Project title:	Pot Chrysanthemums : Comparison of the effects of reduced night-length on winter pot quality when imposed using either assimilation or tungsten lighting.
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Project leader:	Dr Paul Carver HRI Efford, Lymington, Hampshire, SO41 OLZ
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Key workers:	**HRI Efford**

	Dr Paul Carver	Project Leader (Author)
	Miss Sarah Williams	Assistant Scientific Officer
	Mrs S Foster	Scientific Officer
	Mr P Burnell	Nursery Staff
	Mr Mike Verran	Nursery Staff
	Mr Colin Hemming	Nursery Staff
	Mr C Vigor	Nursery Staff (Foreman)

Locations:	HRI Efford, Lymington, Hampshire, SO41 OLZ
Project co-ordinator:	Mr Dave Abbott, Southern Glasshouse Produce Ltd. Barnham, West Sussex PO22 OAQ
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CONTENTS

1. RELEVANCE TO GROWERS AND PRACTICAL APPLICATION

1.1 Background

Previous HDC-funded trials (PC92b) demonstrated that pinching pot mums in long-days and the use of reduced night-length, could be used to promote more plant bulk during the winter period.

This study showed that reducing the night-length to 11 hours 40 minutes marginally increased plant growth, with a small increase in production time. When night-length was further reduced to 11 hours 20 minutes, there were marked increases in plant size, but an unacceptably long delay in production time. Therefore, controlling night-length between 11 h 40 to 11 h 20 may provide the best balance between increased plant growth, quality and duration.

The increased plant bulk produced under reduced night-lengths, although desirable, needs to be controlled to conform to the specifications of the multiples. The application of additional plant growth regulators to achieve the market specification is an important factor determining plant form and quality.

Many growers do not currently have assimilation lighting installed over their entire production area, and consequently only light a comparatively small area. Studies on spray chrysanthemums (HDC PC 148), demonstrated marked increases in plant dry weight from the use of tungsten lighting . If this could be transferred to pot chrysanthemum crops, the capital cost of installing tungsten lighting over the production area is far smaller than assimilation lights, and may be a more attractive option to growers. One potential draw back of using tungsten lighting is that plants may become elongated, due to the increased far-red component of the tungsten light source.

The main difference between assimilation and tungsten lighting is that plants use assimilation lights to photosynthesise and grow, whereas, (when used at low level for night-break as in this trial) tungsten lighting serves only as a photo-periodic trigger and does not stimulate photosynthetic activity. This study compared the growth and development of pot mums when using assimilation lighting throughout short days, against use in the first three weeks of short days only.

It is currently not clear to what extent reduced night-length affects flower initiation compared to the rate of flower development. In order to understand more about how night-length might be dynamically manipulated during production, this study aimed to identify which phase of production was most sensitive to reduced night-length.

The objectives of the work were therefore as follows:

1. To examine the effect of an 11 hour 30 minute night-length as a means of increasing plant bulk during the winter, without extending crop duration, using both assimilation and tungsten lighting.

2. To examine the effect of controlling plant height using additional plant growth regulator to achieve the market specifications of the multiples on plants produced using reduced night-length.

3. To examine the sensitivity of flower initiation and development to reduced night-length, by using periods of 11.30 hour night-length during production under tungsten and assimilation regimes.

For objectives 1 & 2, five short day treatments (A to E) were established, as follows.

A 5 klx (12W/m^2) for weeks 1 – 3 with 13 hour night-length, followed by ambient light and night-length (commercial standard)

B 5 klx (12W/m^2) for weeks 1 – 3 with 13 hour night, followed by ambient light but with night-length controlled to 13 hours using tungsten lighting.

C 5 klx (12W/m^2) for weeks 1 – 3 with 11.30 hour night-length, followed by ambient light but with night-length controlled to 11:30 using tungsten lighting

D 2 klx (4.8W/m^2) throughout short days with 13 hour night-length controlled using assimilation lights (commercial standard for 2 klx treatments)

E 2 klx (4.8W/m^2) throughout short days with 11.30 hour night-length controlled using assimilation lights.

For all treatments cuttings of three varieties (Charm, Onyx Time & Swing Time) were stuck in weeks 41, 45 & 48.

For Objective 3 plants were transferred between treatments A to C after 2, 4, 6 and 8 weeks of production, with reciprocal transfers from C to A at the same time. This process was repeated for Treatments D and E.

Therefore, transfers between A and C compared the effect of periods with 11.30 hour night-length using tungsten lighting with ambient night-length control at different stages of the crop. Similarly, transfers between D and E compared periods of 11.30 hour night-length with 13 hour night-length control using assimilation lighting.

This part of the trial used the variety Charm, stuck in weeks 41, 45 and 48.

1.2 Summary of results

Five cuttings were stuck in 14D pots filled with Levington M2 compost, and rooted at a base (media) temperature of 20°C, with cyclic night-break tungsten lighting supplied for a total of 17 days (0.5 W/m^2 at crop height). In subsequent short days, a minimum night and day temperature of 18°C (venting at 23°C) was provided, with CO_2 enrichment applied to reach a target level of 1000 ppm, reduced to 500 vpm with venting in excess of 5%. Plants were soft-pinched in short days (SD) to 7-8 leaves. Daminozide (as B-Nine) to control plant height, was applied at rates specific to each variety and vigour under each treatment regime. Pots were spaced at $41/m^2$ (pot thick) during the 17 day propagation phase, decreasing to $27/m^2$ for 14 days from the start of short days. The final spacing was $13/m^2$ from day 31 after sticking. Liquid feeding commenced at the start of short days and continued at each irrigation. The dilute feed applied contained 300 mg/l N, 60 mg/l P_2O_5 (26 mg/l P) and 250 mg/l K_2O (207 mg/l K).

The main results were as follows

- 11.30 hour night-length control significantly increased plant dry weight, with no significant difference between tungsten or assimilation lighting.

- Production time was extended by up to 12 days when using 11.30 night-length control, although tungsten lighting was found to be marginally quicker (9 day delay).

- 11.30 hour night-length significantly increased flower development in excess of the standard supermarket specification. As all treatments reached this specification the benefits to the grower are unlikely to be increased income.

- Height control was dependant on variety and stick week. 11.30 hour night-length control using assimilation lighting produced plants 1-2 cm over the height specification. These increases could feasibly be controlled by extra PGR inputs, but larger increases (7cm) from using tungsten lighting may be too great to be effectively controlled.

- Transfer treatments showed plants were most sensitive (in terms of flower initiation and development) to 11.30 hour night-length at the start of short days. Under assimilation lights the critical period was the first 4 weeks of short days, increasing to the first 6 weeks with tungsten lighting.

- Cropping time under continuous 11.30 hour night-length control could be reduced, if it was only used for the first two weeks of production. This treatment produced plants with slightly lower dry weights, but the benefits of increased flower development associated with 11.30 night-length. The saving in production time was approximately 1 week compared to plants grown under continuous 11.30 hour night-length.

1.3 Action points for growers

This programme of work has demonstrated the potential for improving winter quality (plant bulk) by manipulation of night-length, although the magnitude of the effect must be offset against consequent increases in production time.

- Plant bulk can be increased using a reduced night-length regime (11.30 hours), to improve the quality of winter crops.

- Tungsten lighting was used successfully to apply reduced night-length regimes, but higher light levels applied using assimilation lighting provided an extra benefit of reduced plant extension.

- 11.30 hour night-length can be used at the beginning of production to increase flower initiation and development, whilst still reducing production time compared to plants under continual 11.30 night-length regimes.

- The rate and frequency of PGR applications will require careful attention, to ensure that any height increases are controlled to within specifications of the multiples.

1.4 Practical and anticipated financial benefits

A financial benefit of this work could be to increase plant bulk by using tungsten lighting for 11.30 hours, a cheaper option than using assimilation lighting. However, it can be argued that using assimilation lighting is more likely give both practical and financial benefits. Assimilation lighting was shown to increase flower development in excess of the commercial specifications, whilst this may not attract an increased income for the grower it determines the security of supply itself, which may be of greater concern.

2.0 SCIENCE SECTION

2.1 Introduction

Previous HDC-funded trials (PC92b) demonstrated that pinching pot mums in long-days and the use of reduced night-length, could be used to promote more plant bulk during the winter period.

This study showed that reducing the night-length to 11 hours 40 minutes marginally increased plant growth, with a small increase in production time. When night-length was further reduced to 11 hours 20 minutes, there were marked increases in plant size, but an unacceptably long delay in production time. Therefore, controlling night-length between 11 h 40 to 11 h 20 may provide the best balance between increased plant growth, quality and duration.

The increased plant bulk produced under reduced night-lengths, although desirable, needs to be controlled to conform to specifications of the multiples. The application of additional plant growth regulators to achieve the market specification is an important factor determining plant form and quality.

Many growers do not currently have assimilation lighting installed over their entire production area, and consequently only light a comparatively small area. Previous work has shown that the most cost-effective use of assimilation lighting is 5 klx in the first three weeks of the short day period, and to finish in ambient light (HDC PC 13b).

Studies on spray chrysanthemums (HDC PC 148), which used tungsten lighting to extend the day-length, demonstrated marked increases in plant dry weight. If this could be transferred to pot chrysanthemum crops, the capital cost of installing tungsten lighting over the production area is far smaller, and may be a more attractive option to some growers than assimilation lights. One potential draw back of using tungsten lighting is that plants may become elongated, due to the increased far-red component of the tungsten light source.

The main difference between assimilation and tungsten lighting is that plants use assimilation lights to photosynthesise and grow, whereas, (when used at low level for night-break as in this trial) tungsten lighting serves only as a photo-periodic trigger and does not stimulate photosynthetic activity. This study compared the growth and development of pot 'mums when using assimilation lighting throughout short days, against use in the first three weeks of short days only.

It is currently not clear to what extent reduced night-length affects flower initiation compared to the rate of flower development. In order to understand more about how night-length might be dynamically manipulated during production, this study aimed to identify which phase of production was most sensitive to reduced night-length.

Objectives

1. To examine the effect of an 11 hour 30 minute night-length as a means of increasing plant bulk during the winter, without extending crop duration using both assimilation and tungsten lighting.

2. To examine the effect of controlling plant height using additional plant growth regulator inputs to achieve the specifications of the multiples on plants produced using reduced night-length.

3. To examine the sensitivity of flower initiation and development to reduced night-length, by using periods of 11.30 hour night-length during production under tungsten and assimilation regimes.

2.2 Materials and methods

2.2.1. Treatments

2.2.1.1 The influence of lighting treatments on winter quality

In total five lighting treatments were examined, based on a combination of the following variables

Night-length control	Ambient 13 Hours 11.30 Hours
Lighting source	Tungsten Assimilation
Lighting intensity	Assimilation 4.8 or 12 Wm-2 (2 and 5 Klux respectively) Tungsten (0.5 Wm-2)

Treatments were coded from A to E (with abbreviations as used in the text)

Code	Abbreviation	Description
A	Standard	5 klx ($12W/m^2$) for weeks 1 – 3 of short days with 13 hour night-length, followed by ambient light and night-length (commercial standard)
B	13 T	5 klx ($12W/m^2$) for weeks 1 – 3 of short days with 13 hour night, followed by ambient light but with night-length controlled to 13 hours using tungsten lighting.
C	11.30 T	5 klx ($12W/m^2$) for weeks 1 – 3 of short days with 11.30 hour night-length, followed by ambient light but with night-length controlled to 11:30 using tungsten lighting
D	13 A	2 klx ($4.8W/m^2$) throughout short days with 13 hour night-length controlled using assimilation lights (commercial standard for 2 klx treatments)
E	11.30 A	2 klx ($4.8W/m^2$) throughout short days with 11.30 hour night-length controlled using assimilation lights.

Stick weeks: 41, 45 & 48.

Varieties: Charm, Onyx Time & Swing Time.

2.2.1.2 Sensitivity of flower development to reduced night-length

This trial examined the transfer of plants between treatments A & C and D & E as described above (Section 1.1.1). Plants were transferred into 11.30 hour-night-length after 2,4,6 and 8 weeks from the start of short days. This also included a replication of reciprocal treatments (treatments starting in 11.30 night-length), resulting in total of 16 treatments, coded as described below.

Treatment Code	Description
AC2	Transfer from Treatment A to C after 2 weeks.
AC4	Transfer from Treatment A to C after 4 weeks.
AC6	Transfer from Treatment A to C after 6 weeks.
AC8	Transfer from Treatment A to C after 8 weeks.
CA2	Transfer from Treatment C to A after 2 weeks.
CA4	Transfer from Treatment C to A after 4 weeks.
CA6	Transfer from Treatment C to A after 6 weeks.
CA8	Transfer from Treatment C to A after 8 weeks.
DE2	Transfer from Treatment D to E after 2 weeks.
DE4	Transfer from Treatment D to E after 4 weeks.
DE6	Transfer from Treatment D to E after 6 weeks.
DE8	Transfer from Treatment D to E after 8 weeks.
ED2	Transfer from Treatment E to D after 2 weeks.
ED4	Transfer from Treatment E to D after 4 weeks.
ED6	Transfer from Treatment E to D after 6 weeks.
ED8	Transfer from Treatment E to D after 8 weeks.

