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CONTENTS

1. PRACTICAL SECTION FOR GROWERS

Production of uniformly high quality pot chrysanthemums, when light levels are lowest during the winter period, is essential if growers are to maintain and increase their market share against the wide range of other products that are increasingly being produced for the winter market. Growers need robust techniques that will enable them to increase plant bulk and quality during the winter without availalble investment in new equipment. For growers who already have supplementary lighting in their production areas, these advances may take the form of modified lighting regimes, whereas new approaches to propagation and pinching the crop may provide benefits to those who currently do not have assimilation lighting as standard.

1.1 Background

Reduced night-length: Previous studies have successfully identified supplementary lighting regimes that help counter the decline in quality of pot chrysanthemums resulting from the drop in solar radiation levels experienced during the winter. Trials funded through the HDC during the past two years (PC 92 b, Yrs 1 and 2) have sought further improvements to winter production for growers utilising a range of supplementary lighting regimes from ambient, through 12 Wm^{-2} (5 klx) for the first 3 weeks of short days, to lighting at 4.8 Wm^{-2} (2 klx) throughout short days.

In the winter of 1995 (PC 92, Year 1) trials examined the potential for further improving winter quality by extending the period of photosynthetic activity by reducing night length to less than 13 hours. Small delays were observed in production using reduced night-lengths of 12 h (from 13 hours; conventionally accepted as giving optimum speed of production). This delay was also linked to small increases in vegetative growth. To investigate if greater benefits could be achieved, (in terms of increased plant bulk, flowering and pot quality), using reduced night-lengths, work in 1996 examined the impact on production using 11 hour night-lengths. These night length treatments were tested in 3 lighting regimes to represent the range currently in use on commercial nurseries.

Data from the 1996 trial demonstrated that production of pots using an 11 hour night-length stimulated marked increases in vegetative bulk, but flowering was variable. The crop was delayed by up to 30 days, and without increasing the amount of growth regulator, pots were far too leggy to be commercially useful. The difference between products of 12 and 11 hour night-lengths raised the question of whether the response to night-length was linear or, was there a minimum night-length which would give increased bulk and quality, without the delays.

The current work investigated the response of an extended range of pot mum varieties to changing night-length with the aim of identifying both; (i) the best night-length for winter production, and (ii) the differing sensitivity of several key commercial varieties to production using reduced night-length treatments ranging from 13 h to 11 hours 20 min (11:20) for 14 cm pots with supplementary lighting at 4.8 W/m^2 (2 klx) throughout short days.

Timing the pinch: Observational studies during the 1995 trial had demonstrated the potential for increasing vegetative growth by pinching plants earlier in production than was normally practised.

During 1996 pinching treatments were given at different points relative to the start of the short day period to investigate the potential of increasing vegetative growth on the breaks prior to flower initiation, and how this might impact on final quality. Pinching before the start of short days stimulated significantly more vegetative growth on the breaks. Although increases in vegetative growth on the breaks were achieved with these treatments, concerns were expressed regarding the potential interaction between pinching treatment and the number of long days given before pinching. Additional increases in vegetative growth may potentially be achieved by increasing the number of long days given before the pinch.

The current trial investigated the interaction between the number of long days (17, 21, 25) and the timing of pinching the plant relative to start of short days (4 days before, at or 4 days after), and aimed to identify benefits that could be achieved by manipulating both the timing of the pinch relative to the start of short days, and the number of long days given before the pinch.

How light levels during production and in the retail environment may impact on post-harvest performance: HDC funded work at HRI Efford has demonstrated the impact high intensity lighting at the end of production can have on pot quality at marketing. This work also raised questions regarding appropriate light levels for plants whilst on display in store prior to purchase. Currently, stores are unlikely to increase the level of lighting applied in their plant retail areas (due to high costs, and the problem of installing mixed lighting types within the store). This project evaluated the impact of varying light intensities within the store shelf-life environment on plants grown with or without supplementary lighting at the end of the period of production.

1.2 Summary of main results

1.2.1 Effects of reduced night-length on plant bulk and quality at marketing

- Growing pots under reduced night-lengths stimulated more vegetative and reproductive development, with more flowering breaks, all contributing to production of a visually striking pot at marketing. However, crop production time was increased.

- The extent of response to reduced night-length varied from variety-to-variety, though, on average, benefits with the least delay in production occurred at the11:40 night-length.

- Pots lit throughout SDs at 4.8 W/m^2 (2 klx), using reduced night-lengths, were larger in terms of height, spread and dry weight than comparable pots grown under 13 hour night-lengths. All pots receiving supplementary lighting throughout had significantly more flowers per pot at marketing than pots lit for the first 3 weeks of short days at 12 W/m^2 (5 klx)

- Pots grown at reduced night-lengths had a significantly more buds and flowers than pots grown in a 13 h night. This increase was mainly due to an increase in bud number developing at extra leaf axils.

- Reducing night-length to 12 hours had little effect on crop duration, but further reductions from 12 h to 11 h 20 min resulted in significant delays of, on average 18%. This represents a delay of 10 days on a 61 SD crop grown in a 13 hour night.

- The greatest effects of reduced night-length were observed when nights were between 11 hours 40 min and 11 hours 20 min.

- Delays associated with reducing night-length from 12h were linear in nature, each minute reduction in night-length representing a 6 hour delay in crops reaching maturity.

- Critical night-length varied with variety. Surf produced 80% of its increased flowering at night-lengths between 12 h and 11:40, whereas Purple about Time only expressed 20% of its flowering response in this range, with the remaining 80% between 11:40 to 11:20 hours.

- **Of the varieties tested:**

    - **Purple About Time:** This variety was relatively unresponsive to reduced night-length, with only small increases in bulk, and flowering associated with small delays compared to the other varieties.

    - **Charm:** Marked increases in plant bulk (height and dry weight), but only a small improvement in total bud and flower production. This variety was prone to large increases in production time under reduced night-length regimes.

    - **Regal Davis:** A prolific flowering variety, which showed moderate increases in bulk in response to reduced night-length, with only average delays. A good candidate for production using reduced night-lengths.

    - **Surf:** This variety produced large increases in vegetative growth as night-length was reduced, but only relatively small increases in total flower production. Large crop delays make this variety sub-optimal for production using reduced night-lengths.

    - **Miramar:** Responsive to reduced night-length, with large increases in total flower production and plant height and dry weight associated, but with relatively long delays.

    - **Purple Lucky Time:** Another prolific flowering variety, with further enhancements in bud and flower production in response to reduced night-length. Increases in plant height and dry weight also occurred with only moderate increases in duration. This appears a relatively good variety for production using reduced night-length.

- **Glow Time:** This variety was highly responsive to reduced night-length, with large increases in total flower production and plant bulk. This was the only variety of those tested that showed marked increases in dry weight in response to changes in night-length between 12 h and 11:40, again highlighting its sensitivity to reduced night-length. However, Glow Time was prone to long delays in production at night-lengths shorter than 11:40.

	Significant increases in			
Variety	**Plant bulk (a)**	**Bud number (b)**	**Response Time (c)**	**Overall score for response to reduced night-length (high score = best) (a + b – c)**
Purple About Time	4	2	3	3
Charm	9	3	7	5
Regal Davis	6	7	3	10
Surf	9	3	8	4
Miramar	9	7	7	9
Purple Lucky Time	8	8	3	13
Glow Time	9	7	6	5

1.2.2 Effects of reduced night-length on post-harvest performance.

- Increased plant bulk achieved from production under reduced night-length had no apparent influence in pot longevity during shelf-life tests. The main benefit appears to be the increased appeal to the consumer at point of sale.

- Despite increasing bud numbers during production, reduced night-length treatments had no significant effect on the number of flowers opening during shelf-life, indicating that the additional buds produced in these treatments failed to continue developing during shelf-life. This would tie in with the need to market winter-produced pots with flowers more fully open, (stage 3, as defined in the HDC pot mum poster, produced as a result of work in Project PC 13c) for the consumer to gain most satisfaction from the product at home.

- Flower colour during shelf-life appeared to be slightly better in pots grown under reduced night-lengths.

- Production using reduced night-length tended to increase the number of distorted flower buds observed during shelf-life, though with the increase in buds in this treatment, the number of open flowers was not affected. The number of distorted buds was highest from the week 42 sticking when buds were developing during a period of declining ambient light.

- Of the varieties tested, only Charm and Miramar showed increased flower opening during the first week of home-life (post sleeve-removal), which may prove attractive to consumers.

1.2.3 Manipulating the number of long days (LDs) and the timing of the pinch relative to the start of short days (SDs) to stimulate increased vegetative growth during the winter period.

- The effects of timing of the pinch, relative to the start of SDs, appeared to outweigh the effects of increasing the number of long days given. Therefore growers should still be able to benefit from early pinching without having to increase the number of LDs (although increasing the number of LDs will give added benefits). One problem associated with early pinching crops after only 13 long days (4 days before start of short days) is that there may be an increased risk of damaging the developing laterals or pinching too hard, both of which will reduce the quality of the final pot.

- The most effective treatment combination for increasing plant bulk and flowering on the breaks was to give pots at least 21 LDs and pinch 4 days before the start of SDs. This resulted in no crop delays relative to the commercial standard, with the benefits of increased plant bulk (height, spread and dry weight) together with higher numbers of breaks with 3 or more open flowers. However, there is the additional cost of extending the LD period to take into acccount.

- Plant bulk was greatest in plants both pinched early and given more LDs. Bulk was influenced by the leafiness of the breaks, and the data show a marked increase in leaf number on the top break in plants pinched 4 days before the start of SDs, compared to those pinched later. In this trial, pots pinched in LDs always produced significantly more leaves than those pinched at or after the start of SDs.

- Of the two varieties tested, Purple About Time responded well to changes in the number of LDs and timing of the pinch, with increased flower production. Charm also showed a strong vegetative response, but this did not translate into marked increases in flower production.

1.2.4 The interaction between light levels at the end of production and in the retail environment: the effects on post-harvest performance.

- Under the conditions tested in the current trial, production lighting regime and choice of variety had the greatest impact on post-harvest performance, with retail light environment of only secondary importance.

- Plants lit throughout SDs produced and retained more open flowers throughout shelf-life than plants finished in ambient light. There was no significant affect of retail light level on number of open flowers during shelf-life.

- Bud distortion appeared to be linked to changing light levels during production such that the number of distorted buds increased in pots produced in declining light levels, and not when light was consistently low or increasing during production. There was a trend for reduced bud distortion in pots finished in ambient light and retailed in the lower light regime, and *vice versa*.

1.3 Action points for growers

- Reduced night-length techniques can improve winter quality without negative impact on shelf-life, but will inevitably incur some crop delay. Growers will need to reduce night-length to less than 12 h in order to gain significant benefits.

- If economic constraints permit, the adoption of night-lengths close to 11:40 will be more effective than 12 h, but the choice of variety will be important in order to optimise returns. For this reason, growers will need to test the response of varieties not included in this trial and how particular production systems may modify response before adopting reduced night-length regimes.

- Current data clearly demonstrate the potential scope for manipulation of pinching technique together with the duration in long days to enhance pot bulk and quality. Based on the current information, growers should aim to give at least 21 long days, and to pinch up to 4 days before the start of short days. There may be potential for more extreme regimes (not tested within the current trial), but the number of long days that can be given will vary based on each grower's own production constraints. Again, it is recommended that small-scale trials with varieties not tested in the scope of this trial are carried out to ensure no negative impact on flowering results.

- Benefits of increasing the number of LDs appear to be greater when ambient light levels are higher (week 42 stick), and become reduced for later stick dates. In order to achieve similar benefits under lower light intensities, more LDs may in fact be necessary. However, this would need further investigation, and the cost of further increasing LDs could be prohibitive.

- From the current data, light levels in the growing environment appear to play a more important role in post-harvest longevity than the retail light environment. For this reason it is important to ensure that the best production lighting regime is adopted and pots are marketed at the correct stage. It must be noted that the trial transport simulation run was based on an average multiple retailers' expected regime. There are no data currently available for the likely impacts of varying the factors in the transport chain for pot mum post-harvest performance, and this may also be important.

1.4 Practical and financial anticipated benefits

- Current data clearly show that U.K. growers are able to produce a far superior (in terms of bulk and visual appearance) pot mum using reduced night-lengths, but at a cost of increasing production time. Each grower will need to calculate the cost of this increased production time in relation to improved marketing opportunities for the enhanced product.

- Results from this work clearly demonstrate the importance of variety selection, and the extent to which night-length can be safely manipulated before serious economic losses may be incurred.

- Future work will study the use of tungsten lighting (compared to assimilation lighting) as an effective means for controlling night-length during pot chrysanthemum production. If the benefits of reduced night-lengths can be realised using tungsten lighting, then the techniques will be immediately applicable to a much broader range of growers with only minimal investment.

2 SCIENCE SECTION

2.1. Introduction

HDC funded work at HRI Efford has focused over several years on the problems of declining quality of pot chrysanthemums produced during the winter period. Decreasing solar radiation levels during the winter result in small plants with relatively low vigour and poor quality foliage when compared to the summer crops. Further problems include low flower counts and slow rates of production during a period when costs per m^2 per day are at the highest point during the year. Supplementary lighting has been extensively studied to counteract this problem, and regimes have been successfully identified which can both speed up production and improve final quality. The industry has progressed using the knowledge generated from this work. Despite the optimisation of lighting regimes, growers still struggle to recover the costs of supplying supplementary lighting, as sales of pot chrysanthemums continuing to suffer over the winter period.

Further cost-effective improvements in plant quality are therefore demanded and the national pot chrysanthemum study group requested that future work be concentrated on developing techniques using the best of the supplementary lighting treatments evaluated.

Night-length

Work over the last two years has demonstrated the potential for manipulating pot chrysanthemum production by reducing length of night within the period of short days. This work was based on the principle that one method for improving winter quality may be to extend the period of production, and hence total period of assimilation, by delaying maturity (in a similar way to the use of an interruption in spray chrysanthemums). To-date, growers have not adopted the use of an interruption for pot chrysanthemums as it would be difficult to impose with many varieties being grown together. An alternative to interruption during the winter may be achieved by reducing night length during the short day period of production. This would increase the duration of flower development together with enhanced vegetative growth. The standard night-length currently used to achieve maximum speed of flowering in the commercial production of pot chrysanthemums (with supplementary lighting) is 13 hours. Research in Holland has examined manipulation of photo-period in winter for spray chrysanthemums and has demonstrated that fresh weight can be increased by reducing night-length (per. Comm. J. D. Abbott). Treatments suitable for the production of pot chrysanthemums in the UK have been examined in recent HDC funded studies at HRI Efford (PC 92b, Years 1 & 2). An 11 hour night length severely delayed maturity and consequently had a large impact on the amount of vegetative growth produced. A 12 hour night however had only a marginal effect in comparison with the standard 13 hour night currently used commercially. Further improvements in the current best supplementary lighting regime may therefore be achieved by investigating the effects of night-lengths between 11 and 12 hours. Night-lengths of these durations might be expected to give a greater impact on the final product with less extreme delays in production. Since the work in Holland also found that the influence of shorter nights varied with varieties, it is also important to evaluate these treatments with a wide range of varieties.

Number of long days and the timing of the pinch

Recent HDC funded work has also demonstrated the impact that pinching may have on the appearance of the final product. In particular this work examined the effects of pinching earlier than currently practised, either while plants were still receiving long days, or on the transfer from long days to short days. The aim of these treatments was to increase the amount of vegetative growth on the break before flowers are initiated and to improve the strength and shape of the final product. Increases in vegetative growth on the breaks were achieved with these treatments but concerns were expressed regarding the potential interaction between pinching treatment and maturity of the plants on pinching. That is the impact of an early pinch may vary according to the number of long days given before pinching, with additional increases in vegetative growth potentially achieved by increasing the number of long days given before the pinch. The current trial investigates the interaction between the number of long days a plant receives and the timing of pinching the plant relative to that start of short days.

Light levels during production and in the retail environment: impact on post-harvest performance

HDC funded work at HRI Efford has demonstrated the impact light intensity lighting at the end of production can have on final pot quality. This work has also raised questions regarding appropriate light levels for plants whilst on display in store prior to purchase. To-date, little research has focussed on how different light levels during production and in the retail environment affect home-life of pot plants. Plants produced under high light conditions will be acclimatised to high light, and may perform better in the home if they continue to receive high light in the retail environment, rather than if they are marketed in a low-light environment. Currently, stores are unlikely to increase the level of lighting applied in their plant retail areas due both to high costs, and to problems associated with non-uniformity of lighting types within store. For this reason, evaluation of the impacts of current 'in-store' lighting regimes on pot performance in shelf/home life was undertaken.

2.2. Objectives

Recent HDC-funded work at HRI Efford indicated that during the winter period there is scope for improving the quality of pot chrysanthemums, using techniques such as reduced night length and manipulating pinch date in relation to the start of short days (SDs) to increase vegetative growth, thereby resulting in a more attractive and robust product (PC 92b, Year 2). Post-harvest, the impact that in-store lighting environment has on the quality of the product also needs to be studied. The trial therefore addresses the following objectives:

- To evaluate the potential for further improving the quality of a range of commercially grown pot chrysanthemum varieties through reducing night-length of pots grown with supplementary lighting at 4.8 W/m^2 (2 klx) throughout short days compared to crops lit with 12 W/m^2 for the first 3 weeks of SDs (13h night) and in ambient light and natural night-length thereafter.

- To identify the potential for extending the range of varieties that can currently be grown through the winter using reduced night-length treatments.

- To examine the interaction between the number of long days and pinching in relation to the start of short days on the vegetative growth and final quality of the pot.

- To evaluate the impact of varying light intensities within the store shelf-life environment on plants grown either with or without supplementary lighting at the end of the production period in the glasshouse.

2.3. Material and Methods

2.3.1. Glasshouse site

All material was propagated in Glasshouse H south and transferred to K Block at the start of SDs. Both the night-length and pinching trials were carried out in K Block. The allocation of treatments to compartments can be seen in Appendix 1.

2.3.2. TRIAL 1: Reduced night-length for improved winter quality

The use of reduced night-length treatments to enhance vegetative growth and plant bulk using assimilation lighting to control photoperiod.

2.3.2.1. Pot chrysanthemum varieties and stick weeks

7 varieties were included in the night-length trial:
Un-rooted cuttings of Charm, Surf, Regal Davis and Miramar (Yoder Toddington Ltd), Purple About Time, Purple Lucky Time and Glow Time (Ficor Ltd).

Variety descriptions:

Charm : Lavender pink decorative; response time 9 weeks
Surf : White decorative; response time 9 weeks.
Miramar : Yellow single with green eye; response time 9 weeks.
Regal Davis : Deep pink single; response time 9.5 weeks.
Purple About Time : Purple decorative; response time 8.5 weeks
Purple Lucky Time : Purple bicolour anemone; response time 9 weeks
Glow Time : Golden yellow bicolour anemone; response time 8 weeks

Sticking weeks: Cuttings were stuck on three occasions, in week 41, 45 and 48.

2.3.2.2 Night-length Treatments

1. Standard commercial: 12 Wm^{-2} (5 klx) for the first 3 weeks of SDs with a 13 hour night-length; then to ambient light and natural night-length.

2. 4.8 Wm^{-2} (2 klx) throughout production with night-length controlled to 13 hours

3. 4.8 Wm^{-2} (2 klx) throughout production with night-length controlled to 12 hours

4. 4.8 Wm^{-2} (2 klx) throughout production with night-length controlled to 11 hours 40 mins

5. 4.8 Wm^{-2} (2 klx) throughout production with night-length controlled to 11 hours 20 mins

Night-length was controlled using assimilation lighting. On / off times were imposed according to met office data for sunrise / sunset to set times for treatments according to the change in day-length during the winter. Computer settings were adjusted as required to take dawn - dusk shifts into account (Table on page 13).

Supplementary lighting during SDs was supplied using 400 W SON-T high pressure sodium lamps.

To prevent light spill between photoperiod treatments, blackouts were closed at dusk or 1800 h daily - whichever was earlier, and opened at dawn or 0700 h - whichever was later.

Similarly, side screens were closed at dusk or the end of the working day - whichever was earlier, and opened at dawn or 0730 h daily - whichever was later.

Shift in lighting set-points during the trial

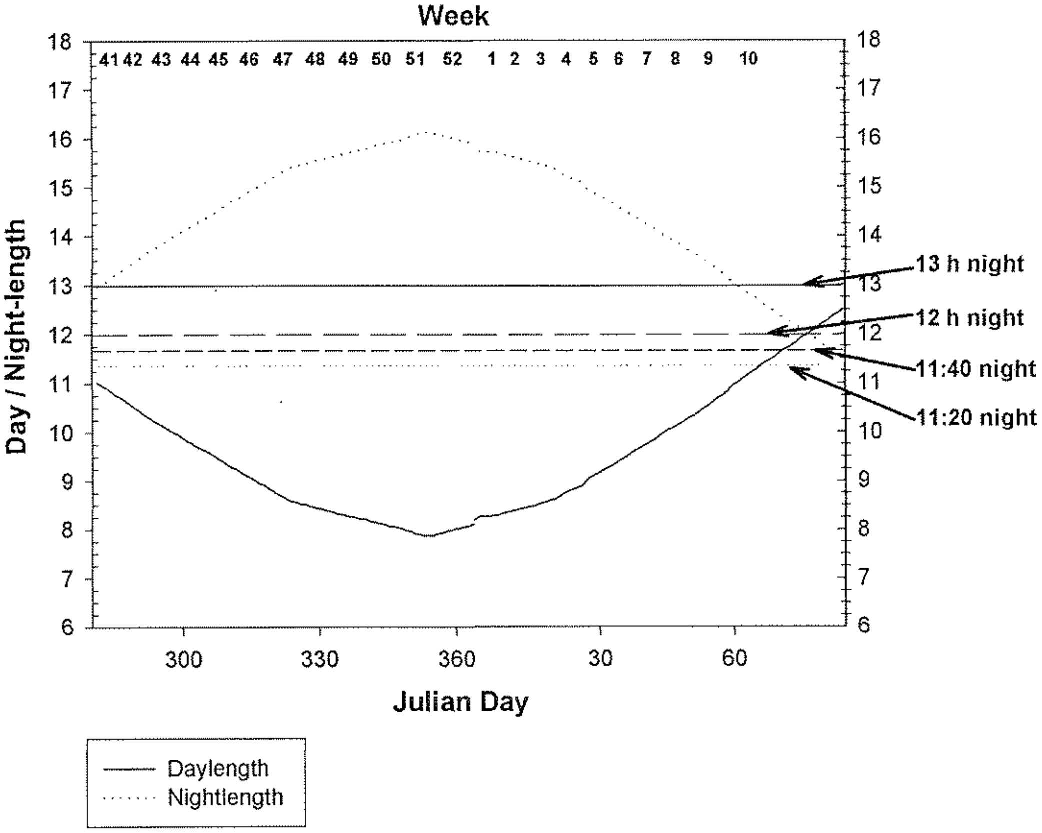
Week	Day of week	Lights off	Lights on:			
			11h 20	11h 40	12h	13h
45	Mon	16:12	03:32	03:52	04:12	05:12
	Thurs	16:06	03:26	03:46	04:06	05:06
46	Mon	16:02	03:22	03:42	04:02	05:02
	Thurs	15:57	03:17	03:37	03:57	04:57
47	Mon	15:53	03:13	03:33	03:53	04:53
	Thurs	15:49	03:09	03:29	03:49	04:49
48	Mon	15:45	03:05	03:25	03:45	04:45
	Thurs	15:42	03:02	03:22	03:42	04:42
49	Mon	15:38	02:58	03:18	03:38	04:38
50	Mon	15:38	02:58	03:18	03:38	04:38
51	Mon	15:40	03:00	03:20	03:40	04:40
52	Mon	15:43	03:03	03:23	03:43	04:43
01	Mon	15:48	03:08	03:28	03:48	04:48
	Thurs	15:54	03:14	03:34	03:54	04:54
02	Mon	16:01	03:21	03:41	04:01	05:01
	Thurs	16:08	03:28	04:48	04:08	05:08
03	Mon	16:10	03:30	03:50	04:10	05:10
	Thurs	16:13	03:33	03:53	04:13	05:13
04	Mon	16:19	03:39	03:59	04:19	05:19
	Thurs	16:25	03:45	04:05	04:25	05:25
05	Mon	16:31	03:51	04:11	04:31	05:31
	Thurs	16:37	03:57	04:17	04:37	05:37
06	Mon	16:41	04:01	04:21	04:41	05:41
	Weds	16:45	04:05	04:25	04:45	05:45
	Fri	16:50	04:10	04:30	04:50	05:50
07	Mon	16:56	04:16	04:36	04:56	05:56
	Thurs	17:03	04:23	04:43	05:03	06:03
08	Mon	17:09	04:29	04:49	05:09	06:09
	Thurs	17:15	04:35	04:55	05:15	06:15
09	Mon	17:20	04:40	05:00	05:20	06:20
	Weds	17:25	04:45	05:05	05:25	06:25
	Fri	17:29	04:49	05:09	05:29	06:29
10	Mon	17:35	04:55	05:15	05:35	06:35
	Thurs	17:41	05:01	05:21	05:41	06:41

Night-length treatments imposed varied from the natural night-length as shown in the diagram below such that, the 13 h and 11:20 night-length treatments were up to 3 hours and 4 h 40 mins shorter (respectively) than the natural night-length (in weeks 51-52). The following table quantifies the amount of PAR light received in each treatment (note that the 12 W/m^2 treatment was for week 1 – 3 of SDs only):

Amount of PAR (photosynthetically active radiation) light supplied above ambient levels in each treatment (MJ m^{-2}d^{-1}):

	Night length treatment (hours)			
Light level	13	12	11:40	11:20
12 W/m^2 (5 klx)	0.475	-	-	-
4.8 W/m^2 (2 klx)	0.189	0.207	0.213	0.219

Changing day- and night-length at HRI Efford; highlighting the difference between natural night-length and that imposed in each treatment



2.3.2.3. *Experimental Design*

5 Night length treatments
x
7 Varieties
x
1 Replicate
x
3 Stick dates

= 105 Total (35 plots per stick date)

Plot size = 24 pots
(7 plots per 7 m bench)

Lighting treatments were applied separately in each compartment, so blocking was according to compartment. Within compartment, individual stick dates were kept together on a single bench (to minimise bench to bench variability within stick date and also to reduce plot edge effects). Plots were randomly assigned within the bench. Analysis of variance was carried out to determine the main effects of reduced night-length within a variety. Lack of replication within (single rep per stick date) and between compartments (single non-replicate compartment for each treatment) meant that trends across stick dates and between different varieties within a treatment could not be strictly analysed using analysis of variance.

