting can be effective on a commercial scale for both increasing the rate of bud initiation, and hence reducing cropping time, and improving pot quality. This work has identified the following two successful lighting protocols for a range of commercial varieties:

i. 12 W/m^2 (5000 lux) for the first three weeks of short days.

ii. 4.8 W/m^2 (2000 lux) throughout the short day period.

The benefits of these two lighting techniques may be summarised as reduced production time for the 12 W/m^2 treatment and improvements in quality along with smaller reductions in production time for the 4.8 W/m^2 treatment. It is possible however that full production time and quality benefits may be achieved in the same treatment if the two lighting regimes are combined. Benefits in terms of flower quality may also be achieved through the use of high intensity lighting (12 W/m^2) towards the end of the crop when buds are developing into open flowers.

Since previous trials concentrated on Princess Anne types initially and latterly on American bred varieties, there is also a need to examine other varieties under the standard lighting regimes identified for potential winter quality improvements.

Economic evaluations conducted in previous trials (Finlay 1993, PC13b) indicated that the 4.8 W/m^2 treatment would cost 17.7p per pot in addition to normal production costs and the 12 W/m^2 treatment would cost 11.7p per pot. The potential for improving returns relative to production costs per unit area was therefore examined in 1993/94 (PC92) on an observational basis. Closer spacings reduced the cost of lighting by 17% to 18%, depending on treatment, and were found to influence plant height and delay flowering slightly. There is therefore a need to fully assess the potential of closer spacings under supplementary lighting regimes, including their impact on quality and shelf life performance.

Spacing may also be used to improve the light received by a pot, particularly in the absence of supplementary lighting. The potential for improving quality at wider

spacings during bud initiation therefore needs to be assessed against the standard lighting protocols developed with economic evaluations to fully compare the relative merits of the different techniques.

Hence the investigation outlined here proposes to examine the combined effects of supplementary lighting and pot spacing to optimise on both production time and quality whilst maximising returns in terms of throughput of pots. These issues will be addressed through the following objectives:

a) to evaluate the potential for optimising on the benefits of both cropping time and quality on the same pot by combining the supplementary lighting treatments identified in earlier studies on a range of commercially grown pot mum varieties.

b) to extend the range of varieties assessed to date under standard supplementary lighting regimes.

c) to assess the influence of closer pot spacings on quality, production time, shelf life and the economics of production.

d) to examine the potential for gaining the benefits observed with supplementary lighting through using wider spacings on an unlit crop.

3. POTENTIAL FINANCIAL BENEFIT TO THE INDUSTRY

The influence of supplementary lighting and pot spacings on commercially produced pot mum varieties may be combined to:

a) optimise on quality and rate of production during the winter period.

b) further extend the range of pot mum varieties produced during the winter.

c) improve the economic viability of supplementary lighting techniques through reduced production time for improved quality pots and reduced space allocation per pot.

d) produce an alternative to supplementary lighting to improve winter quality whilst removing the requirement for investment in lighting units and expenditure on electricity.

These factors may be combined and balanced against production costs to maximise returns and a financial evaluation of the treatments will also be included.

4. SCIENTIFIC/TECHNICAL TARGET OF THE WORK

The quantitative and qualitative influence of supplementary lighting and spacing on winter production of pot chrysanthemums will be examined relative to plant form, rate and quality of bud initiation, flowering uniformity, production time and post

production longevity.

5. CLOSELY RELATED WORK - COMPLETED OR IN PROGRESS

HDC funded work on supplementary lighting has provided an ongoing subject of investigation over the past few years at HRI Efford and Lee Valley EHS.

Studies on spacing in AYR chrysanthemums in natural light conditions have been funded by MAFF at HRI Littlehampton and have determined principles of response for this crop. Further HDC funded work on supplementary lighting and spacing for AYR chrysanthemums has also been proposed for the Winter 1994/95 period.