Therefore, transfers between A and C compared the effect of periods with 11.30 hour night-length using tungsten lighting with ambient night-length control at different stages of the crop. Similarly, transfers between D and E compared periods of 11.30 hour night-length with 13 hour night-length control using assimilation lighting.

2.2.2 Cultural details

2.2.2.1 Plant material

Unrooted cuttings of Charm were purchased from Yoder Toddington Ltd. (raised in Kenya). Unrooted cuttings of Swing Time and Onyx Time were purchased from Cleangro Ltd. (raised in Brazil).

Charm	Lavender pink decorative, 9 weeks response time (medium-tall class).
Swing Time	Medium-large lemon yellow decorative with green centre and strong vegetative growth (medium-tall class), 7.5 week response time.
Onyx Time	Medium-large orange single, 7.5 week response time (medium-tall class).

2.2.2.2 Propagation

Five cuttings were stuck in 14D pots filled with Levington M2 compost. Bottom heating was applied to give a compost temperature of 20°C. After sticking, pots were covered with clear polythene, which remained in place for 10 days before plants were weaned off. Cyclic night-break lighting (50% cycle for 5 hours; 10:30 pm – 03:30 am) was given for a total of 17 days from sticking. Night-break lighting was supplied using tungsten lighting, at an illumination of 0.5 W/m^2 at canopy height.

2.2.2.3 Short day environment

Heating set points were adjusted according to ambient conditions and lighting regimes to achieve an equivalent average in all compartments, with a minimum night and day temperature of 18°C. Venting set points were also adjusted to achieve comparable temperatures across all compartments, and were 23°C.

Thermal screens were drawn across at 1800 hours or dusk (whichever was earlier) and removed at 0700 hours daily. Lighting treatments were applied below the screens.

CO_2 enrichment was applied to reach a target level of 1000 vpm with the vents open less than 5%, decreasing to 500 vpm with venting in excess of 5%.

2.2.2.4 Growth regulation

Plants were soft-pinched in short days (SD) to 7-8 leaves. Daminozide (as B-Nine) to control plant height, was applied according to the specific requirements of each variety and vigor (under each treatment regime) as follows:

	Timing and rate of application of B-nine growth retardant (g/l)			
	1	**2**	**3**	**4**
Variety	24 / 48 hours after sticking	Breaks 1.5 – 2.0 cm long	7 – 10 days after application 2	
Charm	1.5	3.0	2.0	1.0 (if required)
Onyx Time	2.0	2.0	1.5	1.0 (if required)
Swing Time	2.0	2.0	1.5	1.0 (if required)

The actual amounts applied are given in the results section.

2.2.2.5 Pot spacing

Pots were spaced at 41 pots/m^2 (pot thick) during the 17 day propagation phase. When moved into the short day environment pots were spaced at 27 pots/m^2 (20.6 cm between pots in the row and 17.9 cm between rows) for 14 days from the start of short days. They were then spaced 13 pots/ m^2 (29.8 cm between pots in the row, and 25.8 cm between rows) from day 31 after sticking.

2.2.2.6 Nutrition

Liquid feeding commenced at the start of short days and continued at each irrigation. The dilute feed applied contained 300 mg/l N, 60 mg/l P_2O_5 (26 mg/l P) and 250 mg/l K_2O (207 mg/l K).

2.2.2.7 Pest and disease control

A routine, preventative spray programme was maintained against Western Flower Thrips. In addition, crops were monitored dailing and spot treatments applied as required.

2.3 Assessments

At marketing

The effects of treatments on production time and plant quality were assessed for 12 pots per plot at marketing stage 3. This marketing stage was defined as three flowers with outer petals all just bending outwards and with 50% of petals at least 20mm long. This was in accordance with the HDC marketing guide, based on (PC 13b).

1. Time taken for each pot in the plot to reach the marketable stage (days).
2. Number of flowers per pot at stages 1-3.
3. Number of flowers per pot at stage 4+.
4. Number of breaks on each plant with 3 or more flowers at bud stage 4+.
5. Average height of five plants per pot (cm).
6. Maximum and minimum pot spread (cm).
7. Average dry weight of plants (g) (these were average dry weights for each of three plants from each treatment).
8. Number of leaves on the uppermost break at marketing.

Shelf life phase - procedure

After the growing phase of the trial, six pots per treatment were put through a transport run (21 hours), a store life phase (10 days), followed by up to four weeks of shelf life. The procedure was as follows:

1. Plants sleeved, boxed and held at 15°C for 15 hours, before a simulated transport run of 6 hours at 12°C.
2. Holding area simulation, 12 hours at 18°C (Store life phase), sleeved in boxes.

3. Shelf life phase, 600 lux lighting with a 12 hour day and night regime, temperature was diurnally constant controlled to between 18-20°C. After 10 days (from sleeving) sleeves were removed and plant assessments (as described below) commenced for 4 weeks (or until plants deteriorated to the stage they should be discarded).

Shelf life- assessments

The following assessments were taken weekly, after the initial 11 days of transport and store life simulation described above.

1. Number of buds per pot at stage 4+.

2. Number of distorted buds per pot.

3. Flower colour, using Royal Horticultural Society colour chart.

4. Qualitative assessment of foliage appearance in:

   (i) The upper canopy
   (ii) Mid canopy
   (iii) Base of canopy

   Within each section foliage was scored as:

   0 = All green
   1 = Green with tinge of yellow
   2 = half green/ half yellow
   3 = Mostly yellow/brown
   4 = Brown or leaves dropped

5 Flower Score (Qualitative assessment of overall appearance of flowers), scored as:

   0 = No deterioration
   1 = Degeneration visible in the center of the flower.
   2 = Flower wilting or necrotic.

2.4 Statistical analysis

Analysis of variance was carried out to assess the significance of treatments effects on the data collected. Replication of data was based on time (stick dates) and varieties. The main effects are presented meaned across variety, stick date and treatment. The use of these means increases the statistical power of the tests, enabling a more detailed analysis of the data. Individual treatment means are presented graphically in the appendix so individual cases can be examined in detail if required.

Terms used:

S.E.D Standard error of differences of means

L.S.D Least significant difference

(*) (P<0.05) The probability of this result occurring by chance is equal or less than 1 in 20 (5%).

3.0 RESULTS AND DISCUSSION

Key observations from the statistical analysis are presented in the following sections, meant across factors such as sticking date, variety and lighting regime. The individual treatment means are presented in a tabulated form in the appendices to allow comparison of trends between experimental factors.

3.1 The influence of lighting treatments on winter quality

3.1.1 Vegetative development and flower production

3.1.1.1 Production time (number of days from sticking to marketing)

a. Lighting treatments

Night length had a significant effect (*) on production time. Under 11.30 hour regimes, production time was increased by 9 and 12 days for tungsten and assimilation lighting treatments respectively (compared to 13 hour night-length treatments with the same light source). Differences between light sources were much smaller, though production time was significantly shorter (*) under tungsten lighting compared to assimilation lighting (for treatments with the same night-length). Under an 11.30 night-length regime tungsten lights reduced production time by 1 day compared to assimilation lighting, this difference increased to 4 days under 13 hour night-length treatments.

Mean number of days from sticking to marketing

Standard	13 T	11.30 T	13 A	11.30 A
76.7	76.5	85.7	77.3	89.9

S.E.D. = 0.148, L.S.D. (P<0.05) = 0.330

b. Lighting treatments x stick date

In agreement with the data above (averaged across all 3 stick dates) the two 11.30 hour night-length treatments resulted in significantly longer (*) production time than other treatments for all three stick dates. Under 11.30 night-length regimes assimilation lighting was found to result in a small, but still significant delay (*) in production time compared with tungsten lighting for all three stick dates. Under 13 hour night-length treatments tungsten lighting only resulted in significant (*) reductions in production time with plants stuck in week 41. Averaged across all treatments crop duration increased significantly (*) from plants stuck in week 41 to those in 45 but not week 48.

Mean number of days from sticking to marketing

	Sticking week		
Treatment	41	45	48
Standard	76.2	76.7	77.1
13 T	76.5	76.9	76.2
11.30 T	85.5	85.6	86.1
13 A	75.6	77.8	78.5
11.30 A	87.9	90.7	90.6
Mean	80.3	81.5	81.7

Between treatment	S.E.D. = 0.257	L.S.D. (P<0.05) = 0.570
Overall mean	S.E.D. = 0.117	L.S.D. (P<0.05) = 0.240

c. Lighting treatment x variety

All varieties responded in a similar manner to night extension treatments applied. Under standard commercial conditions (Standard) Charm had a significantly lower (*) production time compared to the other two varieties.

Mean number of days from sticking to marketing

	Variety		
Treatment	Charm	Oynx Time	Swing Time
Standard	74.4	77.3	78.3
13 T	74.5	77.6	77.4
11.30 T	84.7	87.6	84.9
13 A	75.9	77.5	78.4
11.30 A	90.3	89.9	89.0
Mean	80.0	82.0	81.6

Between treatment	S.E.D. = 0.337	L.S.D. (P<0.05) = 0.681
Overall mean	S.E.D. = 0.178	L.S.D. (P<0.05) = 0.363

3.1.1.2 Plant dry weight

a. Lighting treatments

The commercial standard treatment (Standard) produced pots with an average plant dry weight of 10.50g. Both of the 13 hour night-length treatments (Tungsten and Assimilation lighting) did not increase plant dry weight compared to the commercial standard treatment. However, plant dry weight under both 11.30 night-length regimes was significantly increased (*) compared to the commercial standard and both of the 13 hour treatments. Under a 11.30 hour night-length regime assimilation lighting there was a pattern of increased plant dry weight, compared to similar night-length control using tungsten lighting, though this did not prove significant.

Mean plant dry weight per pot (g)

Standard	13 T	11.30 T	13 A	11.30 A
10.50	10.45	13.41	10.00	14.36

S.E.D. = 0.466, L.S.D. ($P<0.05$) = 1.078

b. Lighting treatments x sticking dates

There was a significant interaction (*) between lighting treatments and stick dates. All three stick dates showed the same trend towards increased plant dry weight under 11.30 night-length regimes. However, using assimilation lighting did not increase plant dry weight significantly compared to tungsten under 11.30 hour night-length.

For each treatment, week 45 produced plants with significantly lower (*) dry weights compared to weeks 41 and 48, which did not differ significantly. During week 45 dry weight increases attributable to 11.30 night length regimes were more pronounced, most likely due to low external light levels during this period.

Mean plant dry weight per pot (g)

	Sticking week		
Treatment	41	45	48
Standard	11.46	8.04	12.00
13 T	11.80	7.55	11.98
11.30 T	14.32	11.36	14.54
13 A	11.40	7.17	11.42
11.30 A	14.58	12.26	16.23
Mean	12.71	9.28	13.23

Between treatment	S.E.D. = 0.811	L.S.D. ($P<0.05$) = 1.807
Overall mean	S.E.D. = 0.117	L.S.D. ($P<0.05$) = 0.261

c. Lighting treatment x variety

All three varieties showed no significant increases in plant dry weight from the commercial standard treatment when night-length was controlled to 13 hours by either tungsten or assimilation lighting. Significant increases (*) were obtained though, when night-length was controlled to 11.30 hours. (this applied to both tungsten and assimilation lighting treatments). Comparing light sources (at 11.30 hours night-length) only Onyx Time produced significantly greater (*) dry weight under assimilation lighting compared to tungsten lighting.

Averaged across all treatments, Onyx Time produced significantly greater (*) dry weight than Charm and Swing Time.

Mean plant dry weight per pot (g)

	Variety		
Treatment	Charm	Oynx Time	Swing Time
Standard	9.78	11.30	10.43
13 T	9.79	11.13	10.41
11.30 T	13.72	14.04	12.45
13 A	9.69	10.44	9.87
11.30 A	14.65	15.43	12.99
Mean	11.53	12.47	11.23

Between treatment S.E.D. = 0.606L.S.D. (P<0.05) = 1.225
Overall mean S.E.D. = 0.212L.S.D. (P<0.05) = 0.433

3.1.1.3 Plant height

All pots were grown to a height specification of 18.5 ± 2.5 cm (excluding the pot) as demanded by the larger multiples.

a. Lighting treatments

The shortest plants were produced under the assimilation lighting regime (13 hour night-length), where the average height of 16.15 cm was significantly lower (*) than all other treatments. The 11.30 night-length treatment under tungsten did not produce plants within the height specification. The 11.30 night-length resulted in significant (*) increases in plant height (compared to 13 hour night-length treatments) under both tungsten and assimilation lighting regimes. Between light sources tungsten lighting resulted in significantly (*) taller plants than under assimilation lighting regimes.

Mean plant height per pot (cm)

Standard	13 T	11.30 T	13 A	11.30 A
17.96	20.15	23.83	16.15	20.75

S.E.D. = 0.255, L.S.D. (P<0.05) = 0.568

b. Lighting treatment x stick date

The same trends described above (a) were observed across all three stick dates, with the 13 hour night-length assimilation lighting regime consistently producing significantly (*) shorter plants than all other treatments (however, during weeks 45 and 48 these plants were under the minimum height specification.