For details of plot layout within compartments see Appendix 2.

2.3.2.4. *Cultural Techniques: Night-length trial*

1) Propagation:

Cuttings were stuck in 14D pots (5 cuttings / pot) filled with Levington M2 compost for each sticking date as detailed on page 11. Pots from all sticking dates were maintained in propagation with cyclic night-break lighting (50% cycle for 5 hours) for a total of 17 days or longer as specified in the treatments. Night-break lighting was supplied using tungsten illumination to give 0.5 W/m^2 at canopy height.

2) Schedule:

Long days for 17 days from sticking as above. Treatments commenced from the start of short days when pots were moved into their appropriate plots. Pot spacing was pot thick (41/m^2) until the start of SDs, then 27 / m^2 and to a final spacing of 13.5 / m^2 14 days after the start of SDs.:

Pots were grown to an average 'winter' specification as detailed by the larger multiples as follows:

i)	Plants / pot	5
ii)	Height at market	27.5 cm (± 2.5 cm) including pot 18.5 cm (± 2.5 cm) excluding pot
iii)	Spread:	27.5 cm (± 2.5 cm)
iv)	Breaks:	3 flowering breaks / plant (minimum)
v)	Market stage:	2-3 of the HDC poster (PC 13c)

3) Environment/Nutrition:

Temperature: 18°C day and night with venting at 23°C day and night.

CO_2: CO_2 set to 1000 vpm with vents up to 5% open, or 500 vpm with vents more than 5% open.

Lighting: (i) Plants were given no supplementary lighting during the propagation phase in long days (LD).

(ii) During short days (SD), supplementary lighting was supplied according to treatments on page 12, using SON-T 400W high pressure sodium lamps.

Nutrition: Liquid feeding at 300 mg/l N : 60 mg/l P_2O_5 (26 mg/l P) : 250 mg/l K_2O (207 mg/l K) commenced from the start of SDs and was applied with every irrigation.

4) Pest and Disease Control:

Routine spray programme applied for preventative WFT control, plus spot treatments as required through daily crop monitoring.

5) Plant Growth Regulation:

The plant growth regulation regime was designed for plants growing under standard commercial conditions. There was a possibility the treatments described would enhance vegetative growth. The B-Nine applications to the treatment plots were the same as the standard commercial benchmark plots, so actual differences in vegetative growth could be recorded. *NB*: for the pinch trial, the second application of B-nine was in accordance with break size and NOT at SDs (as some treatments had not been pinched by the start of SDs).

Daminozide (as B-Nine) was applied as follows:

Variety	**Timing and rate of application of B-nine growth retardant (g/l)**				
	1 24 / 48 hours after sticking	**2** Start SDs nb pinch trial	**3** Breaks 1.5 - 2.0 cm long	**4** 7 - 10 days after 3	**5** 7 days after 4
Purple About Time	2.00	-	2.00	-	-
Charm	1.5	-	3.0	3.0	1.5 (if required)
Regal Davis	1.5	-	3.0	3.0	-
Surf	1.5	-	3.0	1.5 (if required)	-
Miramar	1.5	-	3.0	1.5 (if required)	-
Purple Lucky Time	2.00	2.00	2.00	2.00	2.00
Glow Time	2.00	-	2.00	2.00	-

2.3.3. TRIAL 2: The number of long days given and timing the pinch to improve winter quality

Treatment to manipulate the timing of the pinch relative to the start of short days in order to increase vegetative growth during the winter period.

2.3.3.1. Pot chrysanthemum varieties used:

Charm and Purple About Time

2.3.3.2. Long day and Pinching Treatments:

Pots were stuck at four day intervals and moved into short days on a common date to give the following long day treatments:

i) **17 long days** (moved to half-spacing at SD)

ii) **21 long days** (moved to half-spacing at SD)

iii) **25 long days** (pot thick for 21 LDs in prop then to half spacing 4 days before start of SDs)

These LD treatments were combined with the following pinching treatments:

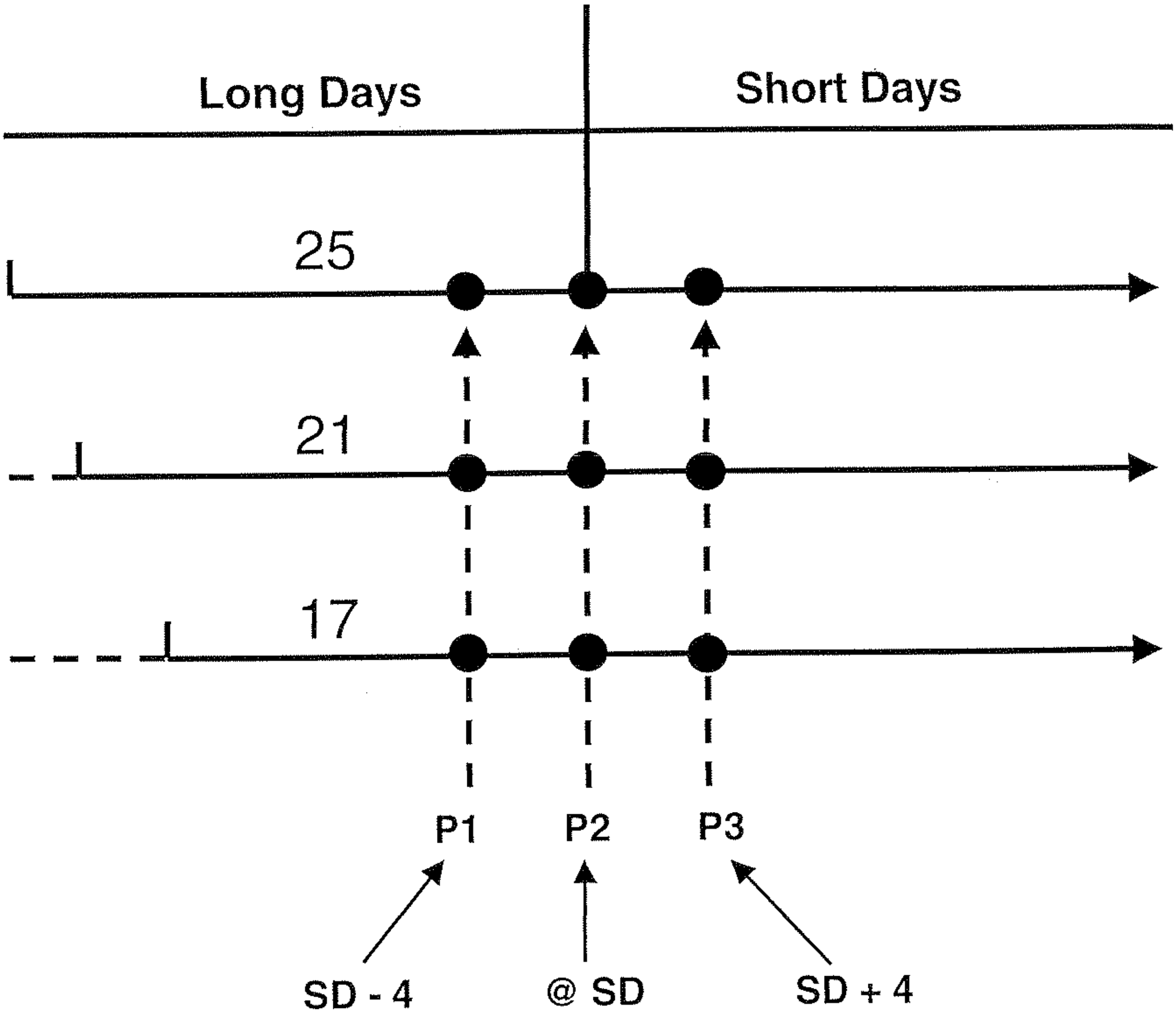
a) **Soft pinch 4 days before the end of long days**

b) **Soft pinch on the transfer from long days to short days**

c) **Soft pinch 4 days after the start of short days.**

Commercial Benchmark Control : 17 long days and soft pinched in short days to 7-8 leaves

Treatments are summarised as follows:



2.3.3.3. Experimental Design

3 LD treatment
x
3 Pinch treatments
x
2 Varieties
x
1 Replicate
\+
2 Commercial standard controls
x
3 Stick dates

= 60 plots (20 plots per stick date)

All LD x pinch treatment combinations for a single stick date were fully randomised within a single compartment. Analysis of variance determined the main effects of number of LDs, and timing of pinch on parameters measured, together with any interaction between number of LDs and pinch date within variety. Lack of replication within (single replicate per stick date) and between compartments (single non-replicate compartment for each treatment) meant that trends across stick dates and between different varieties within a treatment could not be strictly analysed using analysis of variance.

For details of plot layout within compartments see Appendix 3.

2.3.3.4. Cultural Techniques: Trial 2

All cultural details EXCEPT for lighting and the number of long days (as described in the treatments section; 2.3.3.2) were as described for the night-length trial above in section 2.3.2. Plants were grown under conditions of ambient light and with natural night-length: i.e. screening at 16:30 and de-screening at 07:30.

2.3.4. TRIAL 3: Shelf-Life phase

Post-harvest transport simulation was designed to mimic an "average" supermarket transport chain. The Efford simulation was based on the response to questionnaires sent to the multiples, and represents an average transport chain (to ensure that plants were adequately tested during the transport phase.

Plants were sleeved, boxed and held at 15°C for 15 hours, followed by 9 hours at 12°C, and a further 15 hours at 18°C to simulate conditions for holding material in-store prior to putting on the shelves.

Once in the "retail" shelf-life environment, lighting was set to give 1000 lux at plant height for 14 h / day unless specified otherwise (see below in section 2.3.4.2. for modifications to this for retail phase treatments), and with day / night temperatures of 18°C and 70% relative humidity.

After 10 days, plants were de-sleeved and pots transferred to a simulated home environment with lighting of 1000 lux and D/N temp of 18-20°C. Assessments of plants commenced at de-sleeving (after 10 days) and continued for four weeks, or until the plants deteriorated to the point at which they were discarded.

2.3.4.1. Impact of Night-length treatment on post-harvest performance:

Plants of all 7 varieties grown in the 13 h and 11:40 night-length treatments in Trial 1 (5 pots / plot; grown with supplementary lighting at 4.8 W/m² throughout short days) were assessed within the shelf life environment. Following the February Efford Open Day, it was decided that as many of the varieties as were available from the 11:20 night-length treatment would also be taken through shelf-life for observation.

2.3.4.2. Interaction between light levels during production and in-store lighting:

For this work, ONLY **Charm** and **Purple About Time** were used. A sub-sample of 5 pots per plot were selected from treatments grown under :

a) 13 h night-length with 4.8 W/m^2 (2 klx) throughout SDs

b) 12 W/m² (5 klx) for weeks 1-3 of short days only, with a 13h night followed by ambient light and natural light length for the remainder of short days.

i.e. Plants either grown with or without supplementary lighting during the final stages of production

Plants were assessed in the "home-life" environment after undergoing each of the two following "retail" shelf life environments:

1) Simulated "retail" shelf life, with in-store lighting (i.e. prior to removing sleeves) set at 1000 lux with warm white fluorescent tubes (to represent the best of the light levels currently specified by the multiple retailers.

2) Simulated "retail" shelf life, with in-store lighting (i.e. prior to removing sleeves) set at 1000 lux with warm white fluorescent tubes, but shade is applied to reduce this level by 60% to simulate a poorly lit position within the store

2.3.5. Experimental Records

2.3.5.1. Growing phase

For Trials 1 and 2 (night-length and long days x pinching): the effect of treatments on production time and plant quality was assessed at Marketing Stage 3 (PC 13c) (i.e. 12 flowers all just bending outwards, 50% of petals at least 20 mm long) by recording:

1. Time taken to reach marketable stage (for each pot in the plot).
2. Number of flowers per pot at stages 1-3 and stages 4+.
3. Number of breaks on each plant in the pot with three or more flowers at bud stage 4+.
4. Plant height – mean of 5 plants per pot (cm).
5. Maximum and minimum plant spread per pot (cm).
6. Bulk dry weight of plants in 3 pots / plot (g).
7. Environmental and solar radiation measurements (average day/night and 24 h temperatures and % RH, with average daily external irradiance).
8. Photographic records as appropriate (including treatment comparisons and a record of qualitative scores).
9. ***Media and foliar analysis at marketing*** in Charm and Purple About Time from the following treatments at each stick date:
    - i) 4.8 W/m^2 (2 klx) throughout SDs with 13h, 12h, & 11h 40 night.
    - ii) 12 W/m^2 (5 klx) weeks 1-3 of SDs with natural night length of 13h.
    - iii) The standard pinch (pinched to 7-8 leaves in SDs) in the LD x pinch trial.

Additional records for the number of long days x pinching trial described above included:

1. Number of leaves remaining on each plant after pinching (recorded as plants were pinched).
2. Number of leaves on the uppermost break at marketing.

2.3.5.2. Shelf-life phase: Trial 3

Shelf life assessments were taken at the point that sleeves were removed (after 10 d in "retail" shelf-life) and then at weekly intervals for four weeks (or until the plant was judged to be ready for disposal if earlier). Records taken on these occasions were:

1. Number of buds per pot at stage 4 or above.

2. Number of distorted buds per pot.

3. Qualitative score of flower colour (where score 0 = no colour loss and score 3 = discoloured senescent flowers) complemented by RHS colour chart measurement of flower colour

4. Qualitative assessment of overall appearance of foliage (where score 0 = no deterioration and score 3 = deterioration to the point where the plant was ready for disposal).

5. Qualitative assessment of overall appearance of flowers (where score 0 = no deterioration and score 3 = deterioration to the point where the plant was ready for disposal).

In addition, regular inspection of the pots determined length of time in shelf life before reaching the qualitative score 3 for deterioration as described above.

2.3.6. Environmental Records

1. Incident radiation (MJ day^{-1}).
2. Average day and night external temperatures and relative humidity.
3. Average Day and night temperatures and relative humidity within the glasshouse.

3. RESULTS AND DISCUSSION

3.1 Trial 1: The use of reduced night-length to increase plant bulk and quality during the winter period.

7 varieties were grown at either 12 W/m^2 (5 klx) for the first 3 weeks of SDs with a 13 h night , followed by ambient light and natural night-length (commercial standard), or 4.8 W/m^2 (2 klx) throughout production, with night-lengths of either 13 h, 12 h, 11 h 40 min or 11 h 20 min.

Statistical analysis of the data enabled investigation of: (i) the overall effect of variety across stick dates; (ii) the effect of night-length treatment either bulked across stick dates or within a single stick date; (iii) the effect of night-length on each variety and comparisons of night-length effects between varieties (either across, or within any given stick date).

The effect of stick date could not be analysed statistically due to the lack of replication within stick date. Consequently, while some trends were observed, these result need treating with caution. Graphs in Appendix 5 relate to the marketing data for each stick date for each variety as presented below.

3.1.1 Characteristics of each variety (data meaned across night-length treatments and stick dates)

Data in Table 1 present the mean responses of all 7 varieties averaged across stick dates and treatments. These data give the overall performance, in terms of duration, height, dry weight, spread and flowering in each variety compared to the other varieties in the trial. The Least Significant Difference (LSD) Figure in the right hand column of the Table should be applied when comparing any two means of a given variable for a pair of varieties.

- **Duration:** Of the varieties tested, Purple About Time and Surf had the shortest duration (in short days), with Miramar and Purple Lucky Time taking the longest, in line with their published response times.

- **Height and Spread:** Purple Lucky Time and Surf were the tallest varieties, and Surf also produced a more bulky pot (in terms of spread). In line with its vigorous height growth, Purple Lucky Time also showed an increased variability in height between pots, which may indicate less uniformity in the final product for this variety. Of the other varieties, Charm, Glow Time and Miramar all produced pots with average height of about 17 – 17.5 cm (measured from the pot rim), with Miramar and Charm giving a good pot spread. The shortest pots were produced from Regal Davis and Purple About Time.

- **Flowering:** Both Purple Lucky Time and Regal Davis were very prolific in their total bud and flower count compared to the other varieties. Purple About Time and Surf produced fewest flowers of the varieties tested, but in Purple About Time the proportion of total flowers which were open at marketing was high, and this would offset the lower total bud and flower count. In Surf however, the low total count was not compensated by a high proportion of open flowers at marketing.

  In Purple Lucky Time, Miramar and Purple About Time, there were relatively high numbers of breaks with 3 or more open flowers. This is another factor which compensated for low total bud and flower counts in Purple About Time. Charm, Glow Time and Surf had few open flowers on the breaks, with Surf showing the most vegetative trends of these three varieties.

- **Dry weight:** Surf, Regal Davis and Glow Time all produced pots with relatively high dry weigh values. Charm, Purple About Time and Purple Lucky Time produced less dry weight per pot. In Purple Lucky Time, which grew tall, the low dry weight would indicate that the stems were thinner compared to the other varieties, though this parameter was not measured in this trial.

Table 1: Performance of 7 pot mum varieties across 3 stick dates averaged across night-length treatments (number in brackets = back-transformed data).

	Variety (response time [days*])							
Variable	**Charm (63)**	**Glow Time (59.5)**	**Miramar (63)**	**Purple About Time (59.5)**	**Purple Lucky Time (63)**	**Regal Davis (66.5)**	**Surf (63)**	**LSD** (5%; 18 d.f)
Duration (d)	61.90	61.23	65.28	59.25	64.75	61.43	59.01	0.679
Height from pot rim (cm)	17.56	17.46	17.20	14.45	19.82	16.43	18.50	0.514
Log SD height	0.196 (1.570)	0.208 (1.614)	0.261 (1.824)	0.201 (1.589)	0.394 (2.477)	0.151 (1.416)	0.225 (1.799)	0.107
Spread (cm)	33.84	31.81	34.54	31.18	31.40	33.67	35.02	0.714
Total flowers (inc. buds)	44.45	45.47	45.91	35.79	72.35	70.79	38.83	2.896
Prop'n. open flowers	0.294	0.270	0.463	0.5547	0.479	0.207	0.343	0.041
Flowering breaks	0.049	0.082	0.384	0.200	1.261	0.145	0.008	0.157
Dry weight (g)	9.82	10.74	10.39	8.79	9.13	10.49	11.01	0.641

3.1.2 Effects of night-length treatment (averaged across varieties and stick date)

Data in Table 2 and Figure 1 present the effect of reduced night-length treatment on each variable measured (across stick dates). It is clear that all measured variables (except for the proportion of open flowers, but see text below) showed significant increases with reducing night-length.

Table 2: Effects of night-length treatment on measured variables (means across varieties and stick dates)

Night-length	**Duration (days)**	**Height (cm)**	**Spread (cm)**	**Total buds + flowers**	**Proportion open fls.**	**No. open flowers on breaks**	**Dry wt (/5 plants) (g)**
11: 20	68.79	21.27	37.38	65.30	0.320	0.457	14.44
11:40	63.15	17.11	33.71	54.92	0.344	0.315	9.63
12	59.70	15.37	31.22	49.09	0.366	0.258	8.80
13	58.43	15.71	31.55	48.95	0.395	0.327	8.16
Standard	58.15	17.07	31.46	34.31	0.441	0.164	9.24
5% LSD	0.574	0.435	0.603	2.45	0.035	0.133	0.541
(1% LSD) (47 d.f)	(0.768)	(0.582)	(0.807)				(0.725)

Data in Figure 1 (and Figures 2 – 5) presents the data in three ways to highlight different aspects and to aid interpretation from several viewpoints:

a) **Absolute scale:** In this format, it is easy to identify trends in the response of any given variable across treatments in the trial. Using plant height (Fig. 1a) as an example (page 32), it is clear that plant height declines slightly from the standard treatment to the 13 & 12 h night-length treatments, but then increases as night-length is reduced to 11:40 and 11:20. However, because absolute values have different starting points, it is difficult to compare the magnitude of each response directly.

b) **Relative scale - % change:** By plotting each variable with a common starting point and against a common scale, it is possible to compare the relative magnitude of each response as compared to the 13 h night-length treatment (it is not valid to compare against the standard as both lighting regime and night-length differ). For example, the 11:40 night-length data point value is calculated by: % value = 100 x (11:40 value ÷ 13 h value). In the plant height example, fig. 1b shows that height changed very little between the 13 h and 12 h night-length treatments. There is an increase in height of 12% between the 12 h and 11:40 night-lengths, and a further 35% increase between the 11:40 and 11:20 night-length treatments. Although this format shows the extent of the response to the applied treatment (reduced night-length) it does not highlight the sensitivity of the response to each treatment: i.e. which particular night-length treatment affects the variable of interest most?

c) **Normalised scale – to visualize which proportion of the total response occurs at which night-length?** Data presented in this form (as in fig. 1c) allow one to represent all the responses on a common scale. The data are expressed as a fraction of the total response obtained from 13 to 11:20 night-lengths as follows:
normalised value = 100 * ((value at NL_I – value at NL_{13h}) ÷ (value at $NL_{11:20}$ – value at NL_{13h})). This system is useful when modeling the data. In the plant height example for fig. 1c we can see that there is no response between 13 and 12 h night-lengths. From 12 h to 11:40, there is 20% of the total response, with the remaining 80% of the response occurring between 11:40 and 11:20. This demonstrates that plant height was affected most when night-length was shorter than 11 hours 40 minutes. In the same way, we can see that crop duration was extended by 50% of the total response (i.e. 5 days out of the total 10 days delay) when night-length changed from 12 h to 11:40, with the remaining 50% of the response occurring between 11:40 and 11:20. This demonstrates that crop duration and plant height show different sensitivity to reduced night-length treatments.