6. DESCRIPTION OF THE WORK

a) Combined supplementary lighting techniques

In evaluating the potential for combining supplementary lighting techniques to optimise on the benefits of cropping time and quality, and assessing the influence of closer pot spacings on these regimes, the following treatments will be compared.

Lighting regimes:

i. 4.8 W/m^2 (2000 lux) throughout short days (S.D.)
ii. 12 W/m^2 (5000 lux) for the first three weeks of S.D. only
iii 12 W/m^2 (5000 lux) for the first three weeks of S.D. followed by lighting at 4.8 W/m^2 (2000 lux) for the remaining S.D. period
iv. 4.8 W/m^2 (2000 lux) for the first seven weeks of S.D. followed by supplementary lighting at 12 W/m^2 (5000 lux) for the remaining S.D. period.

Spacing densities:

i. Intermediate - 24 pots/m^2, Final - 12.5 pots/m^2 (standard)
ii. Intermediate - 30 pots/m^2, Final - 15 pots/m^2 (close)
iii. Intermediate - 36 pots/m^2, Final - 18 pots/m^2 (close).

Plants will receive no supplementary lighting during the long day period.

Supplementary lighting during S.D. will be provided continuously by 400W high pressure sodium (SONT/T) lamps for 11 hours from 0700 - 1800 hrs.

A temperature regime of 18°C day and night will be maintained throughout the trial.

CO_2 will be applied to 1000 v.p.m. with vents less than 5% open and to 500 v.p.m. with vents at or above 5% open.

Chemical growth regulations using Alar and Phosphon will be applied as appropriate for each variety.

Standard winter feed will be applied to all pots at each irrigation.

Varieties:

Yuba, Charm.

Sticking dates:

Weeks 40, 45, 50.

Assessments:

The effect of treatments on production time and plant quality will be assessed at marketing stage 3 (ie 12 flowers all just bending outwards, 50% of petals at least 20mm long) by recording:

1. Time taken to reach marketable stage.
2. Uniformity of flower development.
3. Plant height - of 5 plants per pot.
4. Maximum and minimum plant spread per pot.
5. Leaf damage.
6. Growing media analysis eight weeks after the start of short days.
7. Environmental and solar radiation measurements.
8. Photographic record as appropriate.

The effect of treatments on the shelf life performance of plants will be assessed on a sub sample of pots selected at marketing stage 3. Pots will be stored in a cool chamber for three days, sleeves removed after four days in shelf life environment and assessed for deterioration at regular intervals over a four week period.

b) **Evaluation of further varieties under supplementary lighting**

To expand upon those varieties assessed to date, Cerise About Time will be grown under the two standard lighting regimes ie:

i. 4.8 W/m^2 (2000 lux) throughout short days (S.D.)
ii. 12 W/m^2 (5000 lux) for the first three weeks of S.D. followed by no supplementary lighting for the remaining S.D. period.

These lighting regimes will be repeated for both standard and close spacings as follows:

i. Intermediate - 24 pots/m^2, Final - 12.5 pots/m^2 (standard)
ii. Intermediate - 30 pots/m^2, Final - 15 pots/m^2 (close).

Plants will receive no supplementary lighting during the long day period.

Supplementary lighting during S.D. will be provided continuously by 400W high

pressure sodium (SONT/T) lamps for 11 hours from 0700 - 1800 hrs.

A temperature regime of 18°C day and night will be maintained throughout the trial.

CO_2 will be applied to 1000 v.p.m. with vents less than 5% open and to 500 v.p.m. with vents at or above 5% open.

Chemical growth regulation using Alar and Phosphon will be applied as appropriate.

Standard winter feed will be applied to all pots at each irrigation.

Sticking dates:

Weeks 40, 45, 50.

Assessments:

As for a above.

c) **Assessment of wider spacings on an unlit crop**

To assess the potential for gaining the benefits observed with supplementary lighting through using wider spacings the following treatments will be compared:

Spacing density:

41 pots/m^2 for two weeks of long days plus the first week of short days.
12.5 pots/m^2 from week 2 of short days onwards.