Averaged across all treatments plant height was significantly lower (*) during week 45 than the other two stick dates. Week 45 also produced the best height specifications, with only 2 treatments (11.30T and 13 A) outside the specifications. Over the three stick dates one treatment, 11.30 T, consistently produced plants over the maximum height specification.

Mean plant height per pot (cm)

	Sticking week		
Treatment	41	45	48
Standard	19.63	16.46	17.78
13 T	22.69	18.25	19.52
11.30 T	24.79	22.12	24.59
13 A	18.05	14.50	15.90
11.30 A	22.22	18.17	21.86
Mean	21.48	17.90	19.93

Between treatment	S.E.D. = 0.444	L.S.D. (P<0.05) = 0.989
Overall mean	S.E.D. = 0.202	L.S.D. (P<0.05) = 0.450

c. Lighting treatment x variety

There was significant (*) interaction between lighting treatments and varieties. For all varieties the 11.30 hour tungsten treatment (11.30 T) resulted in plants being over the specification. Onyx Time was generally the tallest variety, with plant height being over the specification for 3 out of 5 treatments.

Mean plant height per pot (cm)

	Variety		
Treatment	Charm	Onyx Time	Swing Time
Standard	17.24	19.45	17.17
13 T	20.11	21.07	19.28
11.30 T	24.80	25.83	20.84
13 A	15.64	17.17	15.71
11.30 A	21.80	21.83	18.63
Mean	19.90	21.08	18.31

Between treatment	S.E.D. = 0.389	L.S.D. (P<0.05) = 0.786
Overall mean	S.E.D. = 0.236	L.S.D. (P<0.05) = 0.482

The quantity of plant growth regulator applied to each treatment is given in the table below. Treatments which resulted in plants being above the height specification (**bold**) and those below it (underlined) are indicated below.

Plant growth regulator (PGR) applications (as B-Nine) to plants in all treatments. Values are expressed as total Alar (g/l) applied during production.

Treatment	**Standard**			**13 T**			**11.30 T**			**13 A**			**11.30 A**		
Stick Week	**41**	**45**	**48**	**41**	**45**	**48**	**41**	**45**	**48**	**41**	**45**	**48**	**41**	**45**	**48**
Variety															
Charm	7	5.5	**6.5**	7	5.5	6.5	**7**	5.5	**6.5**	5	4.5	3.5	**5**	4.5	**3.5**
Swing Time	4	4	**4.75**	4	4	4.75	**7**	**6**	**5.25**	4	5	3.25	**5**	5	**3.25**
Onyx Time	3.5	5	4.75	3.5	5	4.75	5.5	5	5.25	3	4	3.25	4	4	3.25

3.1.1.4 Spread per pot

Minimum and maximum pot spread records were combined to produce average spread figures which were analysed statistically. All pots were grown to a spread specification of 27.5 ± 2.5 cm as demanded by the larger multiples.

a. Lighting treatment

The commercial standard treatment (Standard) produced an average pot spread of 33.35 cm, which this was not significantly increased by controlling night-length to 13 hours using tungsten lighting. Using assimilation lighting at 13 hours night-length actually reduced spread compared to the commercial standard. Controlling night-length to 11.30 increased plant spread by approximately 2cm, though there was no significant difference between using tungsten or assimilation lighting. All treatments produced plant spreads in excess of the specification.

Average spread per pot (cm)

Standard	13 T	11.30 T	13 A	11.30 A
33.35	33.63	35.97	32.31	35.93

S.E.D. = 0.272, L.S.D. (P<0.05) = 0.606

b. Lighting treatment x stick week

The same trend observed in the treatment average above was seen across all three stick dates. Plant spread was significantly (*) increased with 11.30 hour night-length treatments, with no significant difference between tungsten and assimilation lighting regimes at this night-length. Plant spread decreased significantly (*) with each stick date, by approximately 1.5cm, but was still in excess of specification.

Average spread per pot (cm)

	Sticking week		
Treatment	41	45	48
Standard	34.49	33.63	31.95
13 T	34.60	33.29	32.99
11.30 T	37.71	35.53	34.68
13 A	33.89	32.07	30.97
11.30 A	38.23	36.21	33.24
Mean	35.78	34.17	32.77

Between treatment	S.E.D. = 0.489	L.S.D. (P<0.05) = 1.089
Overall mean	S.E.D. = 0.215	L.S.D. (P<0.05) = 0.479

c. ***Lighting treatment x variety***

Charm and Swing Time plant spread increased significantly (*) when grown under 11.30 hour night-length compared to the Standard and 13 hour night length with the same light source. Swing Time did not show any clear differences between treatments, and overall had significantly (*) lower spread than the other two varieties.

Average spread per pot (cm)

	Variety		
Treatment	Charm	Oynx Time	Swing Time
Standard	32.9	35.1	32.1
13 T	33.4	34.9	32.5
11.30 T	36.7	37.5	33.7
13 A	32.1	33.7	33.1
11.30 A	37.1	36.9	33.8
Mean	34.5	35.6	33.0

Between treatment	S.E.D. = 0.337L.S.D. (P<0.05) = 0.682
Overall mean	S.E.D. = 0.178L.S.D. (P<0.05) = 0.363

3.1.1.5 Developing (stages 1-3) and open (stages 4+) buds and flowers

a. ***Lighting treatments***

Compared to the commercial standard treatment, developing bud numbers (stages 1-3) were not significantly increased by a night-length of 13 hours using tungsten lighting. All other treatments resulted in significant (*) increases in developing bud numbers (compared to the commercial standard regime). Using tungsten lighting at 11.30 hours was found to give the same number of developing buds as the 13 hour night-length with assimilation lighting. However, when assimilation lighting was used at 11.30 hours night-length developing bud numbers were significantly (*) higher than all other treatments. Under this regime developing bud numbers were almost double compared to commercial standard practice.

At marketing the two treatments under assimilation lighting produced significantly more (*) open flowers compared to treatments of the same night-length under tungsten lighting. Light sources appeared more influential than night-length in terms of increasing the number of open flowers per pot. Despite this neither tungsten or assimilation lighting significantly increased flower numbers compared to standard commercial practice.

Developing (stages 1-3) and open (stages 4+) buds and flowers per pot

	Standard	13 T	11.30 T	13 A	11.30 A
Stages (1-3)	16.25	16.10	24.40	24.06	31.44
Stage (4+)	12.41	11.80	11.07	13.33	12.34

(Stages 1-3) S.E.D. = 0.531, L.S.D. (P<0.05) = 0.962

(Stages 4+) S.E.D. = 0.442, L.S.D. (P<0.05) = 0.802

b. Lighting treatment x sticking week

Significant interaction (*) was seen between lighting treatments and the week of sticking. The same trends described above were seen across all stick weeks, but the number of developing buds and flowers varied significantly (*) between weeks. Plants stuck in week 45 had significantly lower numbers of developing buds than in weeks 41 and 48. Overall, week 41 was shown to produce significantly (*) more developing buds than the other two stick dates. Averaged across all treatments the number of open flowers fell significantly (*) from week 41 to 45 but the drop from week 45 to 48 was not significant. As a result plants stuck in week 41 had approximately 5 more open flowers than those stuck in week 48.

Developing (stages 1-3) and open (stages 4+) buds and flowers per pot

	Stages (1-3)			Stage (4+)		
Treatment	41	45	48	41	45	48
Standard	20.5	11.1	17.1	14.9	11.6	10.8
13 T	22.1	8.8	17.4	13.6	11.3	10.5
11.30 T	24.7	23.8	24.7	13.8	10.1	9.3
13 A	24.1	25.2	22.6	17.1	11.7	11.2
11.30 A	28.6	33.5	32.2	16.5	10.1	10.4
Mean	24.1	20.5	22.8	15.2	11.1	10.4

(Stages 1-3)

Between treatment	S.E.D. = 0.925	L.S.D. (P<0.05) = 2.061
Overall mean	S.E.D. = 0.419	L.S.D. (P<0.05) = 0.934

(Stage 4+)

Between treatment	S.E.D. = 0.584	L.S.D. (P<0.05) = 1.301
Overall mean	S.E.D. = 0.350	L.S.D. (P<0.05) = 0.780

c. Lighting treatment x variety

Varieties responded in a similar manner to lighting treatments. Charm generally produced significantly (*) more developing bud numbers than Onyx Time and Swing Time. The reverse situation was seen in the number of open flowers, the number being significantly (*) greater for Swing Time compared to Onyx Time and Charm.

Developing (stages 1-3) and open (stages 4+) buds and flowers per pot

	Stages (1-3)			Stage (4+)		
Treatment	Charm	Onyx Time	Swing Time	Charm	Onyx Time	Swing Time
Standard	18.3	18.6	11.8	11.3	12.8	13.2
13 T	19.0	17.1	12.2	10.3	12.3	12.8
11.30 T	29.6	21.1	22.4	9.4	10.5	13.3
13 A	29.9	23.3	19.1	11.0	13.9	15.0
11.30 A	37.7	26.5	30.2	10.3	12.2	14.6
Mean	26.9	21.3	19.1	10.4	12.3	13.8

(Stages 1-3)

Between treatment	S.E.D. = 0.925	L.S.D. ($P<0.05$) = 1.870
Overall mean	S.E.D. = 0.415	L.S.D. ($P<0.05$) = 0.847

(Stage 4+)

Between treatment	S.E.D. = 0.585	L.S.D. ($P<0.05$) = 1.183
Overall mean	S.E.D. = 0.209	L.S.D. ($P<0.05$) = 0.427

3.1.1.6 Leaf numbers

a. Lighting treatments

Compared to standard commercial conditions, all treatments given a night-length of 11.30 hours significantly (*) increased leaf numbers. Assimilation lighting did not increase leaf numbers under 13 or 11.30 hour night-length control, compared to equivalent treatments under tungsten lighting.

Average leaf number on uppermost break per plant

Standard	13 T	11.30 T	13 A	11.30 A
7.52	7.51	8.09	7.22	8.15

S.E.D. = 0.077, L.S.D. ($P<0.05$) = 0.171

b. Lighting treatment x stick week

There was significant (*) interaction between lighting treatment and stick date. Averaged across all treatments leaf numbers fell significantly with each successively later stick week. The observations of increased leaf numbers under 11.30 hour night-length control occurred during weeks 45 and 48. During week 41 assimilation lighting with an 11.30 night-length resulted in significant increases in leaf number compared to 13 hour night-length treatments.

Average leaf number on uppermost break per plant

	Sticking week		
Treatment	41	45	48
Standard	8.63	7.37	6.58
13 T	8.79	7.35	6.39
11.30 T	8.74	8.11	7.41
13 A	8.18	7.10	6.37
11.30 A	8.82	7.68	7.96
Mean	8.63	7.52	6.94

Between treatment	S.E.D. = 0.134	L.S.D. ($P<0.05$) = 0.299
Overall mean	S.E.D. = 0.161	L.S.D. ($P<0.05$) = 0.359

d. Lighting treatment x variety

There was significant (*) interaction between lighting treatments and variety. Swing Time produced significantly (*) more leaves per plant (8.47) compared to the other two varieties. With all varieties leaf numbers increased significantly (*) under 11.30 hour night-length treatments compared to 13 hour treatments with the same light source. With Charm and Onyx Time a night-length of 11.30 hours produced significantly (*) more leaves per plant than standard commercial practice, irrespective of light source.

Average leaf number on uppermost break per plant

	Variety		
Treatment	Charm	Onyx Time	Swing Time
Standard	7.31	6.88	8.39
13 T	7.23	6.96	8.34
11.30 T	8.19	7.29	8.78
13 A	7.20	6.44	8.02
11.30 A	8.28	7.34	8.45
Mean	7.64	6.98	8.47

Between treatment	S.E.D. = 0.142	L.S.D. ($P<0.05$) = 0.287
Overall mean	S.E.D. = 0.090	L.S.D. ($P<0.05$) = 0.184

3.1.2 Shelf Life

As described previously in Materials and Methods (Page 11), shelf life was recorded following a 21 hour transport simulation and 10 days in storelife simulation (10 days, in sleeves). Hence the weekly records taken correspond to the following number of days from marketing (after the end of storelife).

Record 1	=	7 days from marketing
Record 2	=	14 days from marketing
Record 3	=	21 days from marketing
Record 4	=	28 days from marketing

3.1.2.1 Leaf Quality

a. Lighting treatments

Leaf quality did not vary significantly between treatments until 21 days into shelf life. At this point plants grown under 11.30 hour night-length with tungsten lighting began to show significantly (*) better leaf quality than those grown under standard commercial practice. In contrast, plants grown under 11.30 hour night-length using assimilation lights showed significantly (*) worse leaf quality than those grown under standard commercial practice. By the end of shelf life this treatment (11.30 A) had significantly worse leaf quality than all other treatments. However, overall leaf quality was good as no scores exceeded 1, indicating only minor deterioration (Green leaves with a tinge of yellow, Page 15).