Effect of reduced night-length on:

- **Plant bulk**: Reducing night-length significantly increased plant bulk when pots were lit throughout production. Height and spread increased by 35% and 19% (respectively) in the 11:20 compared to the 13 hour night-length treatment (lit throughout). However, when compared to the standard natural night-length treatment (lit for weeks 1-3 only), there was no benefit in terms of increased height and spread until night-length was 11:40 or shorter. This trend was supported by the mean dry weight data, which also showed no increase beyond the standard treatment until night-length was 11:40 or less. Height and spread both responded in a similar way to reduced night-length, with reductions from 13h to 12 h, and marginal increases from 12 h to 11:40, with more marked increases in each with reductions in night-length below 11:40 (fig. 1 b). In contrast, dry weight showed significant increases from 13 to 12 h night-lengths, and further increases as night-length was reduced below 11:40, with 80% of the total response between 11:40 and 11:20 (fig. 1c). Increases in dry weight, although linked to increases in height and spread, are also influenced by the reproductive development.

- **Flowering:** Lighting plants throughout short days (using a 13 hour night) increased total bud and flower counts by an average of 42% compared to plants lit only during the first 3 weeks of SDs. Total flower and bud production was increased by a further 33% in plants lit throughout short days and grown at night-lengths between 12 h and 11: 20 (this represents an increase of over 90% relative to the plants only lit for the first 3 weeks of SDs).

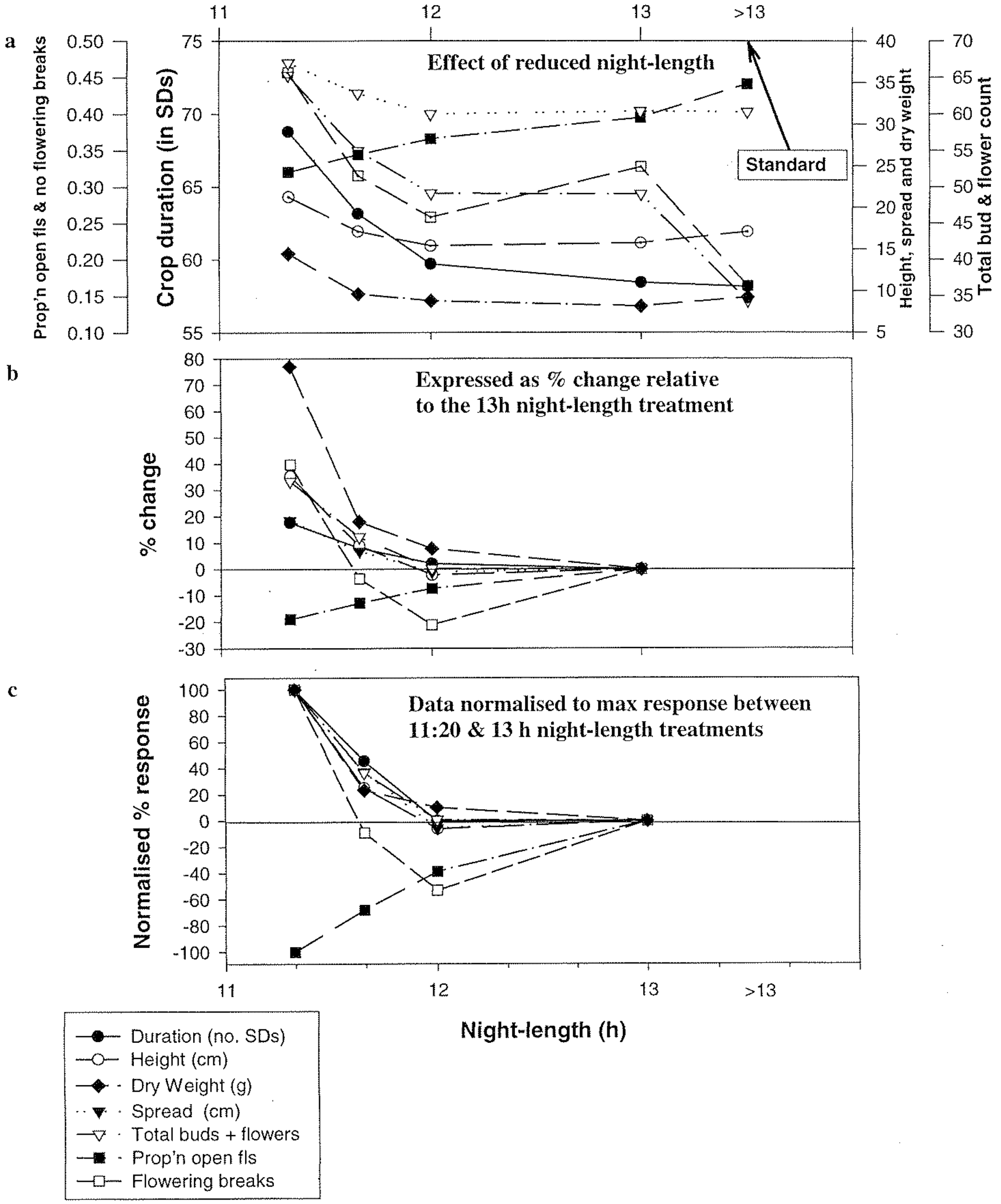
- In line with increased total numbers of buds and flowers, there was a 39% increase in the number of breaks with 3 or more open flowers in the 11:20 compared to the 13 h night-length treatment and a 178% increase when compared to the standard treatment (lit weeks 1-3 and natural night-length). It is interesting to note the decrease in the number of flowering breaks in the 12 h night-length treatment compared to the 13 h treatment, indicating the poor ability of a 12 h night to initiate flowers on the lateral breaks (which were not stimulated to develop in the same way as in the reduced night-length treatments). All of the enhancement in flowering breaks occurred when night-length reduced below 11:40, i.e. concomitant with enhanced vegetative growth (and extended duration).

- The proportion of open flowers, (in relation to the total bud & flower count) was reduced by 27% in the 11:20 night-length compared to the standard natural night-length treatment. However, the increase in total reproductive output (buds + flowers) due to reduced night-length meant that, even with a smaller proportion of open flowers, there were still more open flowers per pot in the reduced night-length treatments than in the standard control. Fig. 1c shows that the decrease in the proportion of open flowers was fairly consistent with decreasing night-length, and did not respond in the same way as the majority of other variables, which showed the largest response between the two shortest night-length treatments.

- **Duration:** The increased vegetative and reproductive growth observed in the reduced night-length treatments was always linked with an increase in crop duration (in SDs). In the shortest night-length, crop duration increased by an average of 18% (or about 10 days) across varieties. The increase in crop duration was almost linear at night-lengths less than 12 h, and this represents an increase of 2.27 days for every 10 minute reduction in night-length below 12 h (to 11hours 20 min).

- As will be seen later, each variety responded slightly differently (in absolute terms) to reduced night-length, so the choice of variety for any particular night-length scenario is important.

Figure 1: Effect of reduced night-length on measured variables (means across varieties and stick dates) expressed in: a) absolute terms, b) as a % change from the standard or c) as normalised % change



3.1.3 Responses of each variety to reduced night-length treatments (averaged across stick dates, refer also to Appendix 9, Plates 1 & 2).

- **Plant height:** As seen above for the overall treatment responses, plant height was affected both by the lighting regime applied (ie. Lit throughout v's only lit at the start of short days) and by night-length. Plants in all varieties were more compact when grown with lighting throughout production, compared to those lit only for the first 3 weeks of SDs, with the largest differences observed in Miramar, Regal Davis and Purple About Time (Table 3 and figs. 2a – c).

- In pots lit throughout short days, there were trends for reductions in height at night-lengths between 13 h and 12 h, with net gains in height only occurring when night-length was 11:40 or less, though these differences did not prove significant.

- No significant increases in height were observed at night-lengths longer than 12 h (fig. 2b).

- Of the varieties tested, Charm showed the largest (52%) and Purple About Time the smallest (20%) height increases in response to reduction in night-length below 12 h. Surf, Glow Time and Miramar all showed > 35% height increases in response to reduced night-length.

- Purple About Time only showed height increases in response to night-lengths shorter than 11:40, whereas all other varieties tested were responding to night-lengths between 12 h and 11:40.

- Of the varieties tested, Glow Time showed the largest response to night-lengths between 12 h and 11:40 (fig. 2c). While this variety may be suitable for manipulation to increase plant size using reduced night-lengths, crop duration also needs to be taken into account (p.36).

These data indicate that if increased plant height is desirable, Purple About Time is less responsive than the other varieties to reduced night-length.

Figure 2 : Effect of reduced night-length on plant height expressed in: a) absolute terms, b) as a % change from the standard or c) as normalised % change

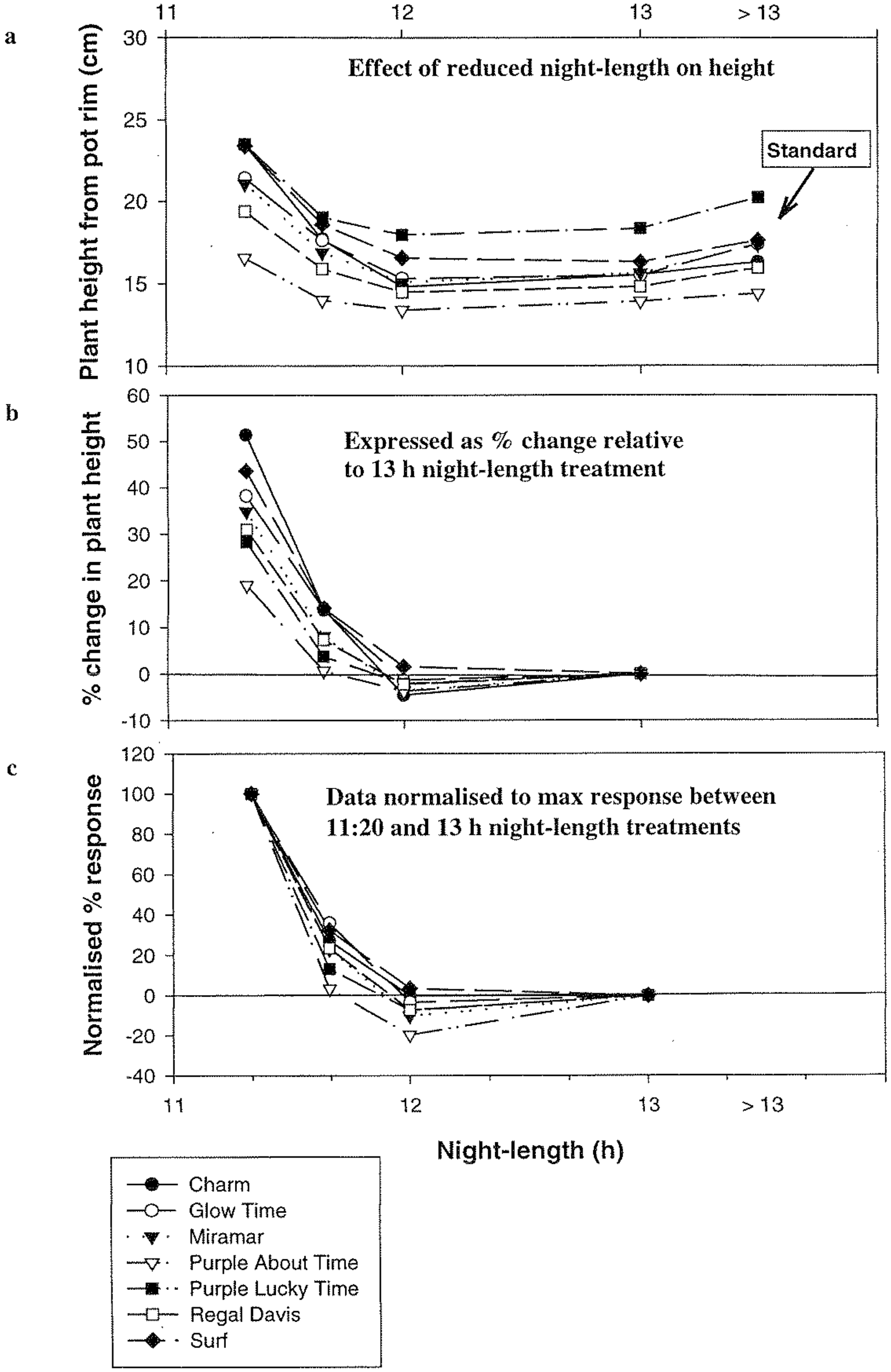


Table 3: Height (cm) variation in response to reduced night-length in 7 pot mum varieties

	Variety						
Night-length	Charm	Glow Time	Miramar	Purple About Time	Purple Lucky Time	Regal Davis	Surf
11: 20	23.49	21.42	21.08	16.56	25.53	19.40	23.40
11:40	17.69	17.63	16.89	14.00	19.03	15.90	18.60
12	14.81	15.30	15.08	13.39	17.96	14.48	16.57
13	15.52	15.50	15.63	13.91	18.34	14.81	16.30
Standard	16.30	17.44	17.34	14.39	20.23	15.93	17.62
5% LSD	← 1.150 →						
1% LSD	1.539						
d.f. 48							

- **Dry weight:** The trends for dry weight are similar to those for height, with slight reductions in dry weight in the 13 and 12 h treatments lit throughout SDs, compared to the standard treatment, and positive gains in dry weight only made at night-lengths of 11:40 or less (Table 4 and fig. 3a – c).

- When comparing the effect of reduced night-length in plants lit throughout SDs, dry weight increased gradually when night-length decreased from 13 to 11:40 in all varieties, and with significant increases occurring when night-lengths were 11:40 or shorter (fig. 3b).

- As for height above, Charm showed the largest (97%) and Purple About Time the smallest (60%) overall increase in dry weight in response to reduction in night-length (fig. 3b).

- All varieties except Glow Time showed 80-90% of their total response at night-lengths shorter than 11:40. Glow Time however exhibited an almost linear increase in dry weight from 12 h to 11:20, again, indicating that this variety is more sensitive to reductions in night-length than the other varieties tested (fig. 3c).

Figure 3 : Effect of reduced night-length on pot dry weight expressed in: a) absolute terms, b) as a % change from the standard or c) as normalised % change

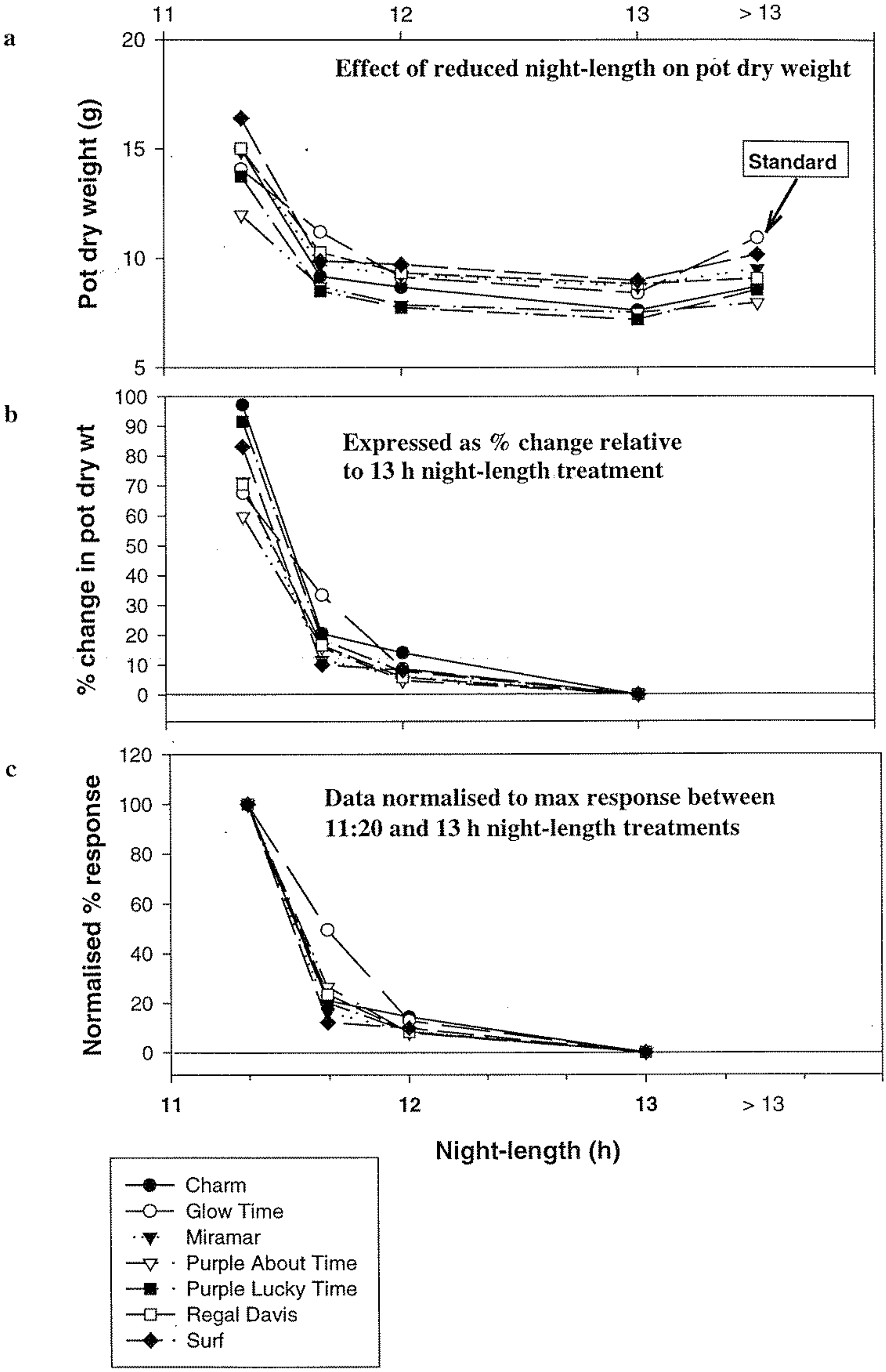


Table 4: Variation in dry weight (g) in response to reduced night-length in 7 pot mum varieties

	Variety						
Night-length	**Charm**	**Glow Time**	**Miramar**	**Purple About Time**	**Purple Lucky Time**	**Regal Davis**	**Surf**
11: 20	14.99	14.06	14.88	11.98	13.74	15.01	16.40
11:40	9.16	11.20	9.69	8.69	8.50	10.26	9.87
12	8.67	9.12	9.22	7.86	7.73	9.32	9.70
13	7.60	8.39	8.68	7.50	7.17	8.80	8.96
Standard	8.67	10.91	9.48	7.93	8.53	9.05	10.14
5% LSD	← 1.434 →						
1% LSD	1.918						
d.f. 48							

- **Flowering:** In all varieties, pots grown with supplementary lighting throughout short days had significantly more buds and flowers than pots only lit for the first 3 weeks of SDs (Table 5 and fig. 4a). The majority of the observed increase was due to enhanced bud production (rather than the number of open flowers; see Figures in Appendix 5). Assimilation lighting supplied throughout short days may be critical for optimal bud development both during production and post-production (in the retail and home environments) in the winter period.

- Reduced night-length stimulated prolific flower and bud development in Purple Lucky Time and Regal Davis, whereas these effects were less marked for Surf, Purple About Time and Charm.

- Significant increases in bud and flower production were only seen when night-length was shorter than 12 h (as would be expected for a short-day plant; see fig. 4b).

- The smallest increase in total flower count in response to the 11:20 night-length treatment was seen in Charm (14.7%), then Purple About Time (21.1%) and Surf (25.6%). Miramar, Glow Time, Purple Lucky Time and Regal Davis showed more marked increases in total flower count (51, 42, 38 and 36% respectively) in response to an 11:20 night (fig. 4b).

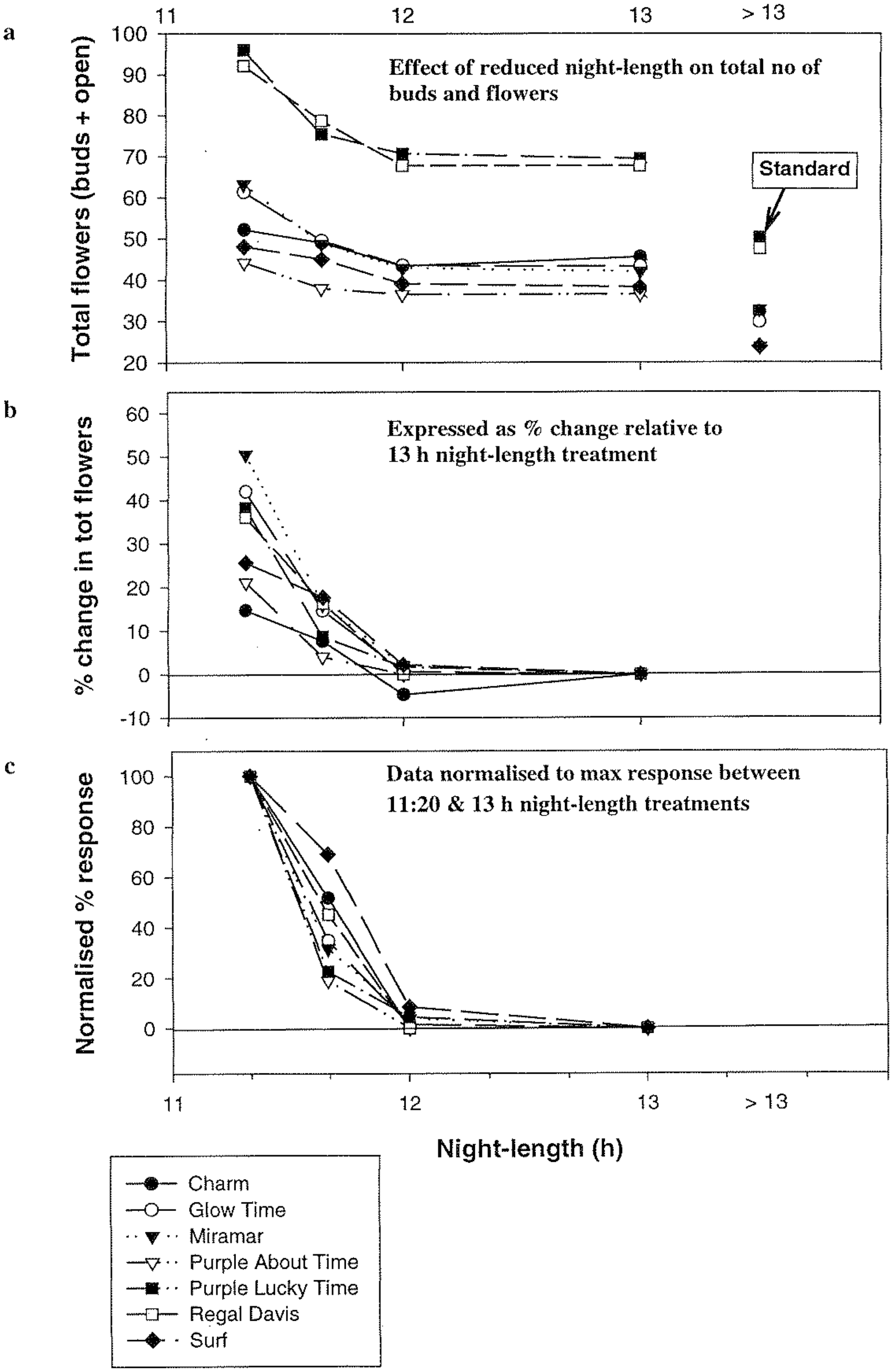
- Normalised data in fig. 4c show that the varieties differed in their sensitivity to reduced night-length. Surf was more sensitive to changes from 12 h to 11:40 than the other varieties. Charm and Regal Davis showed a linear response from 12 h to 11:20, and the remaining varieties all showed larger responses to reductions in night-length from 11:40 to 11:20 than from 12 h to 11:40 (fig. 4c). This suggests that although both Surf and Charm showed relatively small responses to reduced night-length (in terms of increased flower production), their response could be elicited by using less extreme reductions in night-length than was necessary for the other varieties.