A temperature regime of 18°C day and night will be maintained throughout the trial.

CO_2 will be applied to 1000 v.p.m. with vents less than 5% open and to 500 v.p.m. with vents at or above 5% open.

Chemical growth regulation using Alar and Phosphon will be applied as appropriate for each variety.

Standard winter feed will be applied to all pots at each irrigation.

Varieties:

Yuba, Charm, Cerise About Time

Sticking dates:

Weeks 40, 45, 50.

Assessments:

As for a above.

7. COMMENCEMENT DATE, DURATION AND REPORTING

Start date 0.10.94; duration 10 months. The experimental work will be completed by early Spring, 1995 and the final report will be produced by 31 July, 1995.

8. STAFF RESPONSIBILITIES

Project Leader:	Dr Debbie Wilson	HRI Efford
Industry Co-ordinator:	Mr David Abbott	Swallowfield Horticultural Enterprises

9. LOCATION

HRI Efford (K-Block)

10. COSTS

Price of trial as outlined =

11. PAYMENT

On each quarter day the Council will pay to the Contractor in accordance with the following schedule:

Quarter/Year	1994	1995
1		
2		
3		
4		

Contract No: PC92a
Date: 21.9.94

TERMS AND CONDITIONS

The Council's standard terms and conditions of contract shall apply.

Signed for the Contractor(s)

Signature.....
Position.. General and Marketing Manager HHI
Date.....12/10/94.....

Signed for the Contractor(s)

Signature.....
Position.....
Date.....

Signed for the Council

Signature.....H M Murray.....
G. J. Kennedy
Position.....P.P CHIEF EXECUTIVE.....
Date.....21-9-94.....

APPENDIX VIII

REFERENCES

Cockshull, K. E. and Hughes, A. P. 1971. The effects of light intensity at different stages in flower initiation and development of Chrysanthemum morifolium. Ann Bot. 35, 915-926

Cockshull, K. E. and Hughes, A. P. 1972. Flower formation in Chrysanthemum morifolium - the influence of light level. Journal of Horticultural Science, 47, 113.

Finlay, A. R. 1993. Chrysanthemums: Supplementary lighting for winter production of pot chrysanthemums. Contract Report HDC PC13b.

Wilson, D. P. 1994a. Chrysanthemums: The influence of supplementary lighting on winter quality and shelf-life of American bred varieties of pot chrysanthemums. Contract Report HDC PC13c.

Wilson, D. P. 1994b. Chrysanthemums: The influence of supplementary lighting and DROP regimes on the winter quality of American bred varieties of pot chrysanthemums. Contract Report HDC PC92.

Table 6c: **The Influence of Supplementary Lighting, Spacing and Negative DIF Treatments on the Number of Open Flowers**

Variety: Cerise About Time

Number of buds at stages 4+ per pot

Lighting Treatment	Sticking Week	Spacing a	Spacing b	Spacing c	Spacing d	Mean
1	40	24.2	22.0			23.1
	45	24.7	17.5			21.1
	50	29.4	27.1			28.3
Mean		*26.1*	*22.2*			*24.2*
2	40	18.7	17.2			18.0
	45	12.3	8.5			10.4
	50	15.8	16.1			16.0
Mean		*15.6*	*13.9*			*14.8*
3	40					
	45					
	50					
Mean						
4	40					
	45					
	50					
Mean						
5	40	14.1	14.4			14.3
	45	11.4	12.7			12.1
	50	15.0	14.6			14.8
Mean		*13.5*	*13.9*			*13.7*
6	40	19.5			20.1	19.8
	45	17.4			15.0	16.2
	50	27.5			26.9	27.2
Mean		*21.5*			*20.7*	*21.1*

Lighting Treatments:

1. 4.8 W/m^2 throughout S.D. (18/18°C)
2. 12 W/m^2 weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m^2 weeks 1-3 S.D. to 4.8 W/m^2 to marketing (18/18°C)
4. 4.8 W/m^2 weeks 1-7 S.D. to 12 W/m^2 to marketing (18/18°C)
5. 12 W/m^2 weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit (18/18°C)

Spacing Treatments:

a. 24 pots/m^2 weeks 1-2 S.D. to 12.5 pots/m^2 weeks 3 + S.D.
b. 30 pots/m^2 weeks 1-2 S.D. to 15 pots/m^2 weeks 3 + S.D.
c. 36 pots/m^2 weeks 1-2 S.D. to 18 pots/m^2 weeks 3 + S.D.
d. 24 pots/m^2 weeks 1 S.D. to 12.5 pots/m^2 weeks 2 + S.D.

Table 7a: The Influence of Supplementary Lighting, Spacing and Negative DIF Treatments on the Average of Maximum Bud Stage per Pot

Variety: Charm

Average of maximum bud stage per pot

Lighting Treatment	Sticking Week	Spacing a	Spacing b	Spacing c	Spacing d	Mean
1	40	7.1	6.4	6.1		6.5
	45	7.7	8.2	7.3		7.7
	50	7.8	7.4	7.7		7.6
Mean		*7.5*	*7.3*	*7.0*		*7.3*
2	40	7.0	6.7	6.8		6.8
	45	7.1	7.6	7.0		7.2
	50	8.0	7.8	7.0		7.6
Mean		*7.4*	*7.4*	*6.9*		*7.2*
3	40	6.7	6.4	6.7		6.6
	45	7.3	7.2	7.3		7.3
	50	7.8	7.5	7.4		7.6
Mean		*7.3*	*7.0*	*7.1*		*7.2*
4	40	7.0	7.2	6.7		7.0
	45	7.6	7.2	7.4		7.4
	50	7.5	7.6	7.0		7.4
Mean		*7.4*	*7.3*	*7.0*		*7.3*
5	40	6.4	6.3	6.2		6.3
	45	7.0	7.1	7.0		7.0
	50	7.9	7.6	7.5		7.7
Mean		*7.1*	*7.0*	*6.9*		*7.0*
6	40	6.6			6.7	6.7
	45	7.4			7.2	7.3
	50	7.7			7.9	7.8
Mean		*7.2*			*7.3*	*7.3*

Lighting Treatments:

1. 4.8 W/m^2 throughout S.D. (18/18°C)
2. 12 W/m^2 weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m^2 weeks 1-3 S.D. to 4.8 W/m^2 to marketing (18/18°C)
4. 4.8 W/m^2 weeks 1-7 S.D. to 12 W/m^2 to marketing (18/18°C)
5. 12 W/m^2 weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit (18/18°C)

Spacing Treatments:

a. 24 pots/m^2 weeks 1-2 S.D. to 12.5 pots/m^2 weeks 3 + S.D.
b. 30 pots/m^2 weeks 1-2 S.D. to 15 pots/m^2 weeks 3 + S.D.
c. 36 pots/m^2 weeks 1-2 S.D. to 18 pots/m^2 weeks 3 + S.D.
d. 24 pots/m^2 weeks 1 S.D. to 12.5 pots/m^2 weeks 2 + S.D.