Mean leaf damage score (1 to 4, to indicate increasing leaf damage)

	Lighting treatment					**Significance**	
Number of days from marketing	Standard	13 T	11.30 T	13 A	11.30 A	S.E.D	L.S.D ($P<0.05$)
7	0.099	0.074	0.086	0.105	0.160	-	-
14	0.191	0.148	0.179	0.179	0.191	-	-
21	0.253	0.201	0.164	0.188	0.469	0.044	0.099
28	0.330	0.219	0.335	0.294	0.515	0.047	0.106

b. Variety

Between varieties, leaf damage was worst for Swing and Onyx Time, by the end of shelf life (28 days) both had significantly greater (*) leaf damage than Charm. For all varieties the worst leaf quality occurred with plants grown under 11.30 hours night-length (assimilation) conditions. However, differences, though significant, were small.

No significant interaction was found in leaf quality between lighting treatments and the week of sticking.

Mean leaf damage score (1 to 4, to indicate increasing leaf damage)

	Variety			Significance	
Number of days from marketing	Charm	Onyx Time	Swing Time	S.E.D	L.S.D (P<0.05)
7	0.041	0.126	0.148	0.027	0.060
14	0.052	0.204	0.278	0.025	0.050
21	0.063	0.317	0.385	0.055	0.113
28	0.129	0.402	0.485	0.028	0.058

3.1.2.2 Flower opening

a. Lighting treatment

Treatments under assimilation lighting had significantly more (*) open flowers than all other treatments. Plants grown under 11.30 hour night-length with assimilation lighting had significantly more open flowers than those under 13.00 hour assimilation lighting treatment.

Number of open flowers per pot

	Lighting treatment					**Significance**	
Number of days from marketing	Standard	13 T	11.30 T	13 A	11.30 A	S.E.D	L.S.D (P<0.05)
7	17.57	17.15	17.24	20.35	22.22	0.445	0.991
14	17.19	16.89	17.46	19.81	22.56	0.594	1.323
21	17.05	16.68	18.08	19.94	22.34	0.798	1.758
28	17.09	16.75	17.02	18.75	22.47	0.624	1.390

b. Variety

Swing Time had significantly (*) more open flowers than Onyx Time, which in turn had significantly (*) more than Charm. This trend was found to remain throughout shelf-life.

Number of open flowers per pot

	Variety			Significance	
Number of days from marketing	Charm	Onyx Time	Swing Time	S.E.D	L.S.D (P<0.05)
7	14.82	19.66	22.24	0.281	0.573
14	15.08	19.37	21.90	0.310	0.633
21	15.23	19.51	21.71	0.302	0.618
28	14.95	18.91	21.39	0.270	0.557

c. Stick week

Between stick dates, plants stuck in week 41 consistently had significantly (*) more open flowers than those stuck during weeks 45 and 48 throughout shelf-life, with numbers during week 48 significantly (*) greater than during week 45.

Number of open flowers per pot

	Stick week			Significance	
Number of days from marketing	41	45	48	S.E.D	L.S.D (P<0.05)
7	21.13	16.64	18.26	0.352	0.784
14	21.32	16.59	18.43	0.469	1.045
21	21.26	16.63	18.56	0.629	1.401
28	20.15	16.74	18.36	0.493	1.098

3.1.2.3 Flower distortion

a. Lighting treatment

Overall, there was a trend towards assimilation lighting treatments increasing the number of distorted buds compared to standard commercial practice. With assimilation lighting distorted bud levels were, also significantly higher in plants grown under 11.30 night-length compared to those under 13 hour night-length.

Number of distorted buds per pot

	Lighting treatment					Significance	
Number of days from marketing	Standard	13 T	11.30 T	13 A	11.30 A	S.E.D	L.S.D (P<0.05)
7	17.57	17.15	17.24	20.35	22.22	0.445	0.991
14	17.19	16.89	17.46	19.81	22.56	0.594	1.323
21	17.05	16.68	18.08	19.94	22.34	0.798	1.758
28	17.09	16.75	17.02	18.75	22.47	0.624	1.390

b. Variety

At the start of shelf life, differences between the three varieties were all significant (*), Charm had the most distorted buds, and Onyx Time the lowest. For the remainder of shelf life the number of distorted buds in Onyx Time remained significantly lower than the other two varieties.

Number of distorted buds per pot

	Variety			Significance	
Number of days from marketing	Charm	Onyx Time	Swing Time	S.E.D	L.S.D (P<0.05)
7	3.36	1.86	2.59	0.267	0.545
14	3.59	2.44	3.53	0.296	0.604
21	3.64	2.26	3.57	0.323	0.661
28	2.60	1.92	3.90	0.272	0.561

c. Stick week

Averaged across stick weeks the number of distorted buds per pot was significantly greater (*) in week 41. Overall, week 45 stuck plants produced the lowest numbers of distorted buds, all trends remained during the four weeks of shelf life.

Number of distorted buds per pot

	Stick week			Significance	
Number of days from marketing	41	45	48	S.E.D	L.S.D (P<0.05)
7	21.13	16.64	18.26	0.352	0.784
14	21.32	16.59	18.43	0.469	1.045
21	21.26	16.63	18.56	0.629	1.401
28	20.15	16.74	18.36	0.493	1.098

3.1.2.4 Flower score

a. Lighting treatment

There was no significant difference in flower score between light treatments during shelf-life. With all treatments, flower scores only exceeded 1 by the final assessment (28 days) of shelf life, indicating that overall flower quality was good. No significant interaction was found between variety or stick week.

3.1.2.5 Summary – Influence of lighting treatments on winter quality

Production time

The penalty for reducing the night-length from 13 to 11.30 hours was found to be 9 and 12 days delay for tungsten and assimilation lighting respectively.

Dry weight

Controlling night-length to 13 hours using tungsten or assimilation lighting did not result in any significant increases in plant dry weight, compared to standard commercial practice. Both 11.30 regimes resulted in significant increases in dry weight, with no significant difference between light source.

All treatments showed dry weight was significantly lower for week 45 stick than for week 41 and 48. The absence of any significant difference between weeks 41 and 48 would indicate there was no preference to increased ambient light at the beginning or end of production (in terms of dry weight increases).

Plant height

The most compact plants were produced when night-length was controlled to 13 hours using assimilation lighting. The 11.30 night-length treatment with tungsten lighting produced plants in excess of the height specification, and overall, use of assimilation stopped plants stretching. Averaged across all treatments, the lowest plant heights were achieved with plants stuck in week 45, this was attributed to the lower dry weights for this stick date.

Spread

All treatments increased plant spread in excess of the specification. Controlling night-length to 11.30 hours resulted in the greatest increase in spread. No significant difference was observed between using tungsten or assimilation lighting at this night-length. Spread decreased significantly with each progressively later stick date by approximately 1.5cm.

Developing (1-3) buds and open flowers (4) per pot

Developing bud numbers (1-3) were significantly increased compared to commercial standard practice only when the night-length was 11.30 hours. With the same night-length, but using assimilation lighting (11.30 A), the number of developing buds was approximately doubled compared to standard commercial practice.

Plants stuck during week 45 were found to have significantly lower numbers of developing buds than for the other two stick dates. Between varieties Charm had the greatest number of developing buds.

No treatment significantly increased the number of open flowers compared to standard commercial practice. However, light source rather than night-length appeared more influential in determining the number of open flowers, this being significantly higher under assimilation lighting rather than tungsten lighting. At marketing Charm had the greatest number of developing buds (1-3) but the lowest number of open flowers.

Leaf number

Both 11.30 hour night-length treatments significantly increased leaf numbers compared to standard commercial practice, although there was no significant difference between tungsten and assimilation lighting regimes. Swing Time was found to produce more leaves than the other two varieties.

Shelf life

After 21 days in shelf-life significant differences were observed in the leaf quality between plants grown under 11.30 hour night-length regimes, where the use of tungsten lights to provide the reduced night-length maintained better quality leaves than for assimilation lights or the commercial standard. In contrast, leaves on plants grown under 13 hour night-length assimilation lighting showed significantly reduced leaf quality compared to standard commercial practice. This possibly demonstrates that the lower light levels in shelf-life were preferred by plants grown under more comparable conditions (tungsten lighting) compared to those under higher light levels (assimilation lighting). Alternatively, the more compact plants produced under assimilation lighting would increase the mutual shading of leaves, resulting in more of the leaves, particularly at the bottom of the plant, being surplus to requirements.
Charm had significantly better leaf quality than the other 2 varieties. Differences between treatments in the number of open flowers at marketing were found to continue through shelf-life, with no significant differences in deterioration observed.

3.2 Sensitivity of flower development to reduced night-length

For clarity the treatment descriptions (below) and the transfer timings (bottom) have been redisplayed, the same information can be found in more detail on pages (7-8).

A	Standard	5 klx (12W/m^2) for weeks 1 – 3 of short days with 13 hour night-length, followed by ambient light and night-length (commercial standard)
C	11.30 T	5 klx (12W/m^2) for weeks 1 – 3 of short days with 11.30 hour night-length, followed by ambient light but with night-length controlled to 11:30 using tungsten lighting
D	13 A	2 klx (4.8W/m^2) throughout short days with 13 hour night-length controlled using assimilation lights (commercial standard for 2 klx treatments)
E	11.30 A	2 klx (4.8W/m^2) throughout short days with 11.30 hour night-length controlled using assimilation lights

For the treatments below the duration transfers occurred (from sticking) are listed in brackets.

Treatment Code	Description
AC2	Transfer from Treatment A to C after 2 weeks. (31 days)
AC4	Transfer from Treatment A to C after 4 weeks. (45 days)
AC6	Transfer from Treatment A to C after 6 weeks. (59 days)
AC8	Transfer from Treatment A to C after 8 weeks. (73 days)
CA2	Transfer from Treatment C to A after 2 weeks. (31 days)
CA4	Transfer from Treatment C to A after 4 weeks. (45 days)
CA6	Transfer from Treatment C to A after 6 weeks. (59 days)
CA8	Transfer from Treatment C to A after 8 weeks. (73 days)
DE2	Transfer from Treatment D to E after 2 weeks. (31 days)
DE4	Transfer from Treatment D to E after 4 weeks. (45 days)
DE6	Transfer from Treatment D to E after 6 weeks. (59 days)
DE8	Transfer from Treatment D to E after 8 weeks. (73 days)
ED2	Transfer from Treatment E to D after 2 weeks. (31 days)
ED4	Transfer from Treatment E to D after 4 weeks. (45 days)
ED6	Transfer from Treatment E to D after 6 weeks. (59 days)
ED8	Transfer from Treatment E to D after 8 weeks. (73 days)

3.2.1 Vegetative development and flower production

3.2.1.1 Production time

a. Transfer treatment

Crop duration (days).

Figures highlighted are for Charm under static treatments (A, C, D & E)

Treatments	AC2	AC4	AC6	AC8	CA2	CA4	CA6	CA8	A	C
	DE2	DE4	DE6	DE8	ED2	ED4	ED6	ED8	D	E
Transfer day	31	45	59	73	31	45	59	73	---	---
A & C	82.80	77.87	74.81	74.29	75.46	79.15	82.43	83.62	74.4	84.7
D & E	88.61	80.72	76.94	76.74	78.10	83.98	86.44	90.55	75.9	90.3

S.E.D. = 0.631 L.S.D. ($P<0.05$) = 1.250

Transfers from standard (A) into 11.30 hour tungsten night-length (C)

Transfer treatment AC8 moved plants from ambient light and night-length (with tungsten lighting) 1 day before the crop reached marketing stage. Within the trial, the increased response of some of the treatments was slightly faster than expected, resulting in some of the later transfer treatments only occurring for relatively short periods of time. The earlier the transfer to the 11.30 hour treatment with tungsten lighting the greater the increase in crop duration. The longest duration was with a transfer into 11.30 hour night-length 2 weeks into short days. Three of the treatments (AC6, AC8 and CA2) had equivalent production time to the standard treatment (A), and all were significantly faster than crops given 11.30 hour night-length lighting (C).

Reciprocal transfers from 11.30 hour night-length tungsten (C) to standard (A)

Treatments again showed that increasing the duration in 11.30 night-length using tungsten lighting resulted in longer production times, but the use of 11.30 hour night-length early in the short day period was shown to have a more detrimental effect than when applied at the end. Using reciprocal treatments AC6 and CA6 (Fig 2.1, Page 36) as an example, giving 11.30 hour night-length at the beginning of short days (CA6) resulted in a significant (*) increase of 4 days, compared to the same duration of 11.30 hour night-length at the end of production (AC6).

Transfers from 13 hour night length assimilation (D) to 11.30 hour night length assimilation (E)

All transfers showed that increasing the duration in 11.30 hour night-length using assimilation lighting increased crop production time, earlier transfers to 11.30 night-length also increased the delay. The 8 week transfer (DE8) had a production time of 76 days, therefore only spending 3 days in the 11.30 hour night-length treatment, and did not result in any further reductions. This demonstrates that the final two weeks of production time under 11.30 hour night-length control did not significantly increase crop duration compared to continual production in 13 hour night-length treatments.