Table 5: Changes in total bud + flower count in response to reduced night-length in 7 pot mum varieties

	Variety						
Night-length	**Charm**	**Glow Time**	**Miramar**	**Purple About Time**	**Purple Lucky Time**	**Regal Davis**	**Surf**
11: 20	52.20	61.33	63.20	44.20	95.97	92.13	48.03
11:40	48.97	49.53	48.73	37.97	75.47	78.77	45.00
12	43.37	43.47	42.83	36.50	70.63	67.73	39.07
13	45.50	43.20	41.99	36.50	69.43	67.73	38.23
Standard	32.20	29.80	32.77	23.70	50.23	47.60	23.83
5% LSD	6.745						
1% LSD	◄ 8.664 ►						
d.f. 48							

- **Duration** (Table 6): Varieties all responded to reduced night-length by delayed flowering and hence an increase in crop duration. Duration increased markedly when night-length was controlled to less than 12h (fig 5a – c; page 40). The sensitivity of each variety varied. Reductions in night-length from 13 h to 12 h had no significant effect on crop duration in Miramar, Purple About Time, Purple Lucky Time or Regal Davis, had small (but significant at P = 5%) delays of 2 – 3 days in Charm, Glow Time and Surf (fig 4b). When night-length was controlled to 11:20, the smallest delays were observed in Purple About Time and Purple Lucky Time(11.4 & 14.3% respectively; but significant at P = 1%), with delays of 26.6%, 26.2% and 23% in Charm, Surf and Glow Time (respectively; again significant at P = 1%).

Figure 4 : **Effect of reduced night-length on total buds + flowers expressed in: a) absolute terms, b) as a % change from the standard or c) as normalised % change**



- Although the average response of all varieties to reducing night-length was more or less linear (see section above relating to Table 2 (page 28) and Figure 1 (page 31)), when the data for each variety are available independently, it is possible to see how duration in each variety responded slightly differently to reduced night-length (fig. 5c; page 40). For example, Regal Davis showed only 35% of its response when night-length changed between 12 h and 11:40, but 65% for further reductions to 11:20; whereas other varieties all tended towards 50% of their response in each night-length range (12 – 11:40 and 11:40 – 11:20). Purple Lucky Time showed the most linear response to reductions in night-length (fig. 5c). All varieties showed more response to changes in night-length between 11:40 and 11:20.

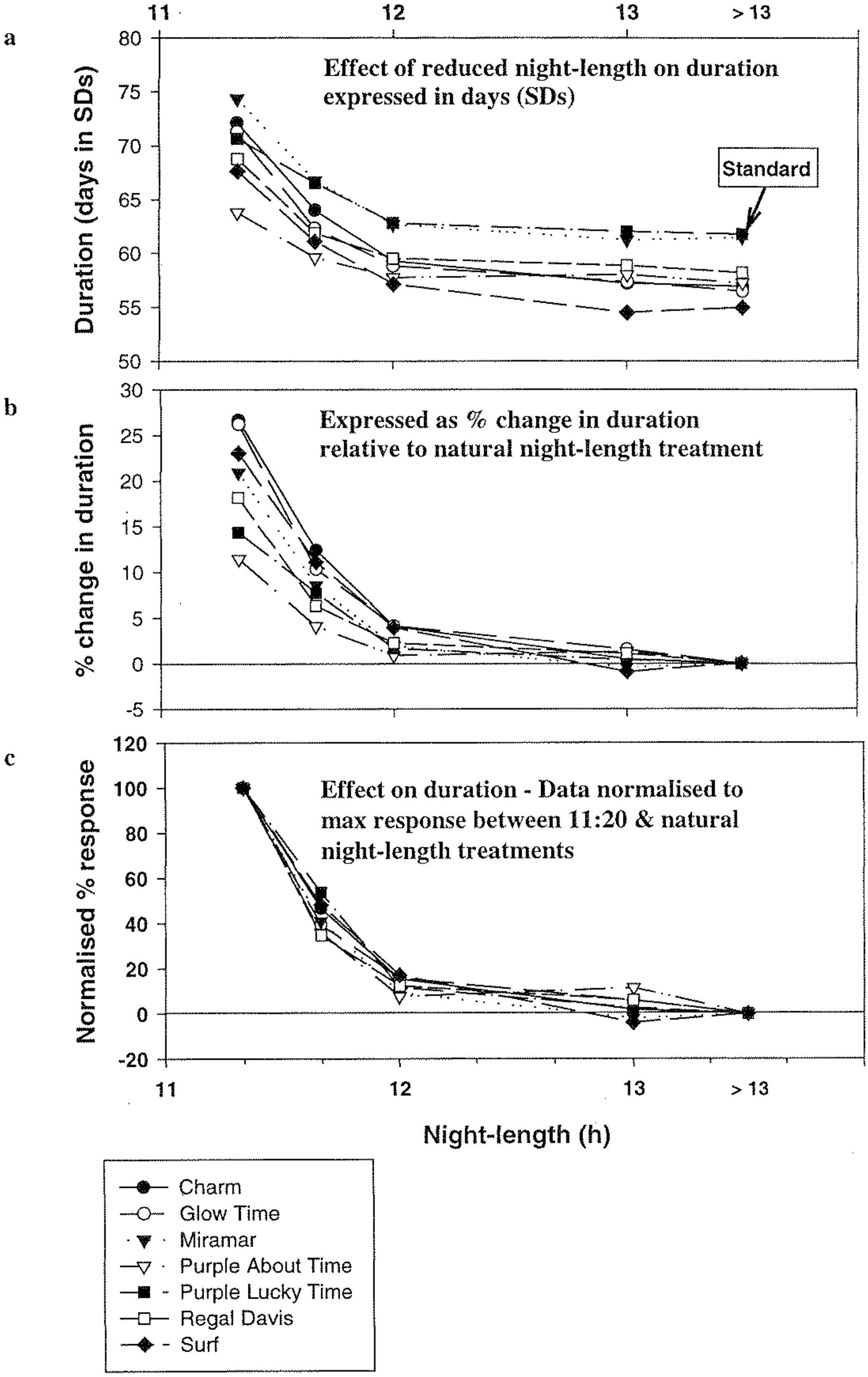
- These data confirm that the largest delays in crop duration occur at night-lengths < 11:40, in contrast to the main benefits, in terms of increased plant size and flowering, not realised until night-length is 11:40 or shorter. Each grower must weigh up the pros and cons of using a particular night-length to suit their own situation. A point between 11:40 and 11:20 may be best in the light of current information available.

Table 6: Changes in crop duration (SDs) in response to reduced night-length in 7 pot mum varieties

	Variety						
Night-length	**Charm**	**Glow Time**	**Miramar**	**Purple About Time**	**Purple Lucky Time**	**Regal Davis**	**Surf**
11: 20	72.10	71.27	74.33	63.77	70.63	68.77	67.63
11:40	64.00	62.30	66.73	59.57	66.53	61.87	61.07
12	59.27	58.80	62.67	57.73	62.80	59.50	57.13
13	57.20	57.33	61.20	57.97	62.00	58.83	54.47
Standard	56.93	56.47	61.47	57.23	61.77	58.20	54.97

5% LSD ← 1.518 →
1% LSD 1.557
d.f. 48

Figure 5 : **Effect of reduced night-length on crop duration expressed in: a) absolute terms, b) as a % change from the standard or c) as normalised % change**



3.1.4 Summary of variety responses to reduced night-length

Number of days delay (comparison with standard regime) and % increased flowering (comparison within 4.8 W/m^2 (2 klx) lit throughout) in each variety associated with each night-length treatment.

Variety	12 hour night-length		11:40 night-length		11:20 night-length	
	Delay (d)	% change in N° buds + flowers	Delay (d)	% change in N° buds + flowers	Delay (d)	% change in N° buds + flowers
Charm	+2.3	-5.0	+7.1	+7.6	+15.2	+14.7
Glow Time	+2.4	+0.4	+5.8	+14.6	+14.8	+42.0
Miramar	+1.2	+2.0	+5.3	+16.1	+12.9	+50.5
Purple About Time	+0.5	0.0	+2.3	+4.0	+6.5	+21.0
Purple Lucky Time	+1.0	+1.7	+4.8	+8.7	+8.9	+38.0
Regal Davis	+1.3	0.0	+3.7	+16.3	+10.6	+36.0
Surf	+2.2	+2.2	+6.1	+17.7	+12.8	+26.0
Mean (± standard deviation)	1.56 (0.74)	+0.18 (2.47)	5.02 (1.59)	+12.14 (5.30)	+11.68 (3.17)	+32.60 (12.57)

The above table summarises the trends in crop duration and flowering (total buds + flowers) for each variety in response to reduced night-length. The largest responses were invariably observed in the shortest night-length, but there were considerable varietal differences. On average, crops were delayed by 5 days in an 11:40 night regime. Associated with this was a 12% increase in total bud and flower number. Further reduction in night-length to 11:20 resulted in average delays of 11.7 days, but with an associated increase in total flower number of 32%.

- **Charm:** Large increases in plant bulk (height and dry weight), but with relatively small increases in total bud and flower production. This variety was prone to long delays in crop duration (Appendix 5, Figures 1-3).

- **Glow Time:** This variety was highly responsive to reduced night-length, with large increases in total flower production and plant bulk. This was the only variety of those tested that showed a marked increase in dry weight for changes in night-length between 12 h and 11:40, again highlighting its sensitivity to reduced night-length. Glow Time was prone to long delays in production which may reduce its appeal for production using night-lengths shorter than 11:40 (Appendix 5, Figures 4-6).

- **Miramar:** Responsive to reduced night-length, with large increases in total flower production and plant height and dry weight associated with relatively long delays (Appendix 5, Figures 7-9).

- **Purple About Time:** This variety was relatively unresponsive to reduced night-length, with only small increases in bulk and flowering associated with short delays compared to the other varieties (Appendix 5, Figures 10-12).

- **Purple Lucky Time:** This variety flowered prolifically with further enhancements in bud and flower production in response to reduced night-length. Increases in plant height and dry weight also occurred with only moderate increases in duration. This appears to be a relatively good variety for production using reduced night-length (Appendix 5, Figures 13-15).

- **Regal Davis:** A prolific flowering variety, with large responses to reduced night-length. This variety showed moderate increases in bulk in response to reduced night-length, and only average delays. This variety appears to be a good candidate for production using reduced night-lengths (Appendix 5, Figures 16-18).

- **Surf:** This variety showed large increases in vegetative growth as night-length was reduced, but the relatively small increases in total flower production and the large crop delays make this variety less suitable for production using reduced night-length (Appendix 5, Figures 19-21).

Overall: effect of reduced night-length during production.

- **There were marked effects of the lighting regime used, with pots grown with 12 W/m^2 (5 klx) for the first 3 weeks of short days and a 13 h night followed by natural night-length; (= commercial standard treatment) producing slightly taller, heavier plants than pots grown with 2 klx (4.8 W/m^2) throughout short days and with a 13 h night. Although plants in the commercial standard treatment were somewhat bigger than the 13 h treatment, they produced far fewer buds which could reduce product perception (value) at marketing) and impact on continued flowering during shelf-life.**

- **All varieties grown with supplementary lighting at 4.8 W/m^2 (2 klx) throughout short days showed marked increases in plant bulk (height, spread and dry weight) and total reproductive development (buds plus flowers) as night-length was reduced to less than 12 h. The largest increases in bulk and flowering were observed when night-length was shorter than 11 hours 40 minutes.**

- **The largest increases in plant size and numbers of total buds and flowers were observed in the 11:20 night-length treatment, but occurred at the expense of delayed crop duration of up to 26% (average of 18% across varieties).**

- **As a guide, there was an approximate linear increase in crop duration with reduction in night-length from 12 h to 11:20. For data averaged across varieties, this represents an average delay of 2.27 days for every 10 minute reduction in night-length below 12 hours. The absolute responses were different for each variety, with an increase of 3.8 days / 10 min reduction for Charm (largest response of varieties tested) and a 1.56 days / 10 min reduction for Purple About Time (smallest reduction). Using the normalised data, delay could be described for each variety as a delay of 2.5% of the total response (between 12 h and 11:20) for that particular variety for every minute reduction in night-length (fig. 5c).**

- **When grown with 2 klx throughout short days, plant bulk only increased above the values in the commercial standard treatment when night-length was reduced to 11:40 or shorter. The benefits in terms of increased plant bulk and flowering, when achieved using reduced night-length treatments have to be offset against the extended crop duration.**

- **Increases in flower and bud production occurred when night-length was less than 12 h, and was dominated by increased bud formation. In absolute terms, Glow Time, Purple Lucky Time and Regal Davis showed the largest increases in total flower and bud production, with relatively small increases seen in Surf, Purple About Time and Charm.**

- **Each variety showed a different sensitivity for flowering in response to night-length, with Surf being most sensitive to changes in night-length from 12 h to 11:40, and Purple About Time being least sensitive in this region (but most sensitive of the varieties tested when night-length changed from 11:40 to 11:20; see fig. 4c).**

- **Effects of reduced night-length treatment were consistent across stick dates.**

3.2 Effect of reduced night-length on post-harvest performance (Trial 3)

Pots of all varieties grown at 4.8 W/m^2 (2 klx) throughout SDs from the 13 h and 11:40 night-length treatments were tested for shelf-life performance.

Where available, pots from the 11:20 night-length treatment were taken from the week 49 stick for shelf-life testing, but due to uneven design, formal statistical analysis of the 11:20 night-length treatment is not possible for the shelf-life phase. However, for comparison with the other night-length treatments, the 11:20 data are included in Appendix 6 when available (Appendix 6; Figures 1 – 6).

Data for the standard commercial treatment (12 W/m^2 (5 klx), 13 hour night-length for the first 3 weeks of SDs followed by ambient light and night-length) have also been plotted for comparison with the treatments lit throughout production where available for Charm and Purple About Time (Appendix 6, Figures. 2 & 3)

3.2.1. Reduced night-length effects on the number of open flowers during shelf-life

Data in Table 7 present the flowering of each variety throughout shelf-life (averaged across treatments and stick dates), and demonstrate the flowering characteristics of each of the varieties when lit throughout short days with supplementary lighting at 4.8 W/m^2 (2 klx)

- Of the varieties tested, Purple Lucky Time and Regal Davis produced significantly more open flowers than the other varieties, with Charm and Surf both producing fewer flowers (Table 7).

- 13h and 11:40 night-length treatments resulted in no significant differences in net loss of open flowers in any variety during shelf-life.

- Both Charm and Miramar showed increases in the number of open flowers during the first 6 days of shelf-life (after sleeve removal), which may be attractive to consumers who like to see continued bud opening early on in the home environment.

- Where data are available from Purple About Time and Charm (see Appendix 6; Figures 2 & 3), it is clear that the plants grown with lighting throughout short days, produced more open flowers than those only lit at the start of short days, and also performed better during shelf-life (in terms of enhanced number of open flowers).

Table 7: Number of open flowers in seven pot mum varieties during shelf-life

(averaged across treatments and potting dates)

	Variety							
Time in shelf-life	**Charm**	**Glow Time**	**Miramar**	**Purple About Time**	**Purple Lucky Time**	**Regal Davis**	**Surf**	**5% LSD** (12 d.f.)
Sleeve removal	14.3	23.3	23.9	26.4	36.9	34.4	18.6	7.27
6 days*	**17.6**	25.8	**28.6**	26.4	37.4	34.4	19.3	3.44
14 days*	17.6	25.6	27.6	26.0	37.2	33.9	18.9	3.26
21 days*	17.4	26.6	27.0	25.6	36.4	33.8	18.8	3.11

* Days after sleeve removal; data in bold type highlights varieties in which several flowers opened during the first 6 days after sleeve-removal compared to the other varieties tested.

- Data averaged across varieties and stick dates show that a reduction in night-length from 13 hours to 11 hours 40 minutes had no significant effect on the number of open flowers during shelf-life (Table 8). This would indicate that the increased number of flower buds observed in the reduced night-length treatments do not continue to develop during shelf-life to give enhanced flowering in the home environment.

Table 8: Effect of reduced night-length on the number of open flowers during shelf-life

(averages across varieties and stick dates).

	Night-length treatment		
Time in shelf-life	**11 hours 40 min**	**13 hours**	**5% LSD** (12 d.f.)
Sleeve removal	24.5	26.4	3.88
6 days*	27.1	27.1	1.84
14 days*	26.7	26.6	1.74
21 days*	26.5	26.5	1.66

* Days after sleeve removal

3.2.2 Reduced night-length effects on the number of distorted buds during shelf-life

Bud distortion here refers to any buds that failed to open during shelf-life resulting in twisting or distortion.

- Bud distortion was most prevalent in Charm (Table 9), which had significantly more distorted buds throughout shelf-life, (highlighted in bold characters), than any of the other varieties tested.

- Although Charm produced more distorted buds than the other varieties, Purple About Time, Regal Davis and Purple Lucky Time all showed marked increases in the number of distorted buds during shelf-life, probably associated with the large number of buds produced in these varieties (see Appendix 5). Surf was the only variety with low bud distortion during shelf-life, again linked to its relatively low bud number at marketing.

Table 9: Effect of reduced night-length on the number of distorted buds in seven pot mum varieties during shelf-life.

	Variety							
Time in shelf-life	**Charm**	**Glow Time**	**Miramar**	**Purple About Time**	**Purple Lucky Time**	**Regal Davis**	**Surf**	**5% LSD** (12 d.f.)
Sleeve removal	1.33	0.00	0.30	0.23	0.60	0.27	0.67	1.35
6 days*	**2.60**	0.23	0.30	0.77	0.87	0.50	0.57	0.70
14 days*	**3.10**	0.36	0.61	1.07	0.80	0.80	0.92	0.87
21 days*	**3.10**	0.50	0.77	1.03	1.90	0.97	0.79	1.24
% increase	130	200	130	**350**	220	260	20	

* Days after sleeve removal

- When data were averaged across varieties, there was a 75% increase in the number of distorted buds during shelf-life in pots grown at 11:40 compared to 13 hour nights (Table 10). The increase in number of distorted buds was not seen at marketing or sleeve-removal, again indicating that the increased number of buds produced in the reduced night-length treatment failed to develop successfully post-harvest.

- The above trend was also observed for the 11:20 treatment compared to the 13 h night-length (where data are available from the week 49 stick; Appendix 6, Figure 3).

Table 10: Effect of reduced night-length on the number of distorted buds during shelf-life

(averages across varieties and stick dates)

	Night-length treatment		
Time in shelf-life	**11 hours 40 min**	**13 hours**	**5% LSD** (12 d.f.)
Sleeve removal	0.49	0.49	0.72
6 days*	1.20	0.47	0.37
14 days*	1.37	0.82	0.46
21 days*	1.54	1.05	0.67

- Days after sleeve removal

3.2.3. Reduced night-length effects on flower colour during shelf-life

- All of the varieties with darker coloured flowers were judged as deteriorating more during shelf-life than varieties with paler coloured flowers, with greatest deterioration in Purple Lucky Time, Regal Davis, Purple About Time and Glow Time (Table 11).

Table 11: Effect of reduced night-length on flower colour deterioration in seven pot mum varieties during shelf-life (increasing scores represent deterioration)

	Variety							
Time in shelf-life	**Charm**	**Glow Time**	**Miramar**	**Purple About Time**	**Purple Lucky Time**	**Regal Davis**	**Surf**	**5% LSD** (12 d.f.)
Sleeve removal	1.00	1.33	1.00	1.00	1.03	1.47	1.00	0.15
6 days*	1.00	1.53	1.00	1.03	1.50	1.60	1.00	0.27
14 days*	1.00	1.85	0.97	1.56	1.93	2.33	1.00	0.33
21 days*	1.33	2.14	1.19	1.70	2.20	2.70	1.00	0.20
% change	33	61	19	70	114	84	0	

* Days after sleeve removal

- Consistent trends indicated that flower colour was maintained better during shelf-life from pots grown in the 11:40 night-length treatment than in 13 h nights, though this did not prove to be statistically significant at all stages during shelf-life (Table 12; see also Appendix 6, Figure 7). This may be linked to the slightly increased light integral received by pots in the 11:40 night-length treatment, which had 1 hour 20 minutes more assimilation light each day.

Table 12: Effect of reduced night-length on flower colour deterioration during shelf-life
(increasing scores represent deterioration; averages across varieties and stick dates)

	Night-length treatment		
Time in shelf-life	**11 hours 40 min**	**13 hours**	**5% LSD** (12 d.f.)
Sleeve removal	1.08	1.16	0.08
6 days*	1.19	1.30	0.14
14 days*	1.46	1.58	0.18
21 days*	1.68	1.82	0.11

* Days after sleeve removal

3.2.4. Reduced night-length effects on flower quality during shelf-life

- Across all varieties, there were marked reductions in flower quality occurring between 1 and 2 weeks after sleeve removal (Table 13).

- There was no significant effect of reduced night-length treatment on either the rate or degree of deterioration of flower quality during shelf-life (Table 14).

Table 13: Effect of reduced night-length on flower quality score in seven pot mum varieties during shelf-life (increasing scores represent deterioration)

	Variety							
Time in shelf-life	**Charm**	**Glow Time**	**Miramar**	**Purple About Time**	**Purple Lucky Time**	**Regal Davis**	**Surf**	**5% LSD** (d.f.)
Sleeve removal	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.04 (12)
6 days*	0.00	0.00	0.00	0.03	0.00	0.06	0.00	0.08 (12)
14 days*	1.00	1.16	1.20	1.03	1.00	1.00	0.42	0.21 (11)
21 days*	2.04	2.01	1.99	2.10	1.47	1.90	1.06	0.24 (9)

* Days after sleeve removal

Table 14: Effect of reduced night-length on flower quality score during shelf-life
(increasing scores represent deterioration; averages across varieties and stick dates)

	Night-length treatment		
Time in shelf-life	**11 hours 40 min**	**13 hours**	**5% LSD** (12 d.f.)
Sleeve removal	0.00	0.01	0.021
6 days*	0.00	0.03	0.043
14 days*	1.04	0.91	0.113
21 days*	1.78	1.81	0.130

* Days after sleeve removal

Overall: Effects of reduced night-length on shelf-life were:

- **Reduced night-length treatments (13 h to 11:40) had no significant effect on the number of open flowers during shelf-life (despite the increase in bud numbers during production).**

- **Reduced night-length treatments tended to increase the number of distorted flower buds observed during shelf-life. While total number of open flowers during shelf-life was unaffected, a small proportion of the increased number of buds produced in reduced night-length treatments failed to open and were recorded as distorted.**

- **The number of distorted buds was highest from the week 42 stick when buds were developing during a period of declining ambient light.**

- **Reduced night-length treatments had no significant effect on pot longevity during shelf-life.**

- **Reduced night-length treatments appeared to result in slightly better flower colour during shelf-life.**

- **Glow Time and Miramar produced from the week 42 stick both exhibited somewhat reduced shelf-life.**

- **Of the varieties tested, only Charm and Miramar showed an increase in the number of open flowers during the first week of home-life (post sleeve-removal), which may prove attractive to consumers.**

3.3 Manipulation of the number of long days (LDs) and the timing of the pinch relative to the start of short days (SDs) to stimulate increased vegetative growth during the winter period.