Table 7b: **The Influence of Supplementary Lighting, Spacing and Negative DIF Treatments on the Average of Maximum Bud Stage per Pot**

Variety: Yuba

Average of maximum bud stage per pot

Lighting Treatment	Sticking Week	Spacing a	Spacing b	Spacing c	Spacing d	Mean
1	40	6.5	6.6	6.0		6.4
	45	8.0	7.5	7.5		7.7
	50	7.7	7.5	6.9		7.4
Mean		*7.4*	*7.2*	*6.8*		*7.2*
2	40	6.4	5.9	6.1		6.1
	45	7.6	7.4	6.8		7.3
	50	7.7	7.6	7.8		7.7
Mean		*7.2*	*7.0*	*6.9*		*7.0*
3	40	6.8	6.5	6.1		6.5
	45	7.4	7.3	7.5		7.4
	50	7.8	7.6	7.2		7.5
Mean		*7.3*	*7.1*	*6.9*		*7.1*
4	40	6.4	6.5	6.4		6.4
	45	7.7	7.6	7.6		7.6
	50	7.5	7.7	7.6		7.6
Mean		*7.2*	*7.3*	*7.2*		*7.2*
5	40	6.4	6.4	6.4		6.4
	45	7.4	7.3	7.2		7.3
	50	8.0	8.0	8.1		8.0
Mean		*7.3*	*7.2*	*7.2*		7.2
6	40	6.5			6.5	6.5
	45	7.5			6.9	7.2
	50	7.3			7.6	7.5
Mean		*7.1*			*7.0*	*7.1*

Lighting Treatments:

1. 4.8 W/m² throughout S.D. (18/18°C)
2. 12 W/m² weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m² weeks 1-3 S.D. to 4.8 W/m² to marketing (18/18°C)
4. 4.8 W/m² weeks 1-7 S.D. to 12 W/m² to marketing (18/18°C)
5. 12 W/m² weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit (18/18°C)

Spacing Treatments:

a. 24 pots/m² weeks 1-2 S.D. to 12.5 pots/m² weeks 3 + S.D.
b. 30 pots/m² weeks 1-2 S.D. to 15 pots/m² weeks 3 + S.D.
c. 36 pots/m² weeks 1-2 S.D. to 18 pots/m² weeks 3 + S.D.
d. 24 pots/m² weeks 1 S.D. to 12.5 pots/m² weeks 2 + S.D.

Table 7c: **The Influence of Supplementary Lighting, Spacing and Negative DIF Treatments on the Average of Maximum Bud Stage per Pot**

Variety: Cerise About Time

Average of maximum bud stage per pot

Lighting Treatment	Sticking Week	Spacing a	Spacing b	Spacing c	Spacing d	Mean
1	40	7.0	6.7			6.9
	45	7.7	7.6			7.7
	50	7.7	7.8			7.8
Mean		*7.5*	*7.4*			*7.5*
2	40	7.2	7.0			7.1
	45	7.8	7.2			7.5
	50	8.1	8.3			8.2
Mean		*7.7*	*7.5*			*7.6*
3	40					
	45					
	50					
Mean						
4	40					
	45					
	50					
Mean						
5	40	7.2	7.3			7.3
	45	7.6	7.5			7.6
	50	8.1	7.7			7.9
Mean		*7.6*	*7.5*			*7.6*
6	40	7.1			6.8	7.0
	45	7.0			7.6	7.3
	50	8.2			8.0	8.1
Mean		*7.4*			*7.5*	*7.5*

Lighting Treatments:

1. 4.8 W/m² throughout S.D. (18/18°C)
2. 12 W/m² weeks 1-3 S.D. to unlit (18/18°C)
3. 12 W/m² weeks 1-3 S.D. to 4.8 W/m² to marketing (18/18°C)
4. 4.8 W/m² weeks 1-7 S.D. to 12 W/m² to marketing (18/18°C)
5. 12 W/m² weeks 1-3 S.D. to unlit (16/20°C)
6. Unlit (18/18°C)

Spacing Treatments:

a. 24 pots/m² weeks 1-2 S.D. to 12.5 pots/m² weeks 3 + S.D.
b. 30 pots/m² weeks 1-2 S.D. to 15 pots/m² weeks 3 + S.D.
c. 36 pots/m² weeks 1-2 S.D. to 18 pots/m² weeks 3 + S.D.
d. 24 pots/m² weeks 1 S.D. to 12.5 pots/m² weeks 2 + S.D.