Reciprocal transfers from 11.30 hour night length assimilation (E) to 13 hour night length assimilation (D)

These transfers demonstrated production time was significantly increased when 11.30 hour night-length was used at the beginning or the end of short days, compared to using it at the end of short days.

b. Transfer treatment x stick date

All treatments showed the same trends as described above, when averaged over all three stick dates. Treatments generally showed significant (*) increases in production time from week 41 to 45, the most notable being treatment AC2.

Transfers between treatments A and C (Crop duration (days))

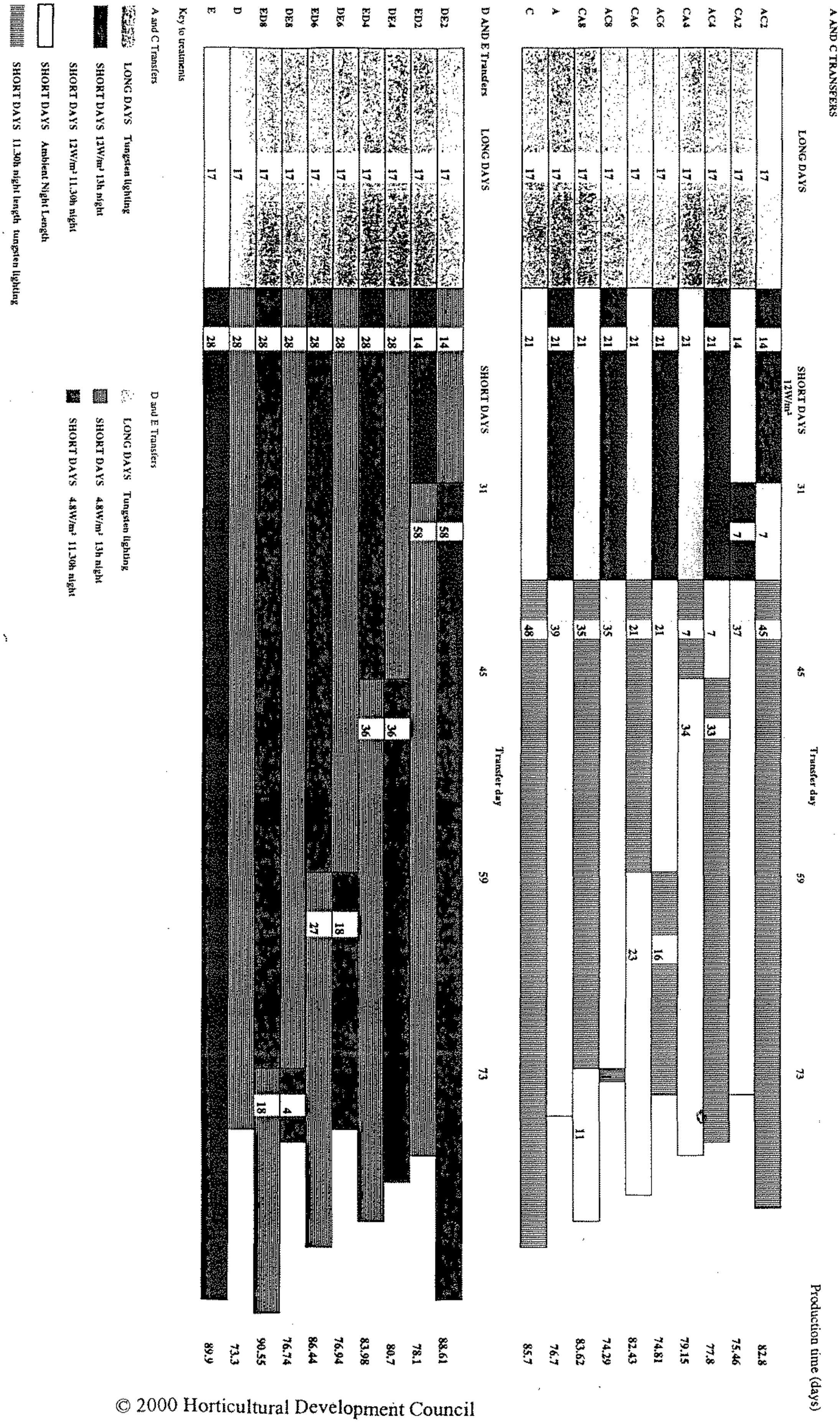
	Treatment Code							
Stick week	**AC2**	**AC4**	**AC6**	**AC8**	**CA2**	**CA4**	**CA6**	**CA8**
41	79.67	77.33	73.28	73.55	75.67	79.17	81.28	84.35
45	82.23	78.42	74.83	74.67	76.03	78.62	81.67	82.83
48	86.50	77.86	76.33	74.66	74.67	79.64	84.33	83.67

Transfers between treatments D and E (Crop duration (days))

	Treatment Code							
Stick week	**DE2**	**DE4**	**DE6**	**DE8**	**ED2**	**ED4**	**ED6**	**ED8**
41	83.50	76.50	74.33	74.67	75.50	78.50	81.67	84.17
45	89.33	83.00	78.12	77.33	82.67	85.00	90.33	93.67
48	93.00	82.66	78.33	78.55	76.14	88.44	87.33	93.80

S.E.D. = 0.631 L.S.D. (P<0.05) = 1.250

Fig 2.1 – Diagramatic representation of production time from sticking for all transfer treatments, compared to continual production under treatments A, C, D & E.



3.2.1.2 Plant height

a. Transfer treatments

Plant height (cm).

Figures highlighted are for Charm under static treatments (A, C, D & E)

Treatments	**AC2**	**AC4**	**AC6**	**AC8**	**CA2**	**CA4**	**CA6**	**CA8**	**A**	**C**
	DE2	**DE4**	**DE6**	**DE8**	**ED2**	**ED4**	**ED6**	**ED8**	**D**	**E**
Transfer day	**31**	**45**	**59**	**73**	**31**	**45**	**59**	**73**	---	---
A & C	23.60	20.50	18.27	17.60	18.31	20.72	22.74	23.89	17.24	24.80
D & E	21.14	16.97	16.14	15.75	16.63	19.69	20.53	22.04	15.64	21.80

S.E.D. = 0.394 L.S.D. (P<0.05) = 0.774

Transfers from standard (A) into 11.30 hour tungsten night-length (C)

As expected, increasing the duration in 13 hour night-length improved height control as vegetative growth was reduced. Plants transferred into 11.30 hour night-length after 4 weeks (AC4) remained under the height specification, but earlier transfers (AC2) achieved this specification. Every extra 2 weeks in 13 hour night-length control, resulted in significant (*) decreases in plant height.

Reciprocal transfers from 11.30 hour night-length tungsten (C) to ambient night length (A)

Height control improved with the duration under 13 hour night-length control. Reciprocal treatments showed the use of 11.30 hour night-length control had a more detrimental effect in increasing plant height when applied at the beginning rather than the end of production.

Transfers from 13 hour night length assimilation (D) to 11.30 hour night length assimilation (E)

The only plants to satisfy the height specification were those which spent the first 2 weeks in 13 hour night-length, before being moved into 11.30 night-length. Progressively later transfers resulted in plants significantly (*) lower than the minimum height specification by up to 2 cm.

Reciprocal transfers from 11.30 hour night length assimilation (E) to 13 hour night length assimilation (D)

Reciprocal treatments showed the use of 11.30 hour night-length had a greater effect on increasing plant height when applied at the beginning of short days. However, with assimilation lighting only one of the treatments produced plants in excess of the height specification (ED8).

c. Transfer treatment x stick date

A similar pattern of results was seen across all stick dates, with plants stuck in week 45 generally the most compact.

Transfers between treatments A and C (Plant height (cm))

	Treatment Code							
Stick week	**AC2**	**AC4**	**AC6**	**AC8**	**CA2**	**CA4**	**CA6**	**CA8**
41	25.22	23.21	20.26	19.62	20.23	23.22	24.10	24.65
45	20.02	18.81	15.73	15.58	17.04	18.81	20.02	20.93
48	25.57	19.48	18.82	17.61	17.67	19.48	24.10	26.09

Transfers between treatments C and A (Plant height (cm))

	Treatment Code							
Stick week	**DE2**	**DE4**	**DE6**	**DE8**	**ED2**	**ED4**	**ED6**	**ED8**
41	21.20	18.95	18.82	18.22	19.47	21.27	20.50	21.87
45	17.53	14.99	13.98	14.07	15.65	16.96	19.57	19.50
48	24.70	16.91	15.62	15.02	14.77	20.85	21.53	24.78

S.E.D. = 0.698 L.S.D. ($P<0.05$) = 1.374

3.2.1.3 Plant dry weight

a. Transfer treatment

Plant dry weight (g).

Figures highlighted are for Charm under static treatments (A, C, D & E)

Treatments	**AC2**	**AC4**	**AC6**	**AC8**	**CA2**	**CA4**	**CA6**	**CA8**	**A**	**C**
	DE2	**DE4**	**DE6**	**DE8**	**ED2**	**ED4**	**ED6**	**ED8**	**D**	**E**
Transfer day	**31**	**45**	**59**	**73**	**31**	**45**	**59**	**73**	---	---
A & C	14.00	12.06	11.33	10.79	11.17	12.22	13.28	13.99	9.78	13.72
D & E	15.61	12.08	10.73	10.84	12.03	13.72	15.18	14.53	9.69	14.65

S.E.D. = 0.577 L.S.D. (P<0.05) = 1.149

Transfers from standard (A) into 11.30 hour night-length tungsten(C)

The greatest dry weight was achieved with plants transferred into 11.30 hour night-length after 2 weeks. All later transfers after 4, 6 and 8 weeks had significantly (*) lower dry weight, although still heavier than those grown continually in treatment A. However, this treatment (AC2) produced plants with a delay of 8 days compared to those grown continually in A These plants were also over the maximum height specification.

Reciprocal transfers from 11.30 hour night-length tungsten (C) to standard (A)

Reciprocal treatments showed that the use of 11.30 at the beginning of short days resulted in a trend towards increased dry matter compared to when applied at the end of short days. However, this was only shown to be significant with a transfer into ambient night-length (A) after 6 weeks (CA6).

Transfers from 13 hour night length assimilation (D) to 11.30 hour night length assimilation (E)

The transfer into 11.30 hour night-length after 2 weeks in short days resulted in the greatest dry weight, but plants had unsatisfactory delays and were above the height specification. Transfers after 4,6 and 8 weeks did not vary significantly in their dry weight.

Reciprocal transfers from 11.30 hour night length assimilation (E) to 13 hour night length assimilation (D)

Reciprocal transfers showed that plant dry weight was significantly increased when 11.30 hour night-length was used at the beginning of short days compared to the end.

a. Transfer treatment x stick date

Data from individual stick dates showed the same trends occurred in all three weeks, although plant dry weight was generally lower during week 45.

Transfers between treatments A and C (Plant dry weight (g))

	Treatment Code							
Stick week	**AC2**	**AC4**	**AC6**	**AC8**	**CA2**	**CA4**	**CA6**	**CA8**
41	15.44	14.02	13.21	12.15	12.37	12.36	14.37	13.85
45	10.86	9.41	8.96	8.73	9.80	10.44	11.21	12.24
48	15.70	12.74	11.83	11.48	11.34	13.85	14.27	15.89

Transfers between treatments D and E (Plant dry weight (g))

	Treatment Code							
Stick week	**DE2**	**DE4**	**DE6**	**DE8**	**ED2**	**ED4**	**ED6**	**ED8**
41	14.24	12.15	12.55	11.60	12.64	14.90	14.54	15.67
45	12.81	9.93	8.87	8.24	11.14	11.75	13.25	12.50
48	19.77	14.17	10.76	12.67	12.31	14.49	17.76	15.35

S.E.D. = 1.136 L.S.D. ($P<0.05$) = 2.236

3.2.1.4 Number of developing (1-3) and total flowers

Developing buds (1-3)

a. Transfer treatments

(Number of developing buds (1-3) per pot).
Figures highlighted are for Charm under static treatments (A, C, D & E)

Treatments	**AC2**	**AC4**	**AC6**	**AC8**	**CA2**	**CA4**	**CA6**	**CA8**	**A**	**C**
	DE2	**DE4**	**DE6**	**DE8**	**ED2**	**ED4**	**ED6**	**ED8**	**D**	**E**
Transfer day	**31**	**45**	**59**	**73**	**31**	**45**	**59**	**73**	---	---
A & C	30.62	19.68	18.11	17.27	18.70	21.32	30.18	30.15	18.3	29.6
D & E	45.11	37.25	29.94	27.62	32.22	35.46	41.67	44.15	29.9	37.7

S.E.D. = 1.453 L.S.D. ($P<0.05$) = 2.883

Transfers from standard (A) into 11.30 hour night-length tungsten (C)

Increasing the duration under 13 hour night-length decreased the number of developing buds (1-3). Treatments moved into 11.30 hour after only 2 weeks produced significantly (*) more developing buds than later transfers. Later transfers did not result in significant increases in developing bud numbers compared to plants grown continually in Treatment A.

Reciprocal transfers from 11.30 hour tungsten night-length (C) to ambient night length (A)

Reciprocal treatments showed that using 11.30 at the beginning of short days resulted in significantly more buds than when used at the end of short days. These increases were significant (*) with transfers after 4 (AC4) and 6 (AC6) weeks.