Charm and Purple About Time were given either 17, 21 or 25 LDs. Each treatment was then given a soft pinch either 4 days before the start of SDs (SD – 4), at the start of SDs (@ SD) or 4 days after the start of SDs (SD + 4). These were compared with pots given 17 LDs and pinched in SDs to 7-8 leaves (standard).

Records were taken at pinching and at marketing. At the pinch, the leaf number remaining below the pinch was recorded for each treatment to determine the effect of the number of LDs on subsequent vegetative development of the breaks.

3.3.1. Effect of number of LDs and timing of the pinch (relative to the start of SDs) on leaf number remaining below the pinch.

Data presented in Appendix 7, Figure 1 and Table 15 show how both increasing the number of LDs given, and delaying the pinch into SDs result in plants with more leaves remaining below the pinch than comparable plants either pinched in LDs or given fewer LDs. In all cases, these treatments are compared with a standard treatment given 17 LDs with a soft pinch to 7-8 leaves in SDs.

In the standard treatment, the timing of the pinch was as follows:

Stick date		**Number of SDs before pinch**
Week 41/42	-	6
Week 45/46	-	11
Week 48/49	-	5

In all stick dates, the Standard treatment was pinched later than the SD + 4 pinch treatment.

Table 15: Effect of LDs and timing of the pinch on leaf number remaining at below the pinch (data across varieties and stick dates): LSD = 0.497; 18 d.f.

	Timing of pinch relative to the start of SDs		
Number of LDs	**SD – 4**	**@ SD**	**SD + 4**
17	6.04	6.26	7.37
21	6.19	7.17	8.45
25	6.62	7.53	8.87
7-8 leaves in SD (standard) 7.75			

- The average timing of the pinch in the standard treatment was 7.3 days into SDs. The leaf number data relate to this, with slightly (but not significant @ P = 5%) more leaves remaining at the pinch than in the 17 LD treatment pinch 4 days in to SD (SD + 4).

- As might be expected, when plants were given more LDs or the pinch was delayed, leaf number remaining on the main-stem increased. In plants pinched 4 days before the start of SDs, increasing the number of LDs given had a less marked effect than in plants pinched at SD + 4. If a plant was pinched at SD – 4, the number of LDs given had to be increased from 17 to 25 before a significant (at P = 5%) increase in leaf number remaining at the pinch was observed. When pinched either at SD or SD + 4, there were significant increases in leaf number as the number of LDs given increased from 17 to 21 and 21 to 25.

- In plants pinched either in LDs or at the start of SDs, any breaks arising from the main-stem were at a lower position than in plants pinched later on in LDs (with higher leaf number remaining below the pinch). This fact should be noted when considering the effects of timing of the pinch on subsequent vegetative growth on the uppermost breaks.

- Data in Table 16 show that the greatest effects of the LD and pinch treatments on leaf number remaining below the pinch were observed when light levels at the start of production were highest (see light data in Appendix 4).

Table 16: Effect of stick date and number of LDs on leaf number remaining below the pinch.

Treatment		Stick week		
		41/42	45/46	48/49
LD treatments	**17**	7.80	6.82	5.04
(means across	**21**	9.01	7.44	5.36
pinch treatments)	**25**	10.02	7.66	5.56
	Standard	8.32	8.42	6.51
Pinch	**SD-4**	7.19	6.90	4.76
treatments	**@ SD**	9.00	6.71	5.47
(means across	**SD + 4**	10.65	8.32	5.72
LD treatments)	**Standard**	8.32	8.42	6.52

Apply LSD	= 0.497 when comparing LD treatments within stick week
(5%; 18 df)	= 0.703 when comparing LD treatment with the standard within stick date

- Of the varieties tested, Purple About Time was more responsive than Charm (see Appendix 7, Figure 1).

3.3.2. Effects of number of LDs and timing of the pinch on plant variables measured at marketing.

The following should be considered in conjunction with Figures in Appendix 7, Figures 2 – 9 and Appendix 9, Plates 3 – 8.

The results in Tables 17 and 18 show that there are subtle, but nevertheless significant (at P = 5%) effects of manipulation of both the number of LDs given (Table 17) and the timing of the pinch (Table 18) on bulk and flowering of pots at marketing.

Increasing the number of LDs given stimulated:

- Significant reductions in crop duration in SDs (P = 5%) if LD period extended to 21 or 25 LDs. The saving in duration in SDs was approximately 1.5 days. However, although time in SDs was reduced by 1.5 days, the overall crop duration (including LDs) was actually increased by either 2.5 or 6.5 days (for 21 and 25 LD treatments respectively).

- The saving in duration (in SDs) was accompanied by increased height (18%), spread (6.4%) and dry weight (24.5%).

- Neither increasing the number of long days nor time of pinch affected total flower number. However, when plants were pinched in SDs, there tended to be marked increases in the number of breaks with 3 or more open flowers (216%) compared to the standard treatment. This was probably due to reduced apical dominance earlier in development in plants pinched during SDs.

Table 17: Overall effects of number of LDs on plant variables recorded at marketing

(means across varieties, sticks and pinch treatments).

Variable	Number of Long Days (LDs) given				5% LSD; 18 d.f*	
	17	**21**	**25**	**Standard (17)**	LD – LD	LD – Standard
Duration (SDs)	61.38	60.88	60.58	62.15	0.59	0.83
Height (cm)	14.61	15.79	16.78	14.21	0.43	0.61
Spread (cm)	29.94	30.73	31.61	29.69	0.55	0.77
Dry Weight (g)	6.63	7.20	7.83	6.29	0.50	0.71
Total flowers	30.87	32.24	33.01	31.75	1.29	1.82
Proportion open flowers	0.433	0.461	0.444	0.473	NSD	
N°. of breaks with 3 or more open flowers	0.092	0.179	0.158	0.050	0.05	0.08

* LSD assigned for comparison between pairs of LD treatments (LD-LD) or between a LD treatment and the standard treatment (LD – STD, in brackets)

NSD = No Significant Difference

- These benefits of extending the long day period need to be offset against the additional cost of providing pots with the extra LDs. As pots are grown at high density during the LD phase, costs associated with extending the LD period are smaller than when manipulating factors at final spacing.

Pinching plants after the start of SDs stimulated:

- Reductions in crop duration, but at the expense of plant bulk and flowering on the breaks.

Pinching plants before the start of SDs stimulated:

- No crop delay (across LD treatments) compared to the standard treatment

- Significant increases in height (16%), spread (8%), dry weight (23%) and leaf number on the uppermost break (73%).

Table 18: Overall effects of the timing of the pinch relative to the start of SDs on plant variables recorded at marketing

(means across varieties, sticks and LD treatments).

Variable	Timing of the pinch				5% LSD; 18 d.f*	
	SD - 4	@ SD	SD + 4	Standard	LD – LD	LD – Standard
Duration (SDs)	61.93	61.06	59.85	62.15	0.59	0.83
Height (cm)	16.48	15.56	15.13	14.21	0.43	0.61
Spread (cm)	32.08	30.61	29.59	29.69	0.55	0.77
Dry Weight (g)	7.74	7.19	6.73	6.29	0.50	0.71
Total flowers	32.97	31.51	31.64	31.75	NSD	
Proportion open flowers	0.455	0.432	0.451	0.473	NSD	
N^o. of breaks with 3 or more open flowers	0.2567	0.1178	0.054	0.050	0.05	0.08
Leaf no. on uppermost break	10.40	8.23	6.06	6.01	0.34	0.48

* LSD assigned for comparison between pairs of LD treatments (LD-LD) or between a LD treatment and the standard treatment (LD – STD, in brackets)

NSD = No Significant Difference

- Again, there was no significant effect of early pinching on total flower number or the proportion of open flowers, but there was a relatively large (4-fold) increase in the number of breaks with 3 or more open flowers. This relates to the increased leaf number (and therefore sites for flower production) on the breaks in plants pinched before the start of SDs.

Overall: interaction between number of long days and timing of the pinch.

- The most effective treatment combination for increasing plant bulk and flowering on the breaks was to give pots at least 21 LDs and pinch 4 days before the start of SDs. This resulted in no crop delays (in terms of SD duration) relative to the standard treatment (17 LDs), with the benefits of increased plant bulk (height, spread and dry weight) together with a greater number of breaks with 3 or more open flowers. The extent to which additional LDs can be given will depend upon the additional cost of increasing the LD phase (pot thick to ½ spacing) compared to the savings in duration in SDs (at final spacing). This will vary between growers.

- Of the two treatments applied, the timing of the pinch relative to the start of SDs appeared to have the most marked effects at marketing (not tested statistically). Therefore growers should be able to benefit from early pinching without having to increase the number of LDs (although increasing the number of LDs will give added benefits). One problem associated with early pinching crops after only 13 long days (17 – 4) is that there is an increased risk of damaging the developing laterals or pinching too hard, both of which will reduce the quality of the final pot.

- Plant bulk was greatest in plants both pinched early and given more LDs. Bulk was influenced by the leafiness of the breaks, and the data showed a marked increase in leaf number on the top break in plants pinched in LDs compared to those pinched later. This is in line with earlier results from PC 13 which showed that the number of leaves on the top break was dependent on the position of the break on the main stem, such that breaks arising from lower on the main-stem would have more leaves. This would occur in plants pinched earlier in production, and in this trial, pots pinched in LDs always produced significantly more leaves on the breaks than those pinched at or after the start of SDs.

- The benefits of increasing the number of LDs were greatest when ambient light levels were highest (week 42 stick), and became reduced for later stick dates. It may be that when light levels are lower, the number of LDs given would need to be increased to compensate for reduced plant vigour. This requires further investigation. However, there will be a limit as to the increase in LDs which can reasonably be given.

- Of the two varieties, Purple About Time exhibited the greatest growth and flowering responses to changes in the number of LDs and timing of the pinch. Charm also showed strong vegetative responses, but this was not correlated with corresponding increases in flowering.

3.4 The interaction between light levels at the end of production and in the retail environment: the effects on post-harvest performance. (Trial 2)

The acclimatization of plants to lower light levels during the final stages of production may enhance their post-harvest longevity (Nell & Barrett, 1986). The current work aimed to investigate the interaction between lighting at the end of production and in the retail environment, and post-harvest performance. If chrysanthemum responds in the same way as many foliage plants, one might expect to see better performance in pots finished under low light conditions and retailed under low light before entering the home environment, than in plants finished in higher light before entering the low-light marketing and home-life environments. This was investigated by asking the question:

Do pots finished in ambient light perform differently during shelf-life from pots lit throughout short days, and how is this affected by light level in the retail environment?

Charm and Purple About Time were used to address the above question.

Plants were grown either with supplementary lighting throughout SDs (4.8 W/m^2), or with 12 W/m^2 for the first 3 weeks of production and then finished in ambient light.

At marketing, pots were put through either a 'good light' (1000 lux) or 'low light' (400 lux) retail environment before being transferred into the simulated home environment (600 lux).

Graphical presentation of the following results can be seen in Appendix 8.

3.4.1 Effect of production x retail light levels on flower number during shelf-life:

- Plants finished in ambient light had significantly fewer open flowers than those lit throughout short days (Table 19). Table 19 shows mean data across varieties. The enhanced flowering in pots lit throughout short days was mainly due to the increased flowering in Purple About Time (40-45% increase in open flower number), rather than Charm which was less responsive (only 5% increase in open flower numbers), to lighting during the SD phase of production (see Table 20).

- Within the production lighting regime, there was no significant effect of retail lighting environment on the number of open flowers during shelf-life (Table 21).

Table 19: Effects of light levels at the end of production on the number of open flowers during shelf-life

(mean across stick date, varieties and retail light level)

Time in shelf-life	Lighting regime		5% LSD	d.f.
	Ambient-finished	Lit throughout short days		
Sleeve removal (SR)	16.50	20.37	1.63	7
6 days after SR	16.30	21.27	1.53	8
14 days after SR	16.20	20.88	1.40	8
21 days after SR	16.08	20.54	1.54	8

Table 20: Effect of light levels at the end of production on number of open flowers in each variety during shelf-life

(mean across stick dates)

Light regime at end of production		VARIETY			
	Time in shelf-life	Charm	Purple About Time	5% LSD	d.f.
AMBIENT	Sleeve removal	15.48	17.53	2.31	7
	6 days after SR	15.03	17.57	2.17	8
	14 days after SR	15.07	17.33	1.98	8
	21 days after SR	14.93	17.23	2.17	8
LIT	Sleeve removal	15.40	25.33	2.31	7
	6 days after SR	16.00	25.93	2.17	8
	14 days after SR	16.50	25.27	1.98	8
	21 days after SR	16.42	24.66	2.17	8

Table 21: Effect of light levels at the end of production and in the retail environment on number of open flowers during shelf-life

(mean across varieties and stick dates)

Light regime at end of production		RETAIL LIGHT LEVEL			
	Time in shelf-life	**1000 lux**	**400 lux**	**5% LSD**	**d.f.**
AMBIENT	Sleeve removal	15.78	17.23	2.31	7
	6 days after SR	15.23	17.37	2.17	8
	14 days after SR	15.47	16.93	1.98	8
	21 days after SR	15.50	16.67	2.17	8
LIT	Sleeve removal	21.07	19.67	2.31	7
	6 days after SR	21.33	21.20	2.17	8
	14 days after SR	20.90	20.87	1.98	8
	21 days after SR	20.43	20.64	2.17	8

3.4.2 Effect of production x retail light levels on number of distorted buds during shelf-life:

- The main factors influencing the numbers of distorted buds were variety and stick date linked to ambient light level during production, with relatively little effect of retail light levels. The number of distorted buds declined significantly in successive stickings, with 1.95 distorted buds / pot in the week 42 stick, declining to 0.27 and 0.01 in weeks 46 and 49 respectively; (5% LSD: 1.51 with 7 d.f.). This indicates that when flowers were initiated in relatively high light (week 42), with bud development during declining light, there is an increased chance of bud distortion. In later pottings, where bud development occurred in low light (week 46), or in increasing light (week 49), either plants were better adapted to the low light, or their ability to adapt to increasing light was better than to declining light levels, and so less bud distortion occurred.
- Charm had significantly more distorted buds than Purple About Time despite producing fewer open flowers during shelf-life (Table 22).

- There was a great deal of variability in the data for bud distortion making it difficult to be confident about the interaction between production and retail lighting relative to degree of bud distortion. Data in Table 22 do indicate that for Charm pots finished in ambient light and retailed in low light had fewer distorted buds than pots retailed through the high light environment (1000 lux). This was less obvious for Purple About Time, in which the incidence of bud distortion was much lower. The reverse pattern was observed in the pot lit throughout short days (i.e. higher incidence of bud distortion in pots put through the low light retail environment).

Table 22: Effect of light levels at the end of production and in the retail environment on number of distorted buds in each variety during shelf-life

(mean across stickings)

Light regime at end of production		CHARM		PURPLE ABOUT TIME			
	Time in shelf-life	**1000 lux**	**400 lux**	**1000 lux**	**400 lux**	**5% LSD**	**d.f.**
AMBIENT	Sleeve removal	0.88	0.67	0.27	0.13	1.75	7
	6 days after SR	2.60	1.60	0.60	0.13	1.93	8
	14 days after SR	2.27	1.47	0.33	0.60	1.18	8
	21 days after SR	1.47	1.33	0.40	0.47	0.97	8
LIT	Sleeve removal	1.33	2.53	0.13	0.00	1.75	7
	6 days after SR	1.13	2.33	0.60	0.13	1.93	8
	14 days after SR	1.80	2.20	0.80	0.30	1.18	8
	21 days after SR	2.33	1.80	0.67	0.08	0.97	8

3.4.3 Effect of production x retail light levels on flower colour deterioration during shelf-life:

- Of the two varieties, deterioration in flower colour score was most marked in Purple About Time (which has a darker flower colour). Charm, with its paler flowers at marketing, may reduce any perceived deterioration in flower colour during shelf-life. Purple About Time has been taken as the best 'model' for studying the impact of lighting on flower colour deterioration (Table 23).

- Flower colour faded more rapidly in Purple About Time finished in ambient light (significant at P=5%).

- There was no significant interaction between production and retail lighting on the subsequent degree or rate of deterioration in flower colour.

- Neither flower nor foliage quality scores were significantly affected by production or retail light, or the interaction between these treatments.

Table 23: Effect of light levels at the end of production on flower colour score in each variety during shelf-life

(mean across pottings)

Light regime at end of production		**VARIETY**			
	Time in shelf-life	**Charm**	**Purple About Time**	**5% LSD**	**d.f.**
AMBIENT	Sleeve removal	0.00	0.00	0.00	7
	6 days after SR	1.00	1.57	0.23	8
	14 days after SR	1.20	2.03	0.26	8
	21 days after SR	1.37	2.23	0.21	8
LIT	Sleeve removal	0.00	0.00	0.00	7
	6 days after SR	1.00	1.10	0.23	8
	14 days after SR	1.00	1.63	0.26	8
	21 days after SR	1.33	1.80	0.21	8

- Graphs in Appendix 8 clearly show that in Purple About Time, pot longevity was increased from the week 42 and 46 stickings, in pots finished in ambient light, but with no effect of retail light environment (Appendix 8, Figure 1). However, this enhanced longevity needs to be offset by the perceived negative factors such as fewer flowers and quicker flower colour deterioration observed in pots finished in ambient light.

Overall: Production x retail lighting effects on post-harvest performance.

- **Production lighting regime and choice of variety had the greatest impact on post-harvest performance, with retail light environment of only secondary importance (under conditions tested in the current trial).**

- **Plants lit throughout short days produced and retained more open flowers throughout shelf-life than plants finished in ambient light. There was no significant effect of retail light level on number of open flowers during shelf-life.**

- **Bud distortion appeared to be linked to changing light levels during production such that the number of distorted buds increased in pots produced in declining light levels, and not when light was consistently low or increasing during production. There was a trend (not statistically significant) for reduced bud distortion in pots finished in ambient light and retailed in low-light environments, suggesting that plants adapted to lower production light environments performed better after marketing through a low light retail environment, confirming results reported for other crops.**

4 CONCLUSIONS

4.1 Effects of reduced night-length on plant bulk and quality at marketing

- Of the night-length treatments investigated to date, 11:40 stimulated some improvements in plant bulk and flower and bud number, without excessive crop delays observed in the 11:20 night-length treatment. Future work will investigate an 11:30 night-length as having the potential for further improved quality combined with acceptable crop durations.

- The extent of response to reduced night-length varied from variety-to-variety and the choice of suitable varieties is crucial for successful use of this technique.

- Growing pots under reduced night-lengths stimulated more vegetative and reproductive development, with more flowering breaks, all contributing to production of a visually striking pot at marketing. However, these increases in plant size and flowering were at the expense of increased crop duration, the extent of which was variety-dependent.

- Pots lit throughout short days at 4.8 W/m^2 (2 klx) using reduced night-lengths were larger in terms of height, spread and dry weight than comparable pots grown under 13 hour night-lengths. All plants lit throughout short days had significantly more flowers per pot at marketing than pots only lit for the first 3 weeks of short days at 12 W/m^2.

- Pots grown at reduced night-lengths had significantly more buds and flowers than pots grown in a 13 h night. This increase in reproductive development was mainly due to an increase in number of positions (nodes) for bud development.

- Reducing night-length to 12 hours had little effect on crop duration, but further reductions from 12 h to 11 h 20 min stimulated significant delays of, on average 18% (this represented a delay of 10 days on a 61 SD crop).

- The greatest effects of reduced night-length were observed when nights were shorter than 11 hours 40 min, the period associated with longer delays in crop duration. An exception was Glow Time, which showed its greatest increase in bulk in response to reductions in night-length from 12 h to 11:40, whereas all other varieties tended to respond more to night-lengths shorter than 11:40.

- When expressed on a normalised scale, changes in crop duration were almost linear with time. The delay per minute that night-length was reduced was equivalent to 2.5% of the total response for any particular variety (e.g. if a variety was delayed by 10 days for a change in night-length from 12 h to 11:20, then for every minute reduction in night, one would expect the crop to be delayed by, on average, 0.025 x 10 = 0.25 d or 6 hours). When data were averaged across varieties, there was a 2.27 day delay for every 10 minute reduction in night-length from 12 h to 11: 20.

- Although crop duration across all varieties showed a conservative relationship with night-length (on a normalised scale), changes in the other variables was variety specific: e.g for Surf, 80% of the observed increase in flower number in response to reduced night-length occurred at night-lengths of between 12 h and 11:40, whereas Purple About Time only expressed 20% of its flowering response in this range, with the remaining 80% change from 11:40 to 11:20.

- **Varietal responses to reduced night-length:**

  - **Charm:** Large increases in plant bulk (height and dry weight), but with relatively small increases in total bud and flower production. This variety was prone to large increases in crop duration under reduced night-length regimes.

  - **Glow Time:** This variety was highly responsive to reduced night-length, with large increases in total flower production and plant bulk. This was the only variety of those tested that showed marked increases in dry weight for changes in night-length between 12 h and 11:40, again highlighting its sensitivity to reduced night-length. Glow Time was prone to long delays in production at night-lengths shorter than 11:40.

  - **Miramar:** Responsive to reduced night-length, with large increases in total flower production and plant height and dry weight associated with relatively long delays.

  - **Purple About Time:** This variety was relatively unresponsive to reduced night-length, with only small increases in bulk and flowering, associated with relatively small delays. There would, therefore, be little advantage in growing this variety using reduced night-length treatments.

  - **Purple Lucky Time:** This prolific flowering variety further enhanced its bud and flower production in response to reduced night-length. Increases in plant height and dry weight also occurred, with only a moderate delay in crop duration. This appears to be a relatively good variety for production using reduced night-length.

  - **Regal Davis:** A prolific flowering variety, with large responses to reduced night-length. This variety showed moderate increases in bulk in response to reduced night-length, and only average delays. This variety also appears to be a good candidate for production using reduced night-lengths.

- **Surf:** This variety showed large increases in vegetative growth as night-length reduced, but with relatively small increases in total flower production. Long crop delays make this variety less suitable for production using reduced night-lengths.

4.2 Effects of reduced night-length on post-harvest performance.

- Increased plant bulk achieved from production under reduced night-length stimulated no significant increases in pot longevity during shelf-life tests. The main benefits to the grower and market through production using reduced night-length would appear to be through increased visual impact to the consumer at the point of sale.

- Despite increasing bud numbers during production, reduced night-length treatments had no significant effect on the number of open flowers during shelf-life, indicating that the additional buds produced in these treatments failed to continue developing during shelf-life. This would tie in with the need to market winter-produced pots with flowers at a more advanced stage of development (in accordance with the findings of previous HDC-funded trials (PC 13c) and subsequent grower-funded posters) for the consumer to gain most satisfaction from the product at home.

- There were no significant effects of reduced night-length treatment on the number of open flowers during shelf-life, or on the overall plant longevity.

- Of the varieties tested, only Charm and Miramar showed increased flower opening during the first week of home-life (post sleeve-removal), which may prove attractive to consumers.

4.3 Manipulating the number of long days (LDs) and the timing of the pinch relative to the start of short days (SDs) to stimulate increased vegetative growth during the winter period.

- The most effective treatment combination for increasing plant bulk and flowering on the breaks was to give pots at least 21 LDs and pinch 4 days before the start of SDs. This resulted in no crop delays in short days relative to the standard treatment, with the benefits of increased plant bulk (height, spread and dry weight), together with higher numbers of breaks with 3 or more open flowers. The extent to which additional LDs can be given will vary form grower to grower.

- Of the two treatments applied, observations suggested that the timing of the pinch relative to the start of SDs had the most marked effects at marketing. Therefore growers should be able to benefit from early pinching without having to increase the number of LDs (although increasing the number of LDs will give added benefits). One problem associated with early pinching before the start of SDs is that there is an increased risk of damaging the developing laterals or pinching too hard, both of which would reduce the quality of the final pot.