Transfers from 13 hour night length assimilation (D) to 11.30 hour night length assimilation (E)

Transfers into 11.30 hour night-length after 2 or 4 weeks resulted in significant increases in buds (1-3), compared to pots grown continually in 13 hour night-length. Those transferred after 6 weeks did not have significantly more developing buds (1-3) than plants grown continually in 13 hour night-length.

Reciprocal transfers from 13 hour night length assimilation (D) to 11.30 hour night length assimilation (E)

Reciprocal treatments again showed that the number of developing buds increased when 11.30 hour night-length was applied at the beginning of short days. As little as 2 weeks of 11.30 hour night-length at the start of short days resulted in significant (*) increases in developing buds (1-3) compared to when used at the end.

b. Transfer treatment x stick date

Transfers between treatments A and C
(Number of developing buds (1-3) per pot)

	Treatment Code							
Stick week	**AC2**	**AC4**	**AC6**	**AC8**	**CA2**	**CA4**	**CA6**	**CA8**
41	37.83	32.17	28.82	26.54	27.33	31.33	37.22	32.14
45	18.36	10.14	9.17	7.00	8.76	8.54	19.76	23.83
48	35.67	16.73	16.33	18.27	20.00	24.07	33.67	34.47

Transfers between treatments D and E (Number of developing buds (1-3) per pot).

	Treatment Code							
Stick week	**DE2**	**DE4**	**DE6**	**DE8**	**ED2**	**ED4**	**ED6**	**ED8**
41	39.83	40.83	37.83	31.83	40.67	43.67	44.33	43.33
45	43.50	35.50	23.67	24.67	29.67	29.61	36.67	39.00
48	52.00	37.41	28.33	26.37	26.33	33.11	44.00	50.12

S.E.D. = 3.00 L.S.D. (P<0.05) = 5.88

Total flowers per pot

a. Transfer treatments

Transfers from ambient night-length (A) into 11.30 hour tungsten night-length (C)

Transfers into 11.30 hour night-length control after 2 weeks (AC2) resulted in significantly greater (*) total flowers than plants grown continually in treatment A. Later transfers did not result in significant increases in open flower numbers.

Reciprocal transfers from 11.30 hour tungsten night-length (C) to ambient night-length (A)

Reciprocal treatments showed that using 11.30 hour night-length control at the beginning of production resulted in significantly more total flowers than when applied at the end. All treatments with the largest number of total flower numbers (approximately 40) received 11.30 hour night-length control during the first 4 weeks of production.

Transfers from 13 hour night length assimilation (D) to 11.30 hour night length assimilation (E)

In contrast to tungsten lighting treatments described above there was a more gradual decrease in flower numbers with reduction of the time plants spent in 11.30 hour night-length.

Reciprocal transfers from 11.30 hour night length assimilation (E) to 13 hour night length assimilation (D)

Reciprocal treatments showed that using 11.30 hour night-length control at the beginning of production resulted in significantly more flowers than when applied at the end. This response was also a gradual increase, in contrast to the sharp increases seen with tungsten lights when 11.30 control was used during the first 4 weeks of production.

(Total number of flowers per pot).

Figures highlighted are values for Charm under static treatments (A, C, D & E)

Treatments	**AC2**	**AC4**	**AC6**	**AC8**	**CA2**	**CA4**	**CA6**	**CA8**	**A**	**C**
	DE2	**DE4**	**DE6**	**DE8**	**ED2**	**ED4**	**ED6**	**ED8**	**D**	**E**
Transfer day	**31**	**45**	**59**	**73**	**31**	**45**	**59**	**73**	**---**	**---**
A & C	40.81	29.66	29.25	28.45	29.79	37.76	40.76	40.69	29.60	40.93
D & E	55.22	47.37	40.50	39.25	44.22	47.87	52.11	55.39	40.93	47.97

S.E.D. = 1.922 L.S.D. ($P<0.05$) = 3.767

b. Transfer treatment x stick date

Data from individual stick dates showed the same trends occurred in all three weeks, although total flower numbers were generally lower during week 45.

Transfers between treatments A and C (Total number of flowers per pot)

	Treatment Code							
Stick week	**AC2**	**AC4**	**AC6**	**AC8**	**CA2**	**CA4**	**CA6**	**CA8**
41	49.17	42.17	42.26	39.93	41.00	44.17	49.46	43.73
45	27.94	20.08	19.17	18.00	19.54	20.48	30.50	34.50
48	45.33	26.75	26.33	27.43	28.83	33.65	42.33	43.83

Transfers between treatments D and E (Total number of flowers per pot)

	Treatment Code							
Stick week	**DE2**	**DE4**	**DE6**	**DE8**	**ED2**	**ED4**	**ED6**	**ED8**
41	52.17	52.83	51.50	47.67	54.33	59.50	56.67	56.17
45	51.00	41.67	31.83	33.17	40.00	39.83	46.50	50.33
48	62.50	47.61	38.17	39.61	38.33	44.28	53.17	59.66

S.E.D. = 2.719 L.S.D. (P<0.05) = 5.329

3.2 Summary

Summary of results averaged across 3 stick dates for transfers between treatments A and C.

Highlighted values indicate those not significantly different (P<0.05) from plants grown continually in treatment A. (Values for A and C treatments given in italics)

	AC2	AC4	AC6	AC8	CA2	CA4	CA6	CA8	*A*	*C*
Production time (days)	82.8	77.87	**74.81**	**74.29**	**75.46**	79.15	82.43	83.63	*74.40*	*84.7*
Height (cm)	23.60	20.50	18.27	**17.60**	18.31	20.72	22.74	23.89	*17.24*	*24.80*
Dry Weight (g)	14.00	12.06	**11.33**	**10.79**	**11.17**	12.22	13.28	13.99	*9.78*	*13.72*
Number of developing buds (1-3)	30.62	19.68	**18.11**	**17.27**	**18.70**	21.32	30.18	30.15	*18.3*	*29.6*
Total flowers	40.81	29.66	29.25	28.45	29.79	37.36	40.76	40.69	*29.6*	*39.03*

Summary of results averaged across 3 stick dates for transfers between treatments D and E.

Highlighted values indicate those not significantly different (P<0.05) from plants grown continually in treatment D. (Values for D and E treatments given in italics)

	DE2	DE4	DE6	DE8	ED2	ED4	ED6	ED8	*D*	*E*
Production time (days)	86.61	80.72	**76.94**	**76.74**	78.10	83.98	96.44	90.55	*75.9*	*90.3*
Height (cm)	21.14	16.97	16.14	**15.76**	16.63	19.69	20.53	22.04	*15.64*	*21.80*
Dry Weight (g)	15.61	12.08	**10.78**	**10.84**	12.03	13.72	15.18	14.53	*9.69*	*14.65*
Number of developing buds (1-3)	45.11	37.25	**29.94**	**27.62**	32.22	35.46	41.67	44.15	*29.9*	*37.7*
Total flowers	55.22	47.37	**40.50**	**39.25**	44.22	47.87	52.11	55.39	*40.9*	*48.0*

Crop duration (days)

Lengthening the duration under 11.30 hour night-length control increased production time. These increases were greatest when 11.30 hour night-length was applied at the beginning of short days. Treatments using 2 weeks of 11.30 hour at the end of short days (AC6 and DE6) were shown to result in equivalent production time as those grown continually under either Standard (A) or 13 hour night-length control (D), respectively.

Plant height

Increasing the duration under 11.30 hour night-length increased plant height. The use of 11.30 hours at the beginning of short days had a more detrimental effect on increasing plant height (in term of meeting the height specification) than when applied at the end. Under tungsten lighting regimes, plants spending more than 4 weeks under 11.30 night-length exceeded the height specification by up to 7cm. Under assimilation lighting regimes height control was improved compared to tungsten lighting, with plants spending up to 4 weeks under 11.30 night-length coming within the height specification, and those over the specification only exceeding it by a maximum of 2cm.

Dry weight

Increasing the duration under 11.30 hour night-length increased plant dry weight. Increases were greatest when 11.30 hour was applied at the beginning of short days This was seen as a trend under tungsten lighting, but a significant effect (*) with assimilation lighting. All increases in dry weight were accompanied by corresponding increases in production time.

Number of buds

Increasing the duration under 11.30 hour night-length increased the number of buds. Reciprocal transfers showed that applying 11.30 hour night-length for two weeks at the beginning of short days increased buds number compared to when it was applied at the end. This effect was seen as a trend under tungsten lighting and a significant effect (*) with assimilation lighting. Results with tungsten lighting showed plants had to be transferred into 11.30 hour night-length within 2 weeks of short days to increase the number of buds. With assimilation lighting it was possible to leave plants in 13 hour night-length control for the first 4 weeks, and still significantly (*) increase bud numbers compared to plants grown continually in 13 hour night-length conditions. This trend was also observed for developing buds (stages 1-3) under the assimilation lighting regimes (treatments D and E). With tungsten lighting plants required an extra 2 weeks in 11.30 night-length control to significantly (*) increase buds (1-3) compared to plants grown continually in treatment A.

Total flowers

Total flower number with tungsten lighting was only increased with early transfers (after 2 weeks) into 11.30 hour night-length (AC2). Reciprocal treatments showed using 11.30 hours for the first 4 weeks (CA4), resulted in significant (*) increases in total flower numbers. With assimilation lighting it was possible to increase the number of total flowers per pot by up to 15 flowers with treatments spending more up to 6 weeks in 11.30 night-length.

4.0 DISCUSSION

The first objective of this trial was to determine if plant bulk could be increased using 11.30 hour night-length controlled by either tungsten or assimilation lighting without extending crop duration.

The results of this study have shown that 11.30 hour night-length did significantly (*) increase plant dry weight with both tungsten and assimilation lighting, though differences between light source were not significant. This was accompanied by a significant (*) increase in production time compared to standard commercial practice or 13 hour night-length regimes using tungsten (13 T) or assimilation (13 A) lighting. These delays were on average 9 and 12 days for tungsten (11.30 T) and assimilation (11.30 A) lighting regimes respectively.

With tungsten lighting dry weights were not significantly (*) different to those with assimilation lighting, but production time was reduced by 3 days.

The second objective was to determine if the effect of 11.30 hour night-length regime on increasing plant height could be controlled effectively with plant growth regulators (PGR) to meet market specifications.

The height control was a problem with 11.30 night-length, with the increased vegetative production producing plants over the height specification. This was found to be more of a problem with the use of tungsten lighting where plants tended to 'stretch' as a result of the far red component in the lamps. Additional PGR inputs (Alar) were used in an attempt to control plant height but some treatments still exceeded the height specification by up to 7cm. This problem was more pronounced during stick weeks 41 and 48 due to the extra vegetative growth produced in these stick dates.

Overall, 11.30 hour night-length treatments with assimilation lighting reduced the height increase to within the height specification for plants stuck in week 45. Those from weeks 41 and 48 were 1-2 cm over the height specification, these increases could possibly be controlled by further increasing the PGR inputs or different timing of application.
With tungsten lighting the variety used was critical. Swing Time was within the height specification, the other two varieties, Charm and Onyx Time, exceeded the height with plants stuck in weeks 41 and 48. These increases produced plants up to 7cm taller than required. It is questionable if these increases in height could be controlled as effectively as the smaller increases seen under assimilation lighting regimes. If they could be controlled, the increased costs of chemical applications and labour inputs would have to be offset against the reduced costs of tungsten lighting.

The final objective was to examine the sensitivity of flower initiation and development (and vegetative growth) to 11.30 hour night-length during production.

Any increases in dry weight from using 11.30 night-length were always associated with increased production time. The interpretation of the results is clearly always going to be a compromise between production time and crop improvement. Therefore, the results are discussed from two viewpoints,

a) What crop improvements can be achieved with the same production time as when grown continually under Standard conditions (A) or 13 hour night-length control (D) (for tungsten and assimilation lighting treatments respectively)?

b) Do any transfer treatments provide the benefits of 11.30 night-length control (in terms of increased dry weight or flower development) but with production time lower than those under continuous 11.30 control?

a) In terms of flower development and quality, both 11.30 hour night-length regimes significantly increased (*) the number of developing buds compared to standard commercial practice (Standard), but with assimilation lighting numbers were actually doubled. However, as all treatments were within the specification it is questionable if this would have resulted in an increase in income for a grower, especially if it was also associated with a 12 day delay.

Transfer treatments with the same production time as Standard (A) or 13 hour night-length (E) are highlighted on Page 45. With the exception of some height differences it can be seen that there were no significant increases in vegetative or flowering development. Therefore it can be concluded that to achieve benefits of 11.30 hour night-length control production time will be increased..

b)The most promising treatments were those using 11.30 hour night-length for the first 4 weeks, these were compared to continuous production under 11.30 hour night-length control.

A saving of 1 week in production was achieved by giving the 11.30 hour night-length treatment (E) during the first 4 weeks of short days, compared to those under this regime throughout. Plant dry weights were marginally lower, but the same number of developing buds and total flowers were achieved. This treatment appears to offer some of the benefits of 11.30 hour night-length but with a lower production time.