- Plant bulk was greatest in plants both pinched early and given more LDs. Bulk was influenced by the leafiness of the breaks, and the data show a marked increase in leaf number on the top break in plants pinched in LDs compared to those pinched later. This is in line with earlier results from PC 13 which showed that the number of leaves on the top break was dependent on the point of insertion of the break on the main stem, such that breaks arising from lower on the main-stem would have more leaves. This would occur in plants pinched earlier in production, and in this trial, pots pinched in LDs always produced significantly more leaves on the breaks than those pinched at or after the start of SDs.

- From Appendix 7, its is clear that the benefits of increasing the number of LDs are greatest when ambient light levels were highest (week 42 stick). It may be necessary to further increase the number of long days (beyond 25 LDs) during the period of lowest light, though this may not always be practical.

- Of the two varieties used, Purple About Time exhibited the greatest growth and flowering responses to changes in the number of LDs and timing of the pinch. Charm showed strong vegetative responses, but this did not appear to be correlated with corresponding increases in flowering.

4.4 The interaction between light levels at the end of production and in the retail environment: the effects on post-harvest performance.

- Under the conditions tested in the current trial, production lighting regime and choice of variety had the greatest impact on post-harvest performance, with retail light environment of only secondary importance.

- Plants lit throughout short-days produced and retained more open flowers throughout shelf-life than plants finished in ambient light. There was no significant effect of retail light level on number of open flowers during shelf-life.

- Bud distortion appeared to be linked to changing light levels during production, such that the number of distorted buds increased in pots produced in declining light levels, and not when light was consistently low or increasing during production. There was a trend (not statistically significant) for reduced bud distortion in pots finished in ambient light and retailed in low-light environments, suggesting that plants adapted to lower production light environments performed better after marketing through a low light retail environment. This needs further investigation.

5. ACKNOWLEDGEMENTS

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  Chrysanthemum Committee members for their help and support

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6. LITERATURE CITED

Nell, T.A, and Barrett, J.E., 1986. Production light level effects on light compensation point, carbon exchange rate and post-production longevity in poinsettias. ***Acta Hort.*** **181:** 257-262.

Appendix 1

Allocation of treatments within K Block (southern array)

Appendix 1 : Allocation of treatments within K Block (south)

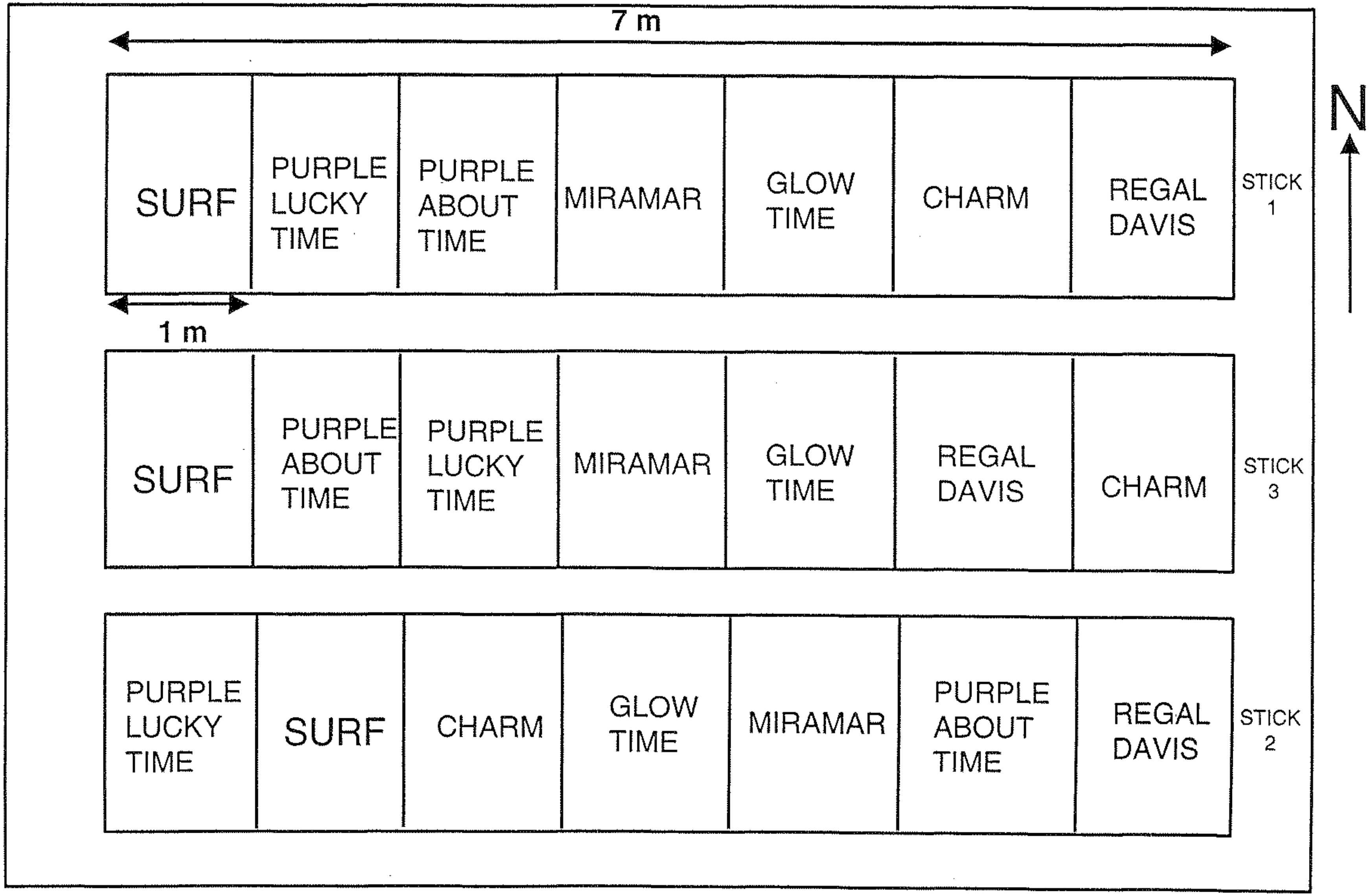
12 12 W/m^2 13 h night	11 4.8 W/m^2 11h40m night	10 4.8 W/m^2 12 h night	9 4.8 W/m^2 13 h night
16 4.8 W/m^2 11h20m night	15 Ambient natural night-length	14 Ambient natural night-length	13 Ambient natural night-length

Appendix 2

Plot layouts within compartments: night-length trial

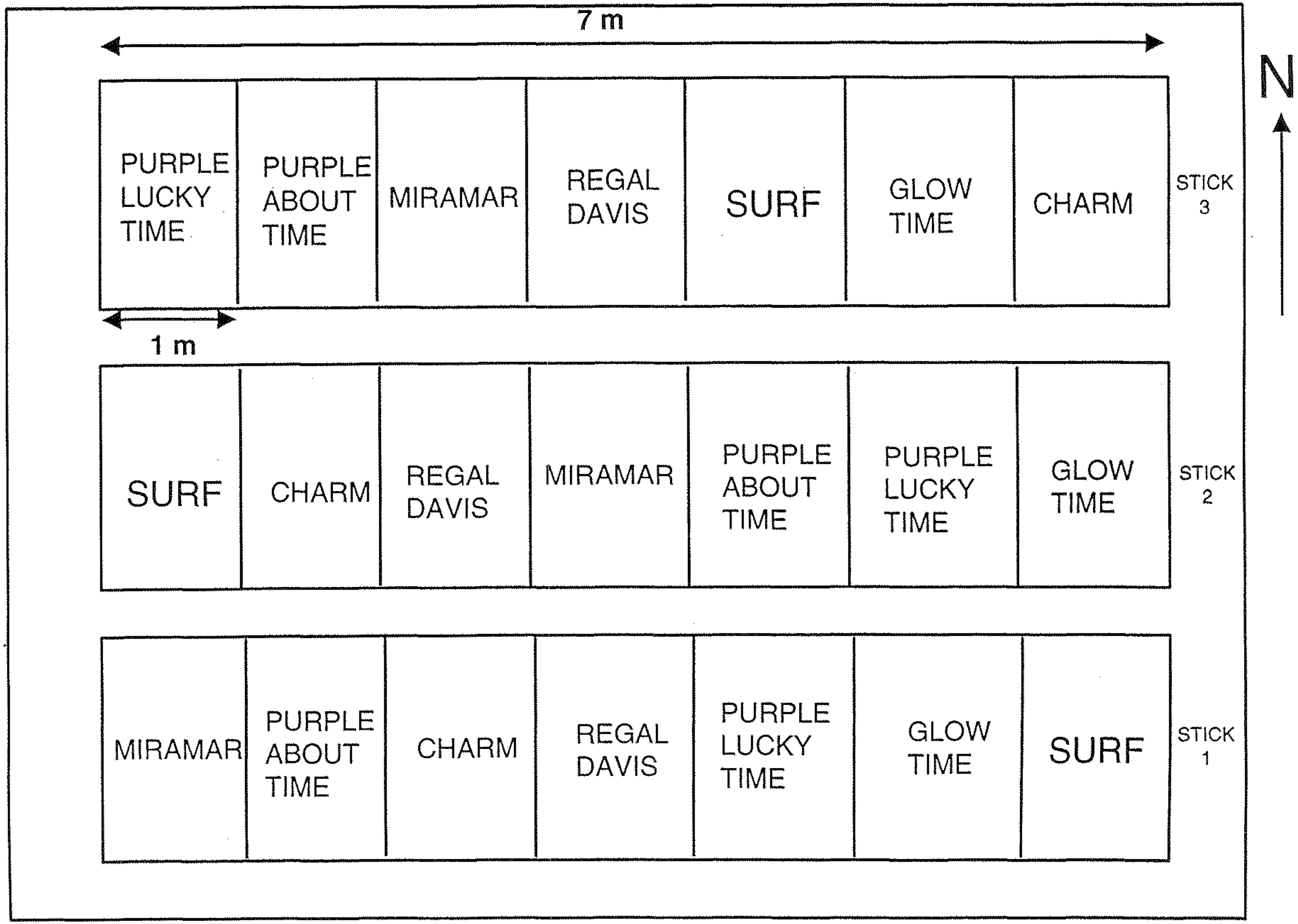
Compartment: 9

Treatment:4.8 W/m^{-2} : 13h Night-length



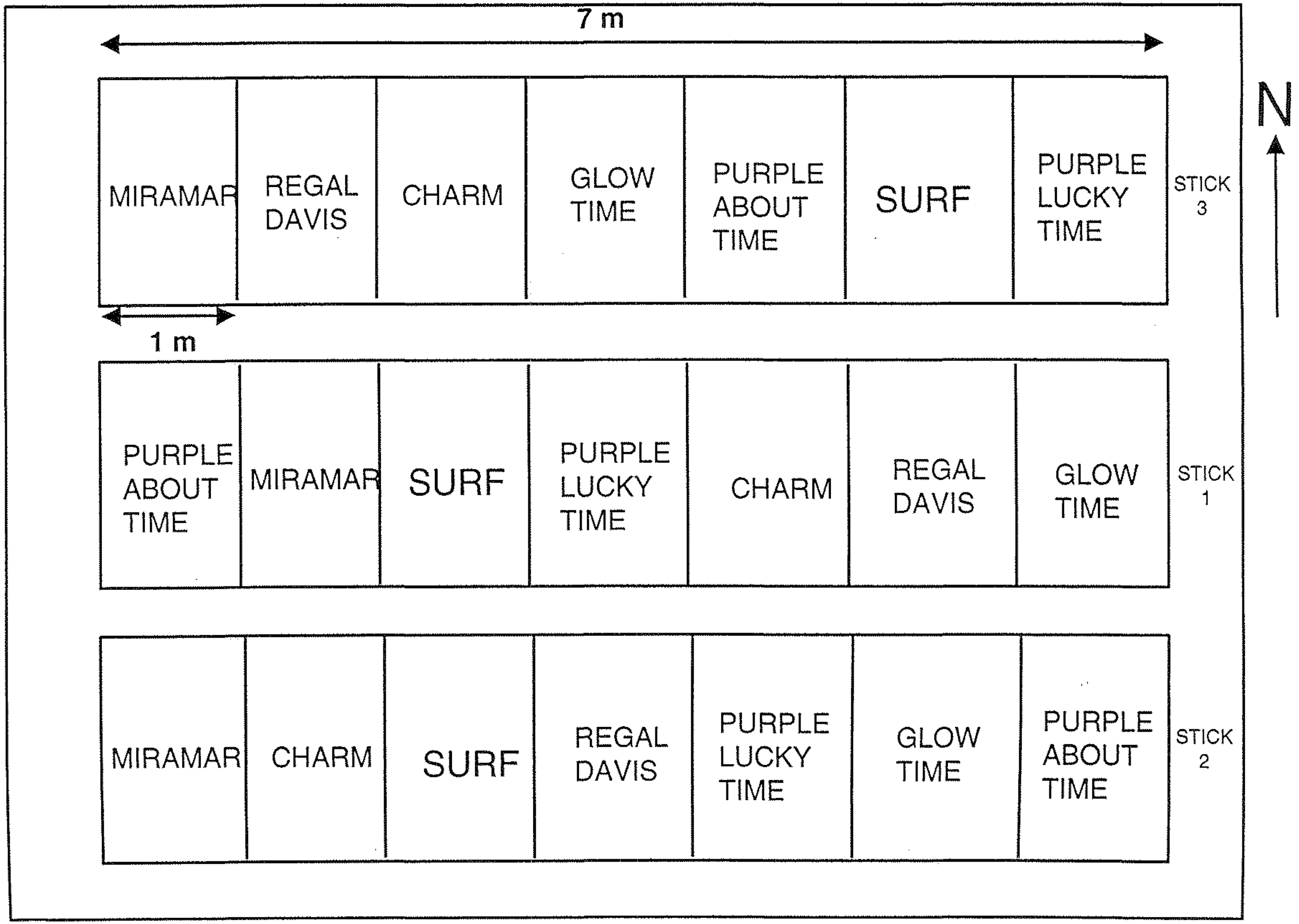
Compartment: 10

Treatment:4.8 W/m^{-2} : 12h Night-length



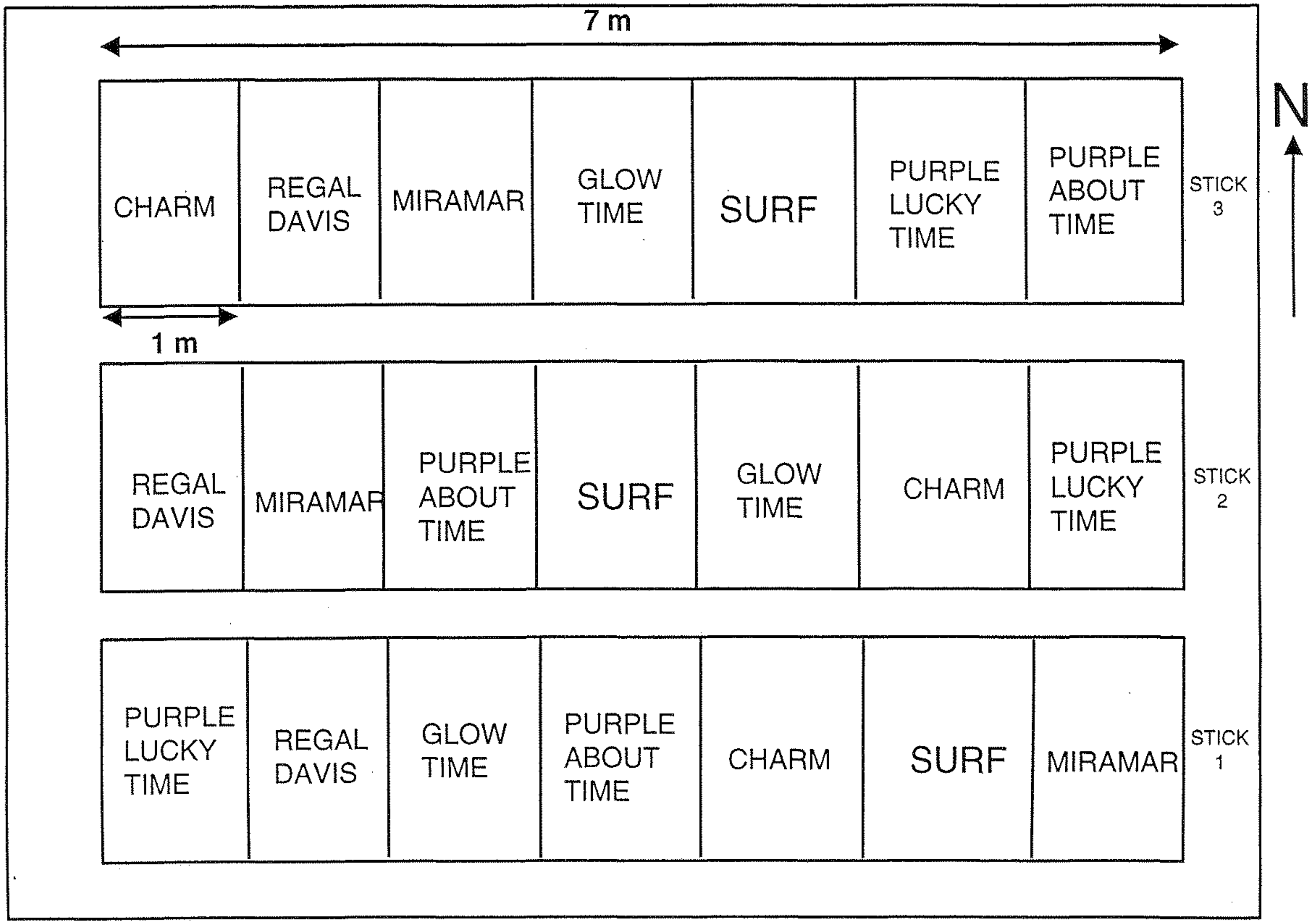
PURPLE LUCKY TIME	PURPLE ABOUT TIME	MIRAMAR	REGAL DAVIS	SURF	GLOW TIME	CHARM	STICK 3
SURF	CHARM	REGAL DAVIS	MIRAMAR	PURPLE ABOUT TIME	PURPLE LUCKY TIME	GLOW TIME	STICK 2
MIRAMAR	PURPLE ABOUT TIME	CHARM	REGAL DAVIS	PURPLE LUCKY TIME	GLOW TIME	SURF	STICK 1

Compartment: 11
Treatment: 4.8 W/m^{-2} : 11h 40 Night-length

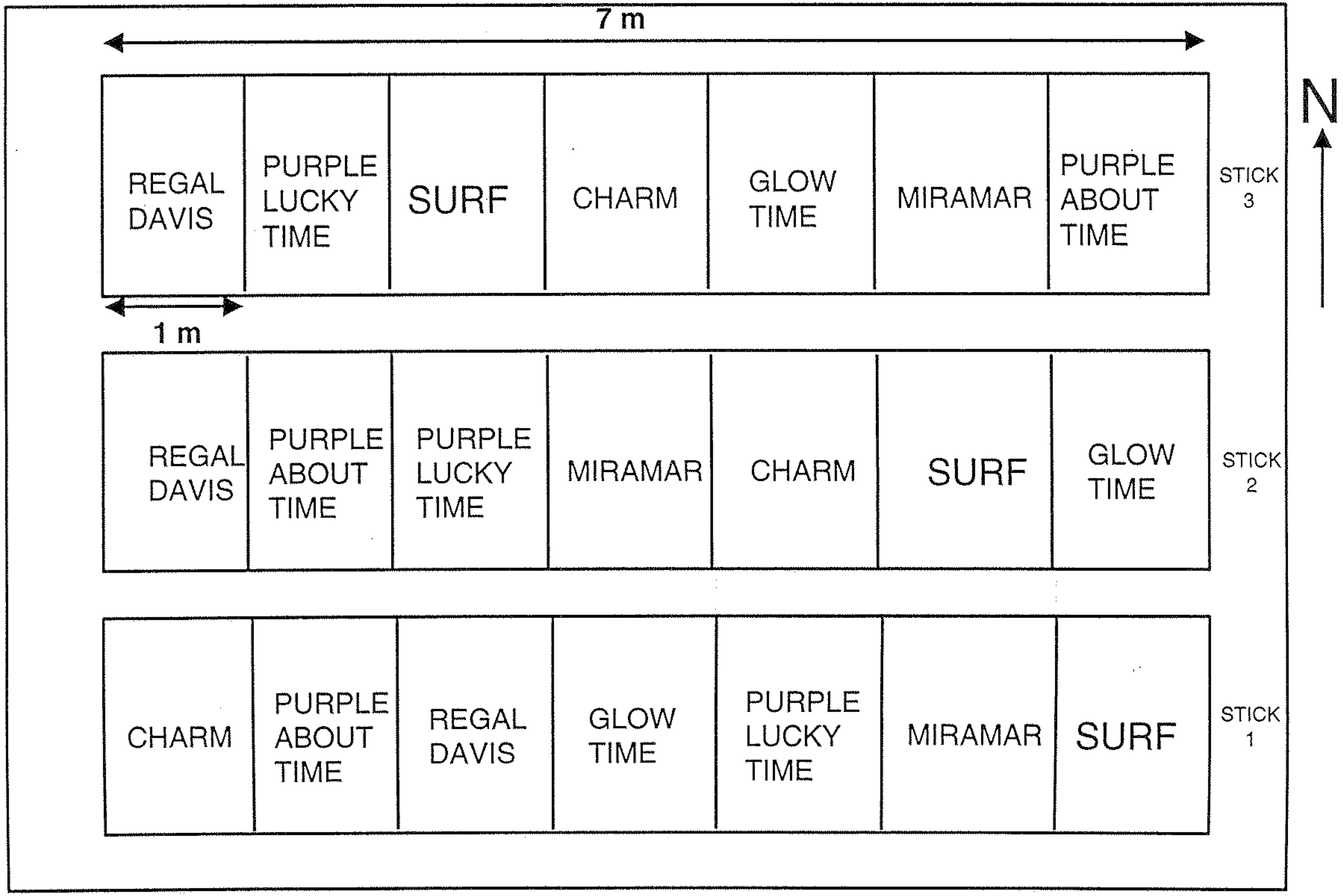


Compartment: 12

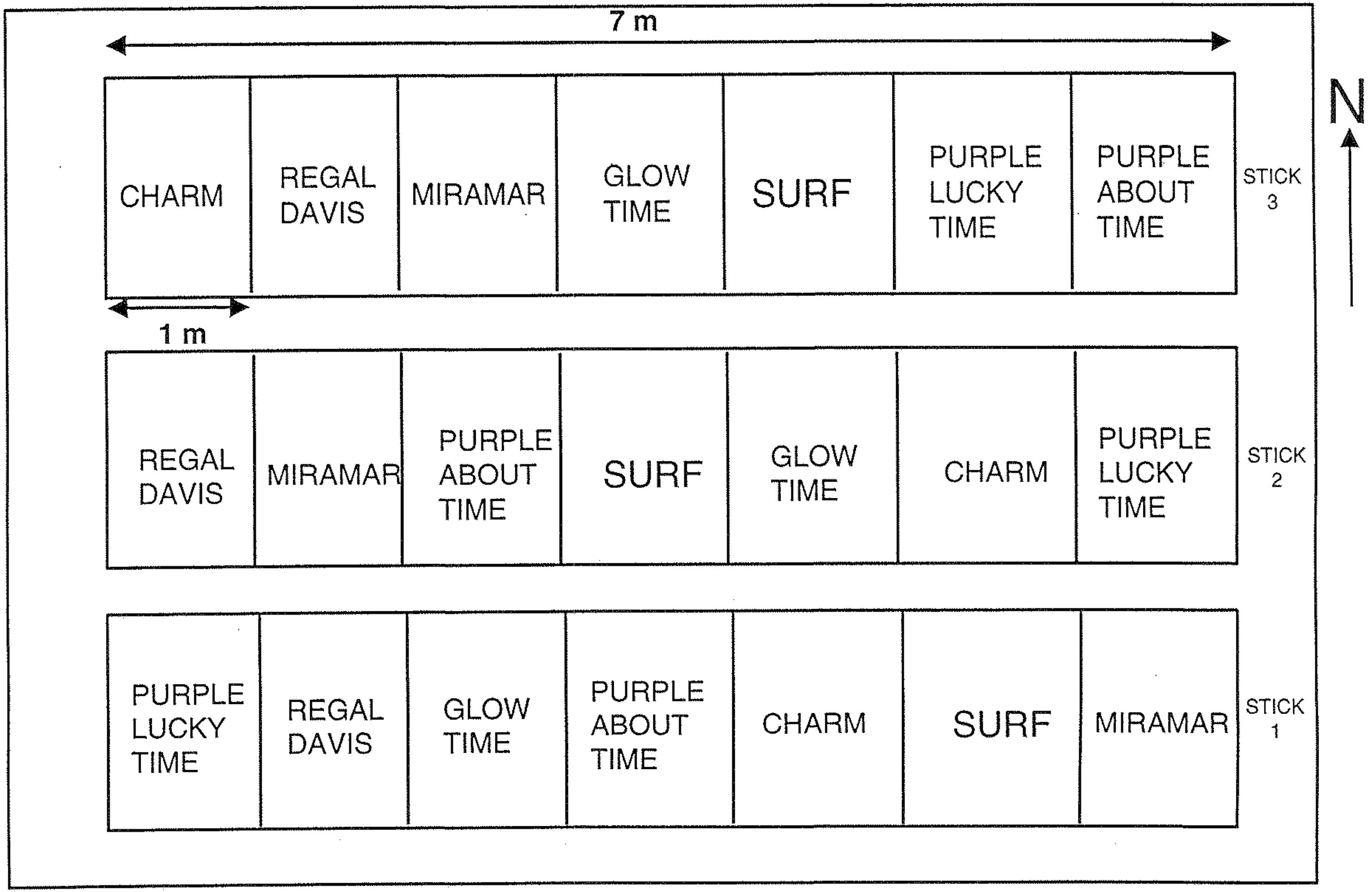
Treatment: 12 W/m^{-2} : 13h Night-length



Compartment: 16
Treatment: 4.8 W/m^{-2}: 11h 20 night-length



Compartment: 13: Transfer from 12 Wm^{-2}
Treatment:Ambient light and natural night-length



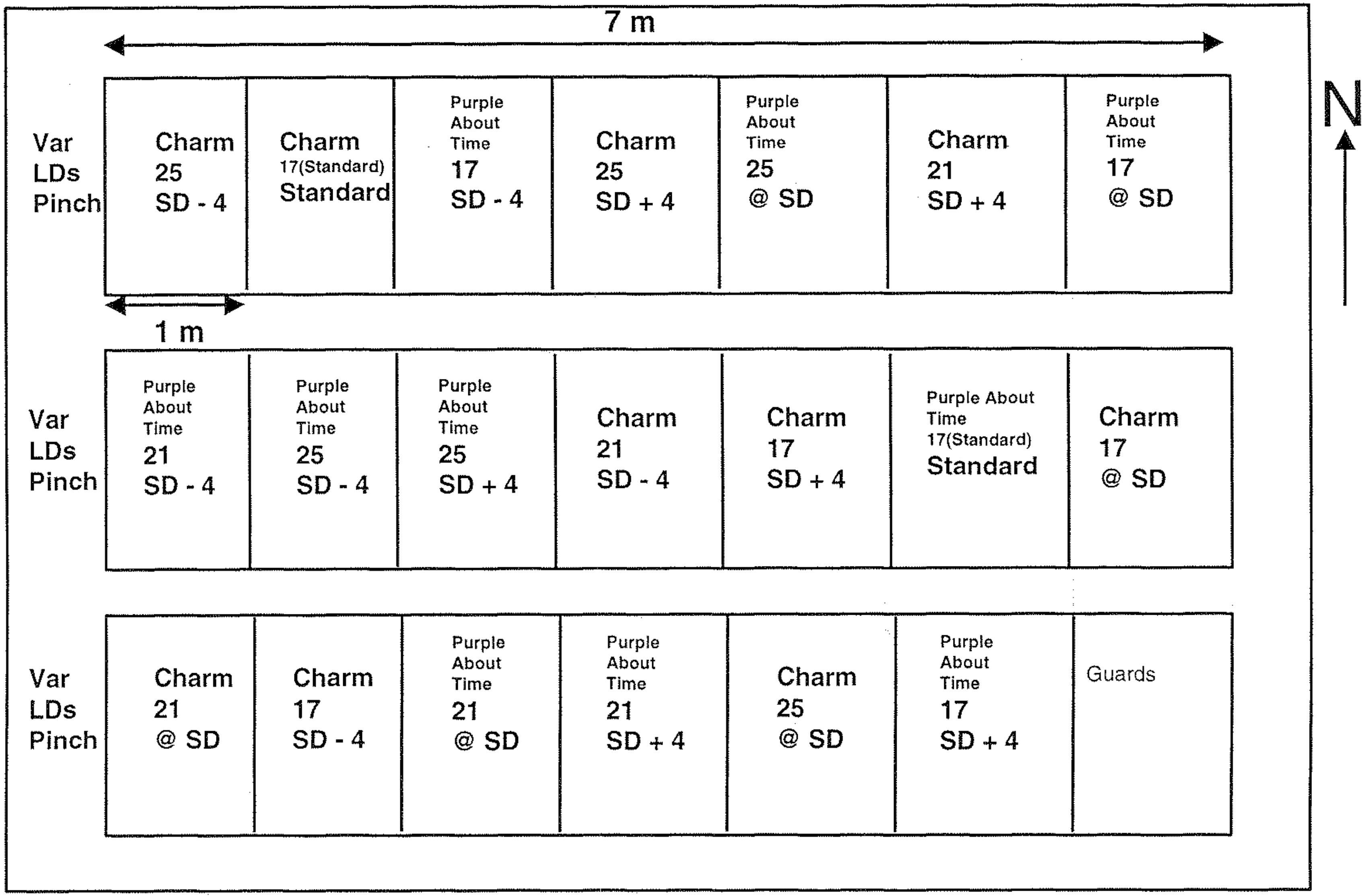
Appendix 3

Plot layouts within compartments:

Long day x pinch

Compartment: 14

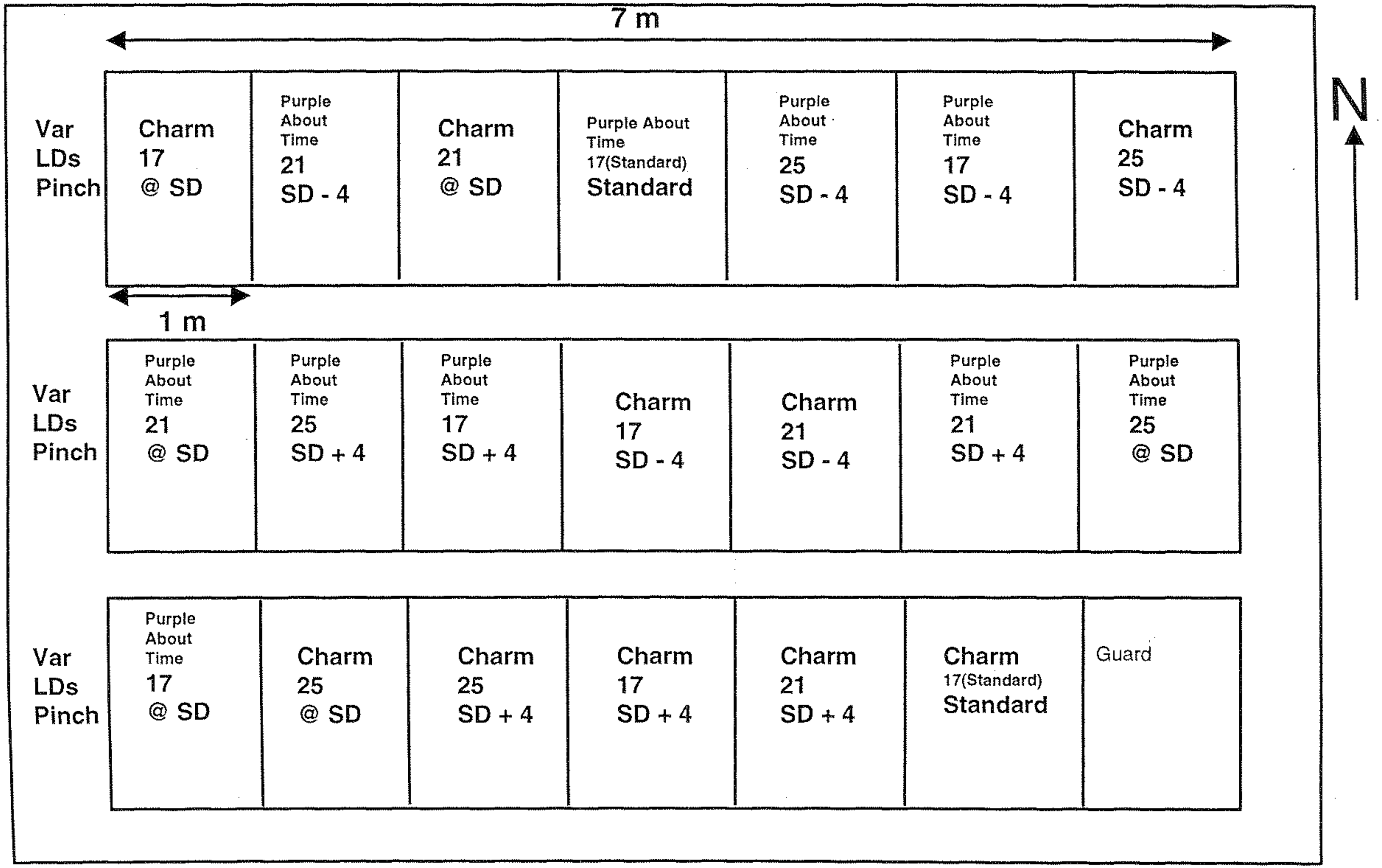
Treatment: Long day and timing of the pinch trial; stick 1 (week 41/42)



Var LDs Pinch	Charm 25 SD - 4	Charm 17(Standard) Standard	Purple About Time 17 SD - 4	Charm 25 SD + 4	Purple About Time 25 @ SD	Charm 21 SD + 4	Purple About Time 17 @ SD
Var LDs Pinch	Purple About Time 21 SD - 4	Purple About Time 25 SD - 4	Purple About Time 25 SD + 4	Charm 21 SD - 4	Charm 17 SD + 4	Purple About Time 17(Standard) Standard	Charm 17 @ SD
Var LDs Pinch	Charm 21 @ SD	Charm 17 SD - 4	Purple About Time 21 @ SD	Purple About Time 21 SD + 4	Charm 25 @ SD	Purple About Time 17 SD + 4	Guards

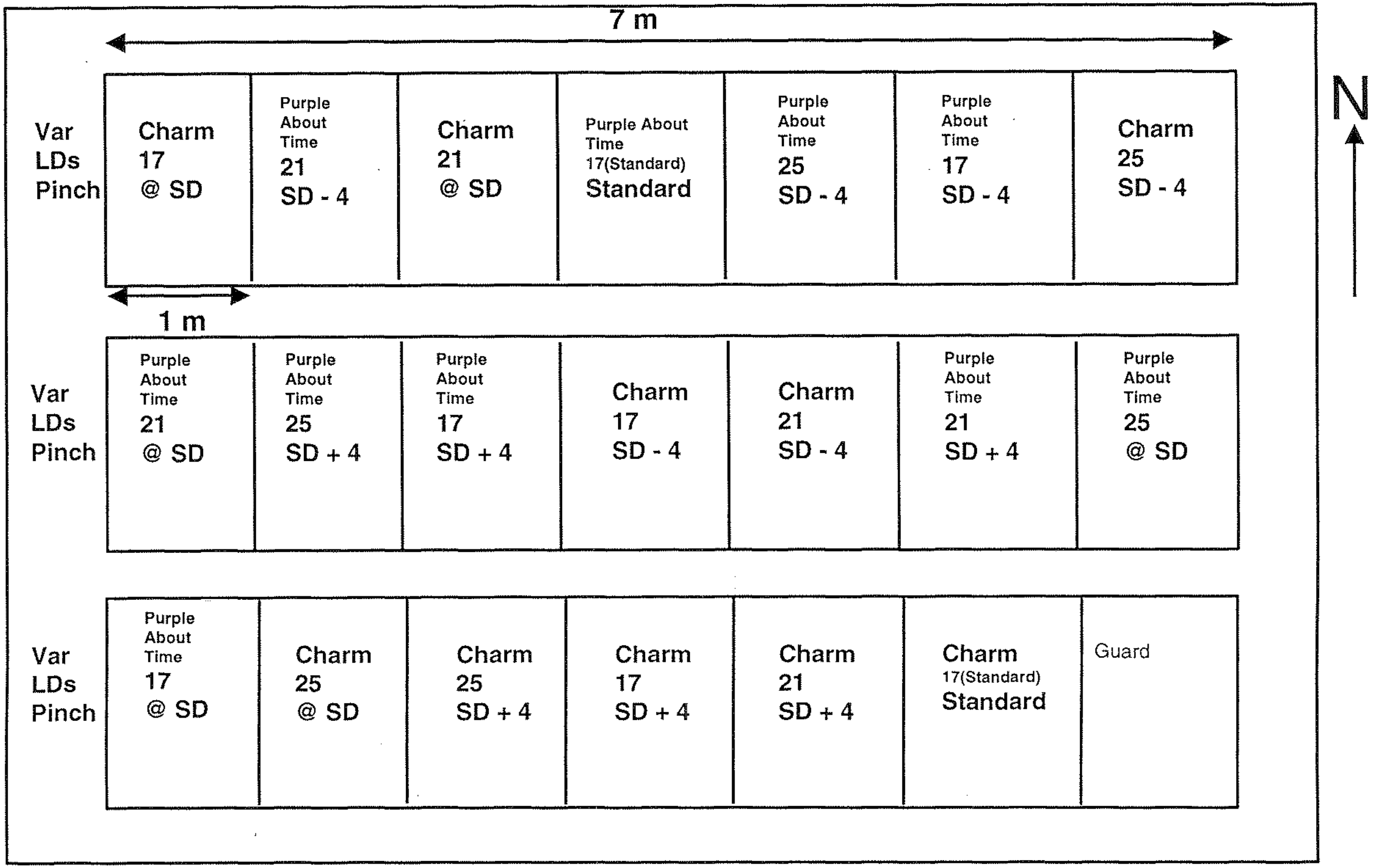
Compartment: 15

Treatment: Long day and timing of the pinch trial; stick 2 (week 45/46)



Var LDs Pinch	Charm 17 @ SD	Purple About Time 21 SD - 4	Charm 21 @ SD	Purple About Time 17(Standard) Standard	Purple About Time 25 SD - 4	Purple About Time 17 SD - 4	Charm 25 SD - 4
Var LDs Pinch	Purple About Time 21 @ SD	Purple About Time 25 SD + 4	Purple About Time 17 SD + 4	Charm 17 SD - 4	Charm 21 SD - 4	Purple About Time 21 SD + 4	Purple About Time 25 @ SD
Var LDs Pinch	Purple About Time 17 @ SD	Charm 25 @ SD	Charm 25 SD + 4	Charm 17 SD + 4	Charm 21 SD + 4	Charm 17(Standard) Standard	Guard

Compartment: 12
Treatment: Long day and timing of the pinch trial; stick 3 (week 48/49)

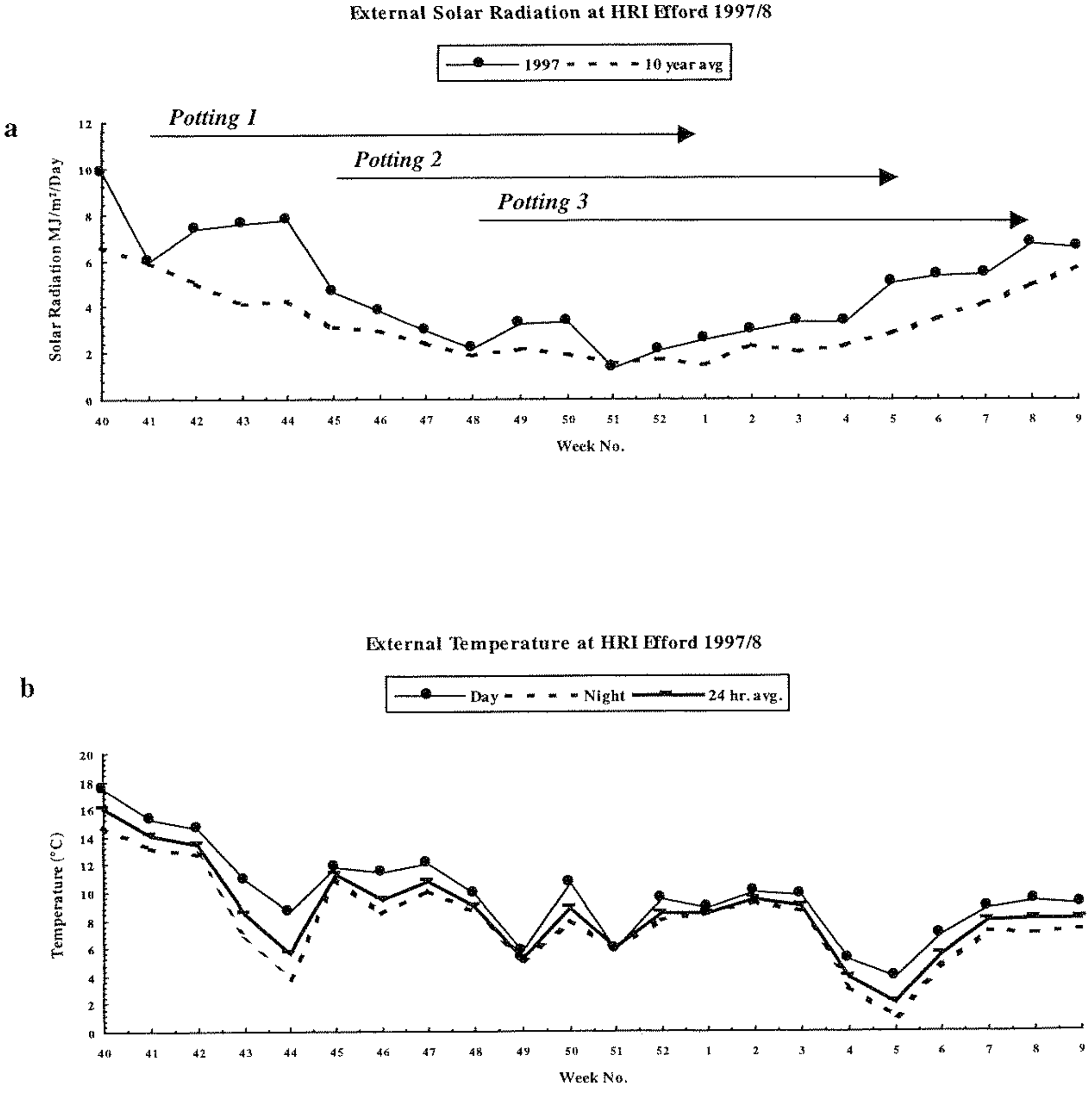


Var LDs Pinch	Charm 17 @ SD	Purple About Time 21 SD - 4	Charm 21 @ SD	Purple About Time 17(Standard) Standard	Purple About Time 25 SD - 4	Purple About Time 17 SD - 4	Charm 25 SD - 4
Var LDs Pinch	Purple About Time 21 @ SD	Purple About Time 25 SD + 4	Purple About Time 17 SD + 4	Charm 17 SD - 4	Charm 21 SD - 4	Purple About Time 21 SD + 4	Purple About Time 25 @ SD
Var LDs Pinch	Purple About Time 17 @ SD	Charm 25 @ SD	Charm 25 SD + 4	Charm 17 SD + 4	Charm 21 SD + 4	Charm 17(Standard) Standard	Guard

Appendix 4

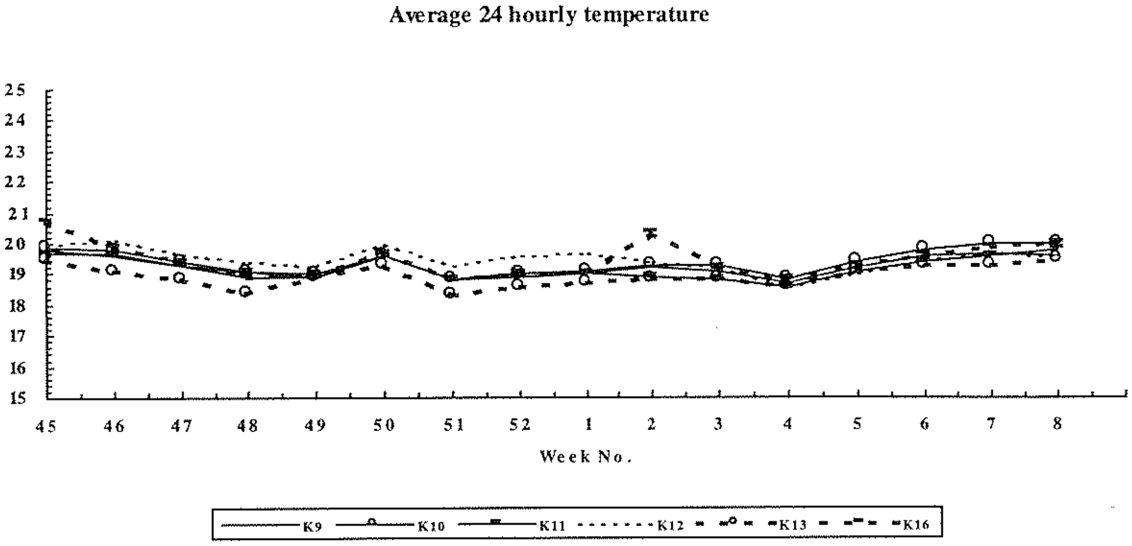
Environmental data

Appendix 4
Figure 1 : Solar radiation and external temperatures : HRI Efford 1997-1998