Similar results in saving crop duration were also achieved under the tungsten lighting regime with a saving of 5 days in production time when plants were transferred for their first 4 weeks under 11.30 hour night-length, but both dry weight, developing bud and flower numbers were significantly (*) lower.

This indicates that using assimilation lighting used for a limited proportion of production time could produce some of the benefits of reduced night-length. This was in contrast to tungsten lighting which showed limited use of 11.30 hour night-length during production could reduce production time but did not increase flower development (compared to treatment C).

The main benefit was shown to be an increase in the number or developing buds and flowers. Increasing the duration of production time under 11.30 hour night-length control increased flower development, but transfer treatments showed flower production was more sensitive at the beginning of short days compared to at the end. The critical period for increasing flower development was found to be the first 4 weeks of short days (assimilation lighting), increasing to the first 6 weeks with tungsten lighting. In both cases during the remainder of production time (up to approximately 8 weeks) flower development was found to be relatively insensitive to reduced night-length treatments.

Whilst the results showed that the delay in production time under the 11.30 hour night-length treatment was significant, plant bulk and flower development were increased, and there appears to be potential for achieving some of the benefits without the extended delay by applying the lighting treatment during the first few weeks of short days. Assimilation lighting, as opposed to tungsten light, gave the best result overall.

5.0 CONCLUSIONS

- 11.30 hour night-length significantly (*) increased plant dry weight, with no significant difference between tungsten or assimilation lighting.

- Production time was increased by up to 12 days when using 11.30 hour night-length, although tungsten lighting was found to be marginally quicker (9 day delay).

- 11.30 hour night-length significantly increased flower development in excess of the standard supermarket specification (All treatments exceeded the specification).

- Height control was dependant on variety and stick week. 11.30 hour night-length using assimilation lighting produced plants 1-2 cm over the height specification. These increases could feasibly be controlled by extra PGR inputs but larger increases (7cm) using tungsten lighting may be too great to be effectively controlled.

- Transfer treatments showed plants were most responsive to 11.30 hour night-length at the beginning of short days.

- Production time under continuous 11.30 hour night-length could be reduced if it was only used for the first 4 weeks of short days. This treatment produced plants with slightly lower dry weights, though still greater than the standard regime, but with the benefits of increased flower development associated with 11.30 night-length. The saving in production time was approximately 1 week compared to continuous 11.30 hour night-length, a delay of only 1 week compared to the commercial standard.

APPENDICES

Appendix 1 – Treatment means; Lighting treatments.

Crop duration in short days (Days)

Treatment	Stick Week	Variety		
		Charm	Onyx Time	Swing Time
Standard	41	56.97	59.93	60.65
	45	56.85	60.85	61.51
	48	58.39	60.14	61.68
Tungsten 13	41	56.85	60.35	61.22
	45	57.76	61.64	60.34
	48	57.97	59.93	59.68
Tungsten 11.30	41	67.35	59.93	67.68
	45	67.23	70.45	68.64
	48	68.43	69.90	67.39
Assimilation 13	41	56.30	59.51	59.89
	45	59.14	60.81	62.31
	48	61.35	61.18	62.06
Assimilation 11.30	41	69.87	72.02	70.77
	45	74.80	72.97	73.30
	48	75.10	73.72	71.97

S.E.D = 0.619 L.S.D (P<0.05) = 1.250

Appendix 1 – Treatment means; Lighting treatments.

Crop duration from sticking to marketing (Days)

Treatment	Stick Week	Variety		
		Charm	Onyx Time	Swing Time
Standard	41	73.97	76.93	77.65
	45	73.85	77.85	78.51
	48	75.39	77.14	78.68
Tungsten 13	41	73.85	77.35	78.23
	45	74.76	78.64	77.34
	48	74.97	76.93	76.68
Tungsten 11.30	41	84.35	87.45	84.68
	45	84.23	86.90	85.64
	48	85.43	88.34	84.39
Assimilation 13	41	73.30	76.51	76.89
	45	76.14	77.81	79.31
	48	78.35	78.18	79.06
Assimilation 11.30	41	86.87	89.02	87.77
	45	91.80	89.97	90.30
	48	92.10	90.72	88.97

S.E.D = 0.619   L.S.D ($P<0.05$) = 1.250

Appendix 1 – Treatment means; Lighting treatments.

Plant dry weight (g)

Treatment	Stick Week	Variety		
		Charm	Onyx Time	Swing Time
Standard	41	10.853	12.030	11.514
	45	6.641	9.271	8.198
	48	11.841	12.601	11.563
Tungsten 13	41	11.493	12.386	11.529
	45	6.284	8.775	7.587
	48	11.605	12.226	12.117
Tungsten 11.30	41	15.281	14.361	13.306
	45	9.796	13.164	11.127
	48	16.080	14.604	12.929
Assimilation 13	41	11.255	11.647	11.296
	45	6.826	7.647	7.032
	48	10.981	12.022	11.269
Assimilation 11.30	41	13.758	16.275	13.714
	45	11.514	13.061	12.211
	48	18.689	16.959	13.046

S.E.D = 1.052 L.S.D ($P<0.05$) = 2.167

Appendix 1 – Treatment means; Lighting treatments.

Plant height excluding the pot (cm)

Treatment	Stick Week	Variety		
		Charm	Onyx Time	Swing Time
Standard	41	19.32	21.25	18.31
	45	15.14	17.88	16.37
	48	17.26	19.27	16.81
Tungsten 13	41	23.05	24.55	20.47
	45	16.84	19.71	18.19
	48	20.44	18.95	19.16
Tungsten 11.30	41	25.47	26.88	22.00
	45	21.90	23.68	20.78
	48	27.03	27.01	19.72
Assimilation 13	41	17.99	18.64	17.51
	45	13.73	15.61	14.18
	48	14.97	17.28	15.44
Assimilation 11.30	41	23.23	23.09	20.35
	45	18.47	19.53	16.50
	48	23.70	22.85	19.03

S.E.D = 0.867 L.S.D (P<0.05) = 1.752

Appendix 1 – Treatment means; Lighting treatments.

Plant spread (cm)

Treatment	**Stick Week**	**Variety**		
		Charm	**Onyx Time**	**Swing Time**
Standard	41	34.58	35.97	32.91
	45	30.97	36.24	33.68
	48	33.02	33.22	29.60
Tungsten 13	41	34.72	36.31	32.77
	45	31.35	36.08	32.45
	48	34.24	32.30	32.43
Tungsten 11.30	41	38.55	38.95	35.64
	45	34.77	37.88	33.93
	48	36.89	35.56	31.60
Assimilation 13	41	33.97	34.89	32.81
	45	31.12	33.28	31.82
	48	31.24	32.87	28.79
Assimilation 11.30	41	39.07	39.02	36.58
	45	36.83	37.66	34.45
	48	35.47	33.95	30.30

S.E.D = 0.848 L.S.D ($P<0.05$) = 1.713

Appendix 1 – Treatment means; Lighting treatments.

Leaf number on the uppermost break, per plant

Treatment	Stick Week	Variety		
		Charm	Onyx Time	Swing Time
Standard	41	8.58	7.85	9.46
	45	6.74	6.98	8.38
	48	6.60	5.81	7.32
Tungsten 13	41	8.57	7.78	10.02
	45	6.84	6.70	8.52
	48	6.27	6.40	6.49
Tungsten 11.30	41	9.06	7.67	9.50
	45	7.72	7.47	9.15
	48	7.80	6.73	7.68
Assimilation 13	41	8.08	7.25	9.20
	45	6.91	6.30	8.09
	48	6.61	5.76	6.76
Assimilation 11.30	41	8.90	8.12	9.44
	45	7.68	6.76	8.62
	48	8.26	7.14	8.48

S.E.D = 0.3171 L.S.D (P<0.05) = 0.6415

Appendix 1 – Treatment means; Lighting treatments.

Number of buds per pot

Treatment	Stick Week	Variety		
		Charm	Onyx Time	Swing Time
Standard	41	34.47	11.86	16.49
	45	12.64	7.39	6.06
	48	21.16	7.70	5.66
Tungsten 13	41	32.33	13.33	16.50
	45	12.86	8.20	4.20
	48	19.93	5.72	6.31
Tungsten 11.30	41	30.27	14.02	14.60
	45	20.66	11.31	9.87
	48	23.61	14.82	5.74
Assimilation 13	41	24.95	8.28	7.82
	45	9.18	3.47	4.31
	48	15.37	5.08	4.25
Assimilation 11.30	41	24.12	11.66	11.95
	45	16.82	4.49	6.91
	48	28.02	7.47	14.72

S.E.D = 1.609 L.S.D (P<0.05) = 3.272

Appendix 1 – Treatment means; Lighting treatments.

Number of developing buds stages (1-3)

Treatment	Stick Week	Variety		
		Charm	Onyx Time	Swing Time
Standard	41	26.86	19.58	14.98
	45	8.67	17.75	7.00
	48	19.47	18.56	13.39
Tungsten 13	41	27.85	20.76	17.76
	45	8.07	15.36	2.94
	48	21.17	15.09	15.92
Tungsten 11.30	41	33.13	20.30	20.75
	45	23.72	23.35	24.26
	48	32.07	19.73	22.27
Assimilation 13	41	33.02	20.07	20.15
	45	28.25	25.50	21.71
	48	28.26	24.22	15.31
Assimilation 11.30	41	34.45	24.01	27.26
	45	38.32	28.27	33.98
	48	40.30	27.13	29.21

S.E.D = 1.604 L.S.D ($P<0.05$) = 3.248

Appendix 1 – Treatment means; Lighting treatments.

Number of open flowers per pot

Treatment	Stick Week	Variety		
		Charm	Onyx Time	Swing Time
Standard	41	12.08	15.50	17.08
	45	10.35	11.72	12.60
	48	11.36	11.15	9.821
Tungsten 13	41	9.95	15.24	15.74
	45	10.08	11.17	12.62
	48	10.89	10.60	9.93
Tungsten 11.30	41	10.89	11.97	18.56
	45	8.95	9.93	11.36
	48	8.33	9.50	10.12
Assimilation 13	41	12.58	19.25	19.33
	45	9.72	11.93	13.47
	48	10.70	10.65	12.32
Assimilation 11.30	41	12.92	16.28	20.15
	45	8.99	9.42	12.00
	48	8.93	10.76	11.56

S.E.D = 1.015 L.S.D (P<0.05) = 2.522

Appendix 1 – Treatment means; Lighting treatments.

Total flower number per pot

Treatment	Stick Week	Variety		
		Charm	Onyx Time	Swing Time
Standard	41	38.95	34.91	32.07
	45	19.02	29.48	19.61
	48	30.82	29.69	23.19
Tungsten 13	41	37.78	35.99	33.49
	45	18.16	26.53	15.57
	48	32.06	25.69	25.86
Tungsten 11.30	41	44.02	32.27	39.31
	45	32.65	33.26	35.61
	48	40.41	29.24	32.41
Assimilation 13	41	45.62	39.32	39.49
	45	37.98	37.44	35.19
	48	39.19	34.86	27.61
Assimilation 11.30	41	47.36	40.28	47.40
	45	47.32	37.70	45.99
	48	49.23	37.90	40.77

S.E.D = 1.737 L.S.D ($P<0.05$) = 3.547

Appendix 2 – Nutrient analysis

STICK WEEK 41

Compost analysis

	Lighting Treatment				
	A Standard	B (13 T)	C (11.30 T)	D (13 A)	E (11.30 A)
Bulk density (g/ml)	0.343	0.373	0.338	0.339	0.349
PH	5.9	5.8	5.8	6	5.9
Conductivity (µS/cm)	278	278	278	208	278
Nitrate (mg/l)	153	178	173	121	206
Ammonium (mg/l)	0.4	1.2	17.3	1.7	1.8
Potassium (mg/l)	83	53	62	32	44
Calcium (mg/l)	100	116	117	76	147
Magnesium (mg/l)	94	114	110	80	138
Phosporus (mg/l)	20	17	21	17	12
Iron (mg/l)	0	0	0	0	0
Zinc (mg/l)	1.02	0.74	1.12	0.63	0.86
Manganese (mg/l)	0	0	0	0	0
Copper (mg/l)	0	0	0	0	0
Boron (mg/l)	0.03	0	0	0	0
Sodium (mg/l)	102	60	102	60	108
Chloride (mg/l)					
Sulphate (mg/l)	29	37	37	28	46

Leaf analysis Stick week 41 – Data not available.

STICK WEEK 45

Compost analysis

	Lighting Treatment				
	A Standard	B (13 T)	C (11.30 T)	D (13 A)	E (11.30 A)
Bulk density (g/ml)	0.308	0.295	0.293	0.307	0.27
PH	5.9	5.9	6	5.8	5.9
Conductivity (µS/cm)	330	370	250	370	330
Nitrate (mg/l)	138	186	96	168	168
Ammonium (mg/l)	0	0	0	0	0
Potassium (mg/l)	61	71	30	70	32
Calcium (mg/l)	120	127	93	128	120
Magnesium (mg/l)	122	123	93	129	119
Phosporus (mg/l)	28	27	22	24	23
Iron (mg/l)	0	0	0	0	0
Zinc (mg/l)	0.54	0.8	0.73	0.59	0.79
Manganese (mg/l)	0.03	0.04	0	0.03	0.02
Copper (mg/l)	0.03	0.06	0.04	0.01	0.06
Boron (mg/l)	0.25	0.09	0	0	0
Sodium (mg/l)	48	60	48	72	48
Chloride (mg/l)					
Sulphate (mg/l)	36	39	27	33	34

Leaf analysis

	Lighting Treatment				
	A Standard	B (13 T)	C (11.30 T)	D (13 A)	E (11.30 A)
Nitrogen (mg/l)	7.29	7.22	7.05	7.37	7.94
Phosporus (mg/l)	1.445	1.743	1.766	1.566	1.639
Potassium (mg/l)	8.61	7.07	7.27	6.98	8.76
Calcium (mg/l)	2.052	2.311	2.314	2.321	2.223
Magnesium (mg/l)	1.487	1.677	1.753	1.654	1.683
Sodium (mg/l)	0.067	0.041	0.04	0.041	0.043
Iron (mg/l)	85.16	67.82	54.74	55.7	62.55
Magnesium (mg/l)	260.45	297.56	269.63	260.82	230.76
Copper (mg/l)	13.66	14.14	11.27	8.39	11.15
Boron (mg/l)	41.36	37.16	39.29	30.01	32.42
Zinc (mg/l)	20.09	19.78	19.28	16.71	17.79

STICK WEEK 48

Compost analysis

	Lighting Treatment				
	A Standard	B (13 T)	C (11.30 T)	D (13 A)	E (11.30 A)
Bulk density (g/ml)	0.396	0.325	0.271	0.335	0.369
PH	5.4	5.6	5.9	5.8	5.9
Conductivity (µS/cm)	283	236	185	185	208
Nitrate (mg/l)	120	96	41	69	46
Ammonium (mg/l)	0.9	0.7	0.2	0.6	0.6
Potassium (mg/l)	38	23	0	20	13
Calcium (mg/l)	109	101	75	77	76
Magnesium (mg/l)	85	76	57	54	58
Phosporus (mg/l)	20	16	15	18	16
Iron (mg/l)	0	0	0	0	0
Zinc (mg/l)	0.03	0.11	0.01	0.07	0.04
Manganese (mg/l)	0.04	0.03	0.02	0.04	0.03
Copper (mg/l)	0.01	0.01	0.01	0.02	0.04
Boron (mg/l)	0.35	0.19	0.13	0.12	0.08
Sodium (mg/l)	84	48	60	42	78
Chloride (mg/l)					
Sulphate (mg/l)	41	33	43	28	32

Leaf analysis

	Lighting Treatment				
	A Standard	B T 13	C T 11.30	D A 13	E A 11.30
Nitrogen (mg/l)	7.55	6.28	5.86	6.47	6.56
Phosporus (mg/l)	1.319	1.212	1.66	1.364	1.321
Potassium (mg/l)	6.76	6.13	7.21	6.85	7.02
Calcium (mg/l)	2.053	2.035	2.452	2.144	1.867
Magnesium (mg/l)	1.314	1.352	1.783	1.421	1.384
Sodium (mg/l)	0.077	0.042	0.073	0.068	0.04
Iron (mg/l)	75.48	90.42	77.24	80.44	76.16
Magnesium (mg/l)	273.45	249.22	255.34	224.67	206.35
Copper (mg/l)	14.73	12.63	11.66	10.89	14.09
Boron (mg/l)	43.32	49.99	43.85	36.31	35.69
Zinc (mg/l)	24.58	26.22	23.88	23.33	24

Appendix 3 – Colour plates of growing trial

(i)

(ii)

Plate 1 – Charm stuck in week 45 grown under treatments A, B, C, D & E from left to right. (i) side view, (i) top view.

(A) Standard : **(B)** = 13 T : **(C)** 11.30 T : **(D)** 13 A : **(E)** 11.30 A

(i)

(ii)

Plate 2 – Onyx Time stuck in week 45 grown under treatments A, B, C, D & E from left to right. (i) side view, (i) top view.

(A) Standard: **(B)** = 13 T : **(C)** 11.30 T : **(D)** 13 A : **(E)** 11.30 A

(i)

(ii)

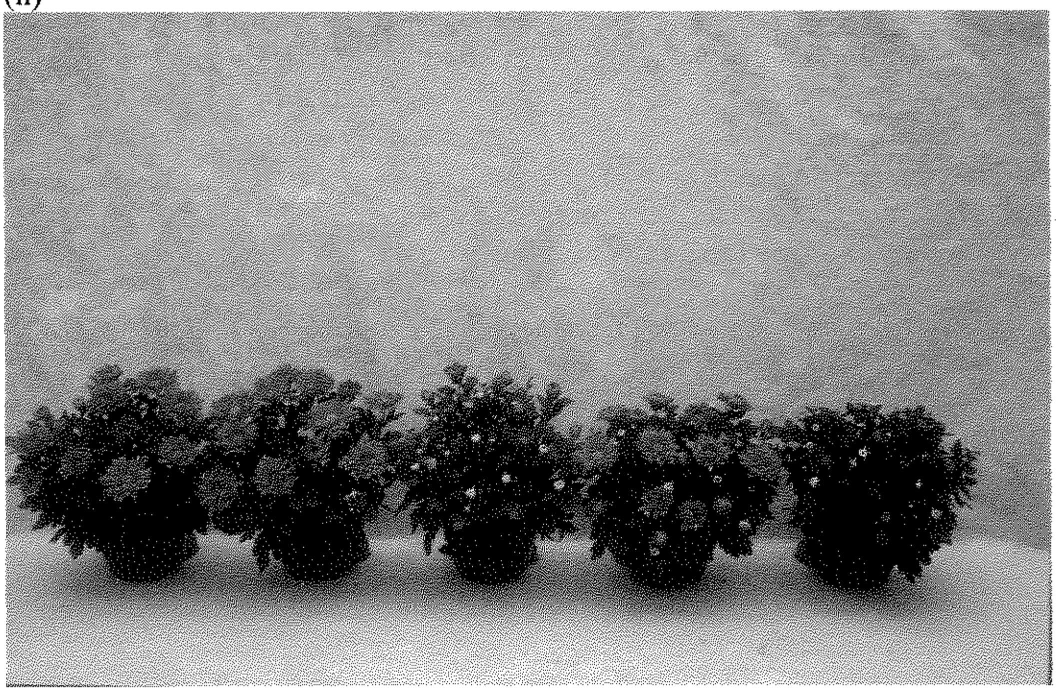
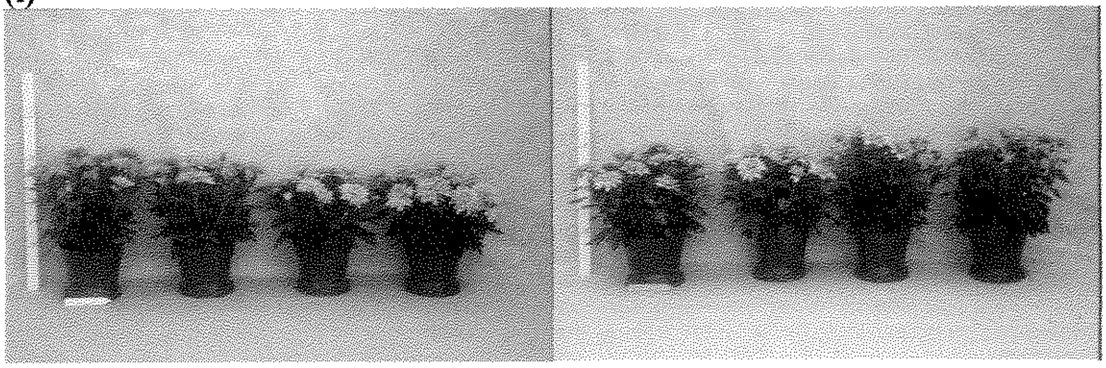


Plate 3 – Swing Time stuck in week 45 grown under treatments A, B, C, D & E from left to right

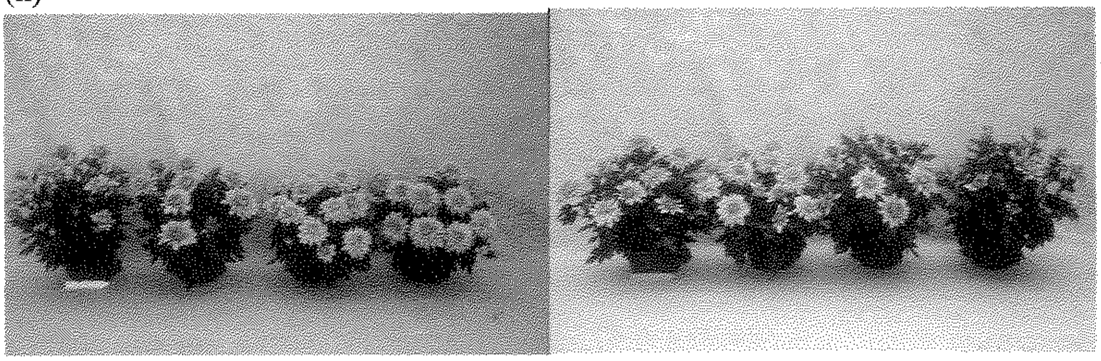
(A) Standard : **(B)** = 13 T : **(C)** 11.30 T : **(D)** 13 A : **(E)** 11.30 A

(i)



AC2 AC4 AC6 AC8 CA2 CA4 CA6 CA8

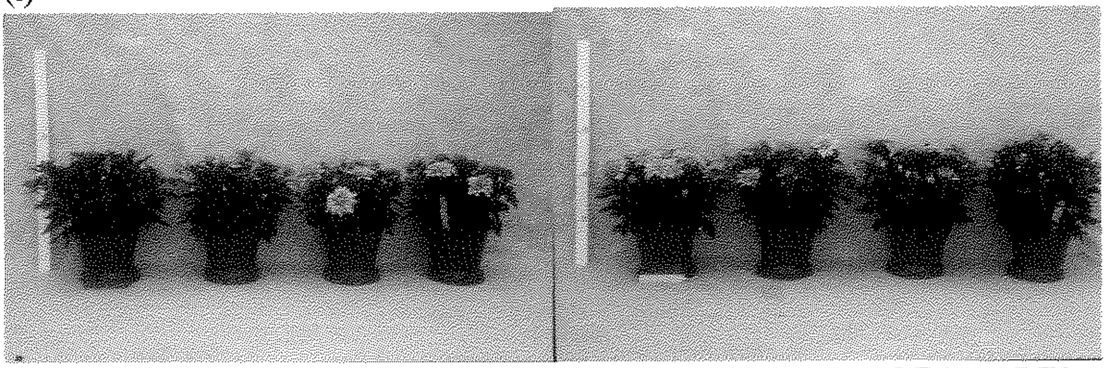
(ii)



AC2 AC4 AC6 AC8 CA2 CA4 CA6 CA8

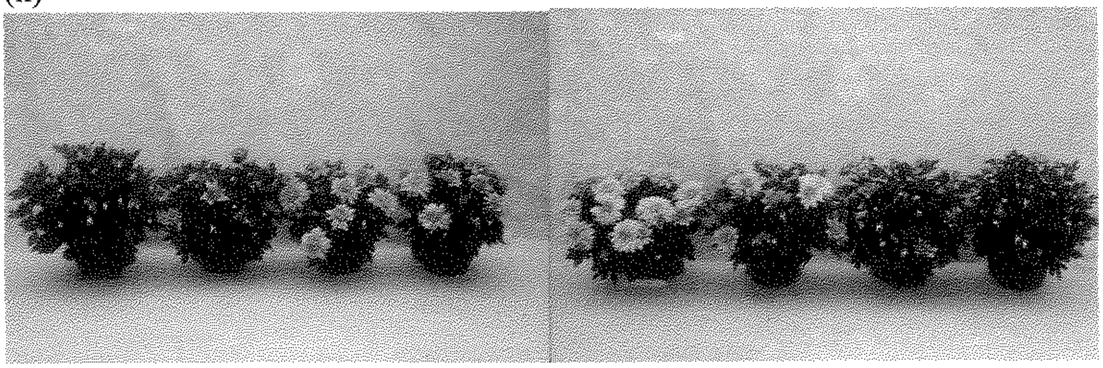
Plate 4 – Charm from the week 45 stick grown under the various transfer treatments between treatments A (Standard) and C (11.30 T) . (i) side view, (i) top view.

(i)



DE2 DE4 DE6 DE8 DE2 DE4 DE6 DE8

(ii)



ED2 ED4 ED6 ED8 ED2 ED4 ED6 ED8

Plate 5 – Charm from the week 45 stick grown under the various transfer treatments between treatments D (13 A) and E (11.30 A).
(i) side view, (i) top view.

Appendix 4

Average daily (sunrise to sunset) incident light levels (MJ m^{-2}) at HRI Efford from week 40 1998 to week 20 1999