Appendix 4
Figure 2: Average compartment temperature and RH : Night-length trial

a



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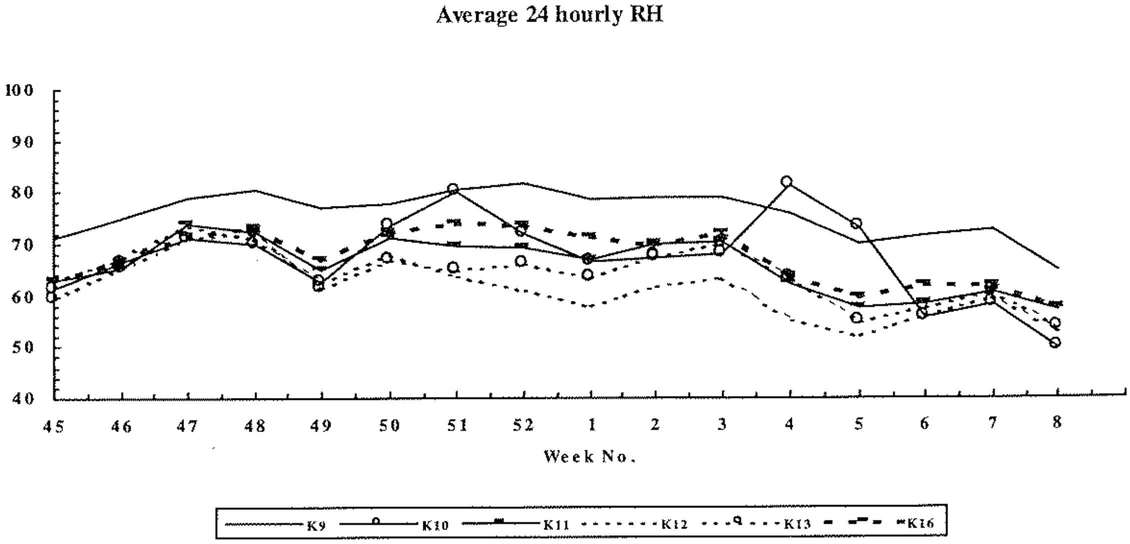
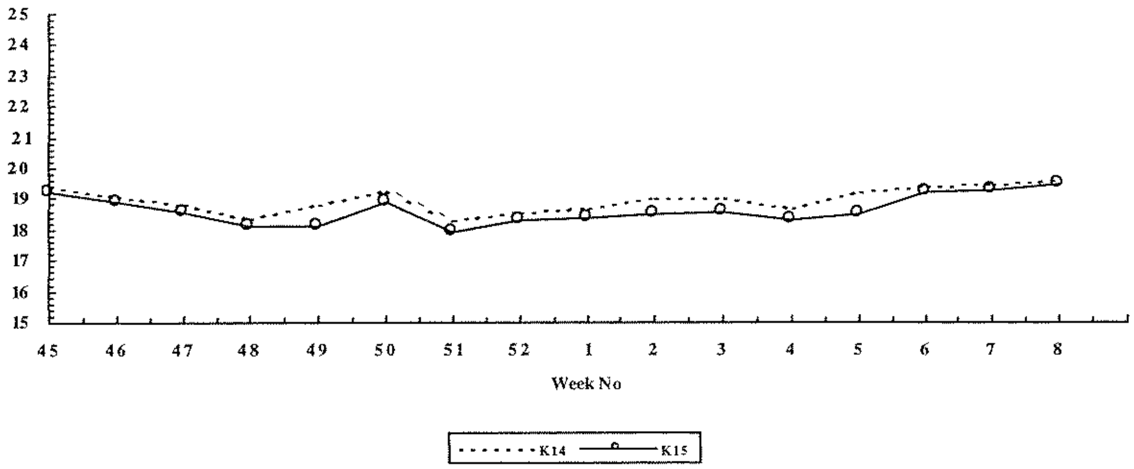


Appendix 4

Figure 3 : Average compartment temperature and RH : Long day / timing the pinch trial

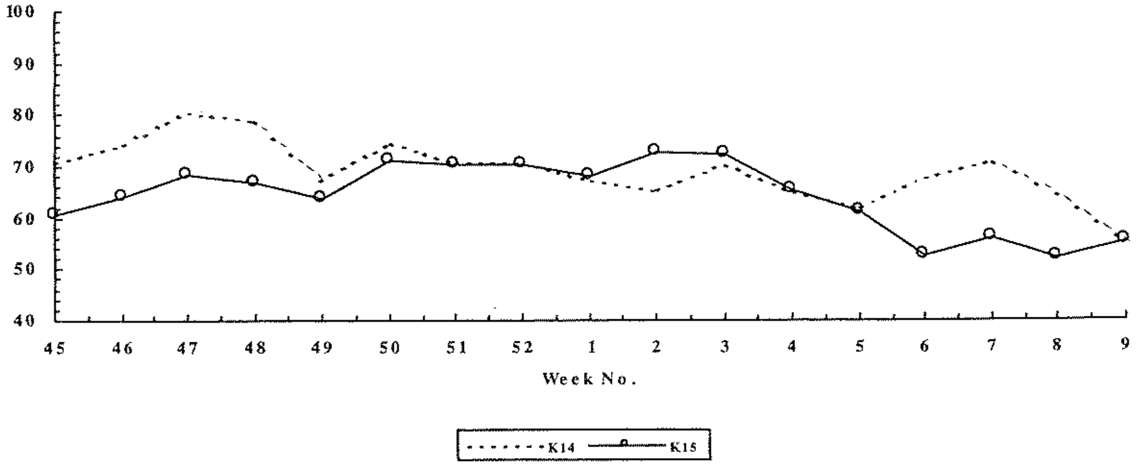
a

24 hourly average temperature



b

24 hourly average RH (%)

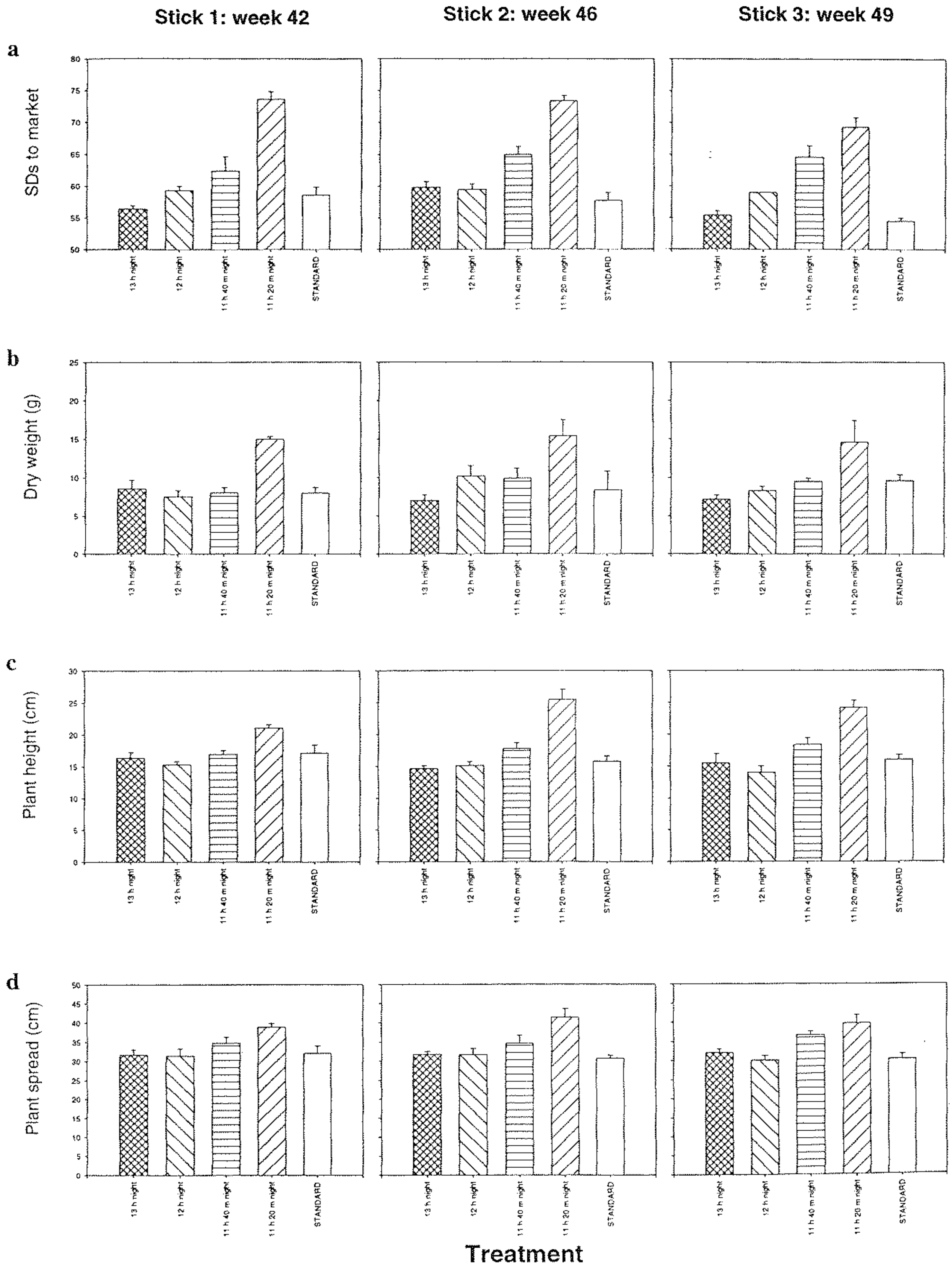


Appendix 5

Effects of reduced night-length: marketing data

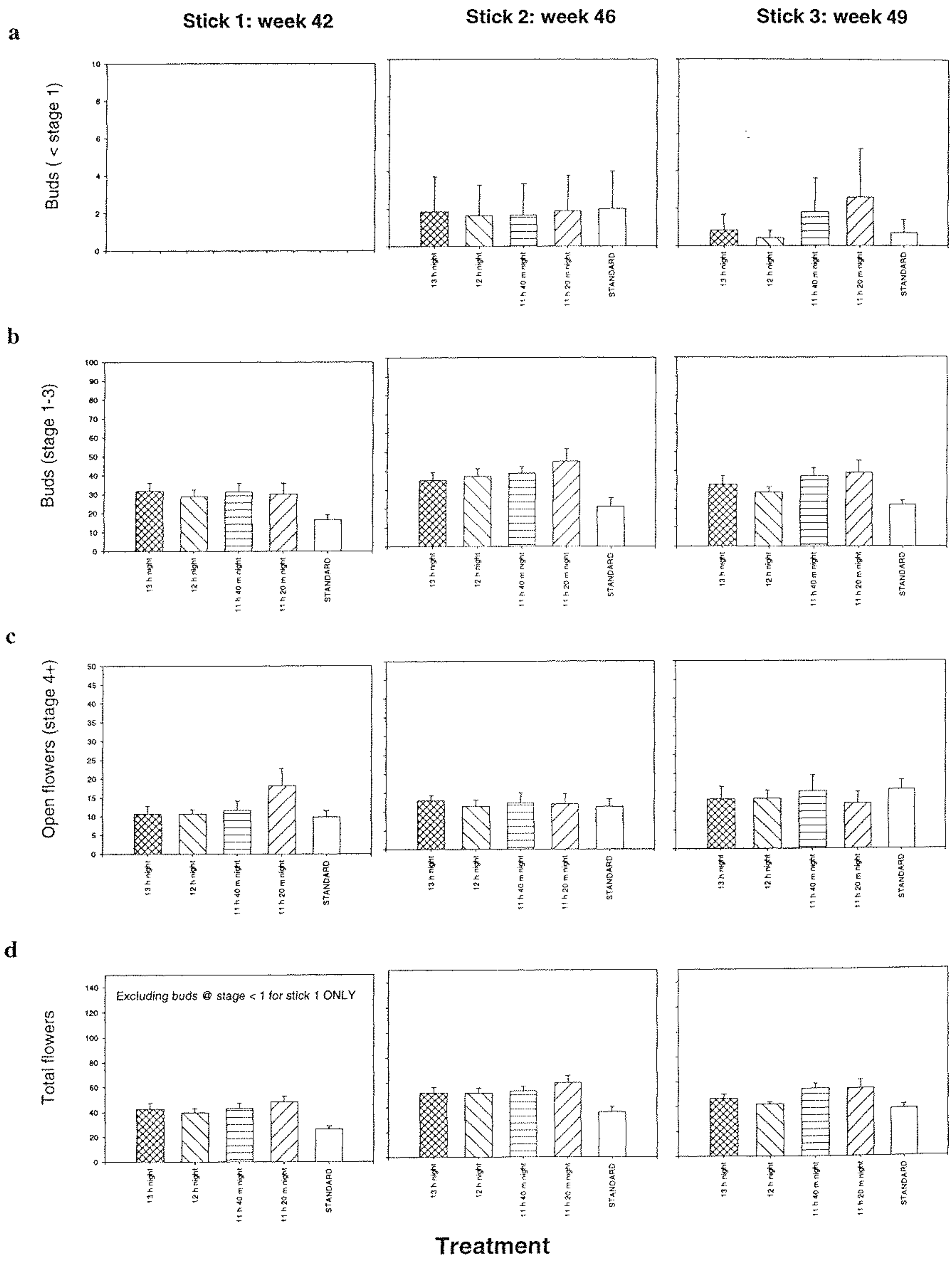
Appendix 5

Figure 1: Charm : Effects of reduced night-length during the winter period (± SD)



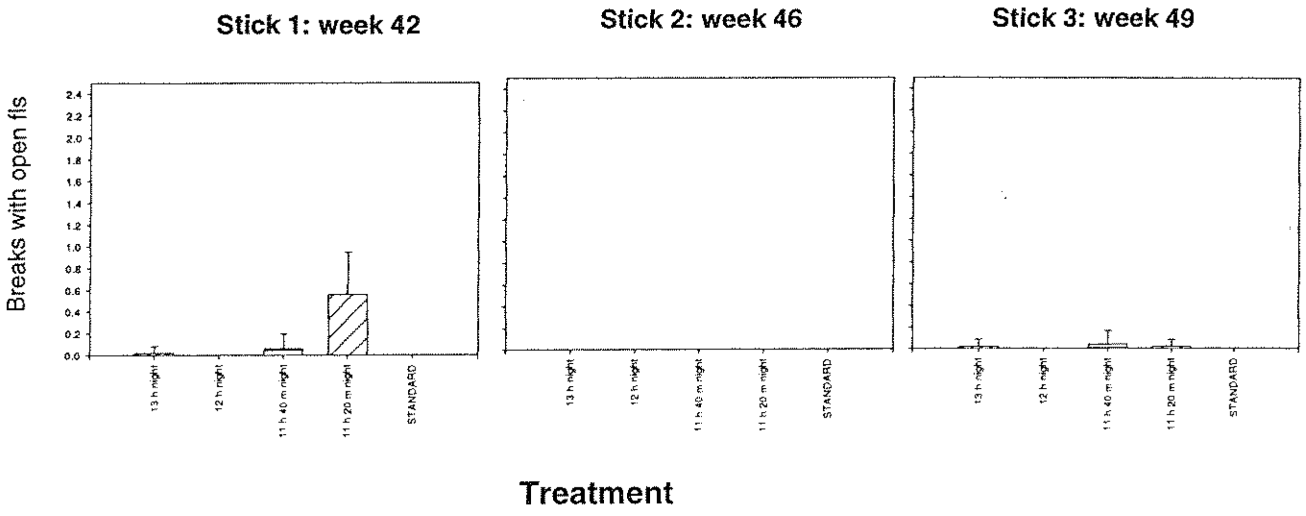
Appendix 5

Figure 2: Charm : Effect of reduced nightlength during the winter period (± SD)



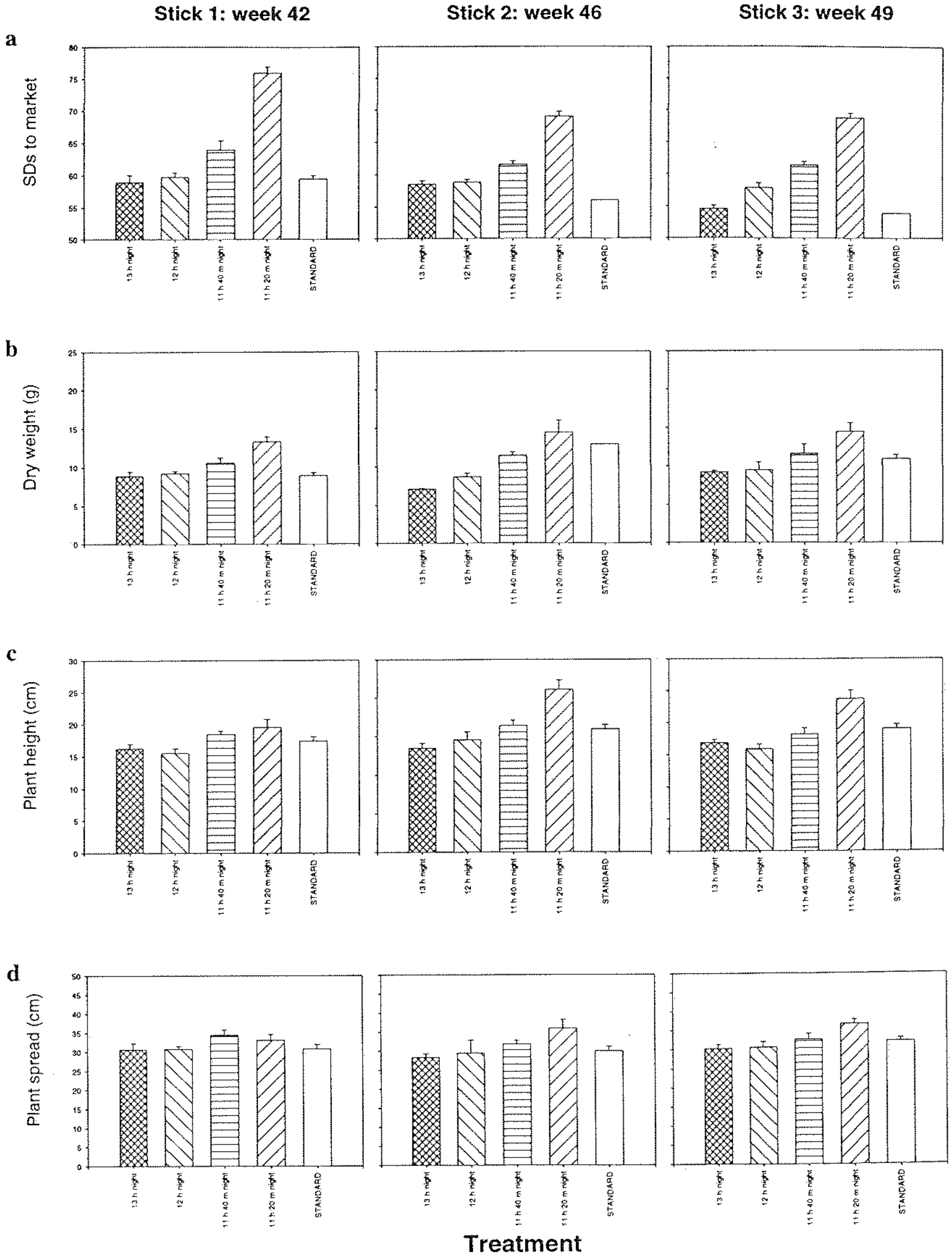
Appendix 5

Figure 3: Charm : Effect of reduced nightlength during the winter period (± SD)



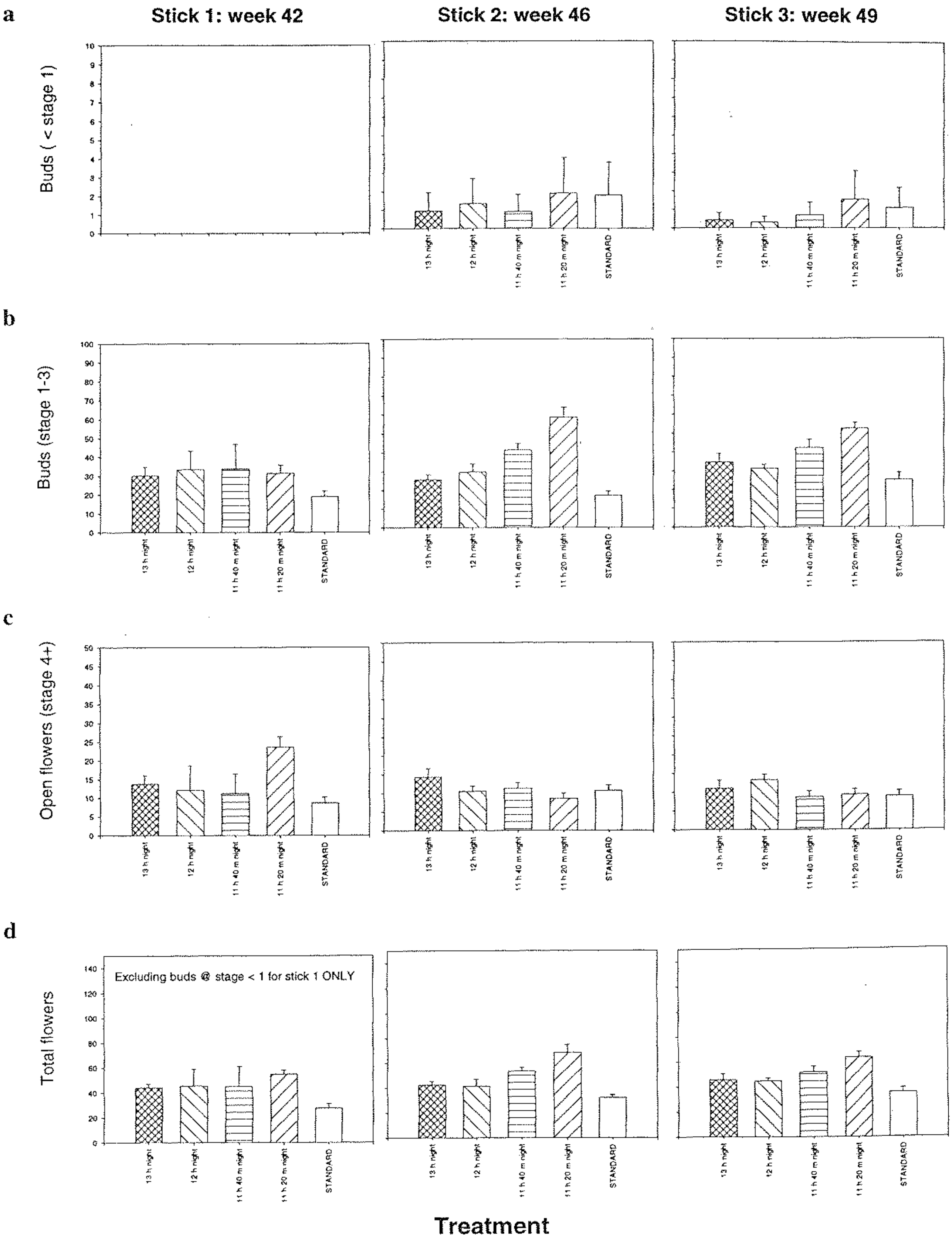
Appendix 5

Figure 4: Glow Time : Effects of reduced night-length during the winter period (± SD)



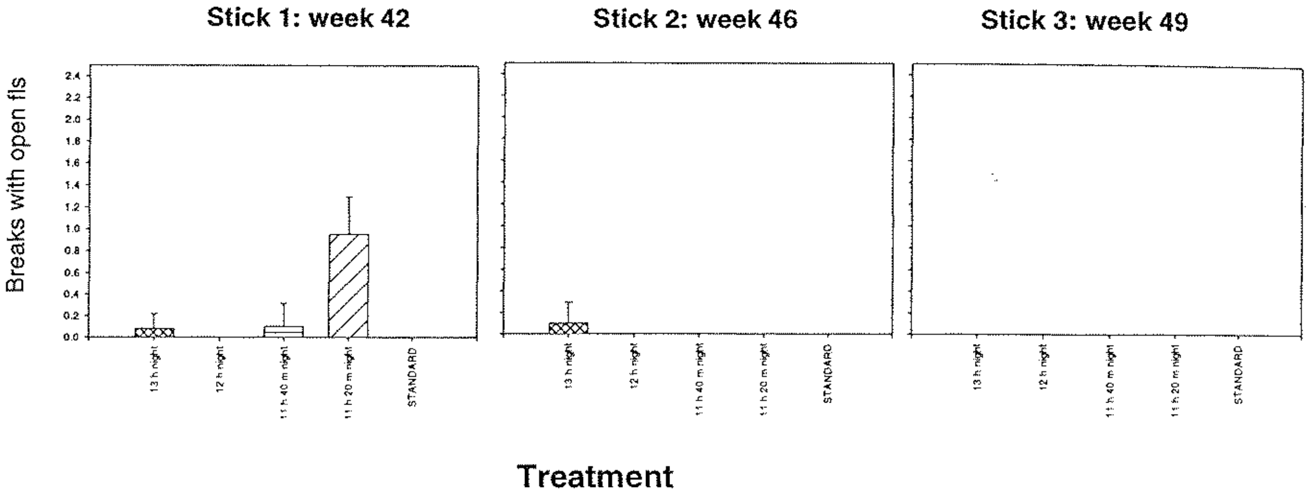
Appendix 5

Figure 5: Glow Time : Effect of reduced nightlength during the winter period (± SD)



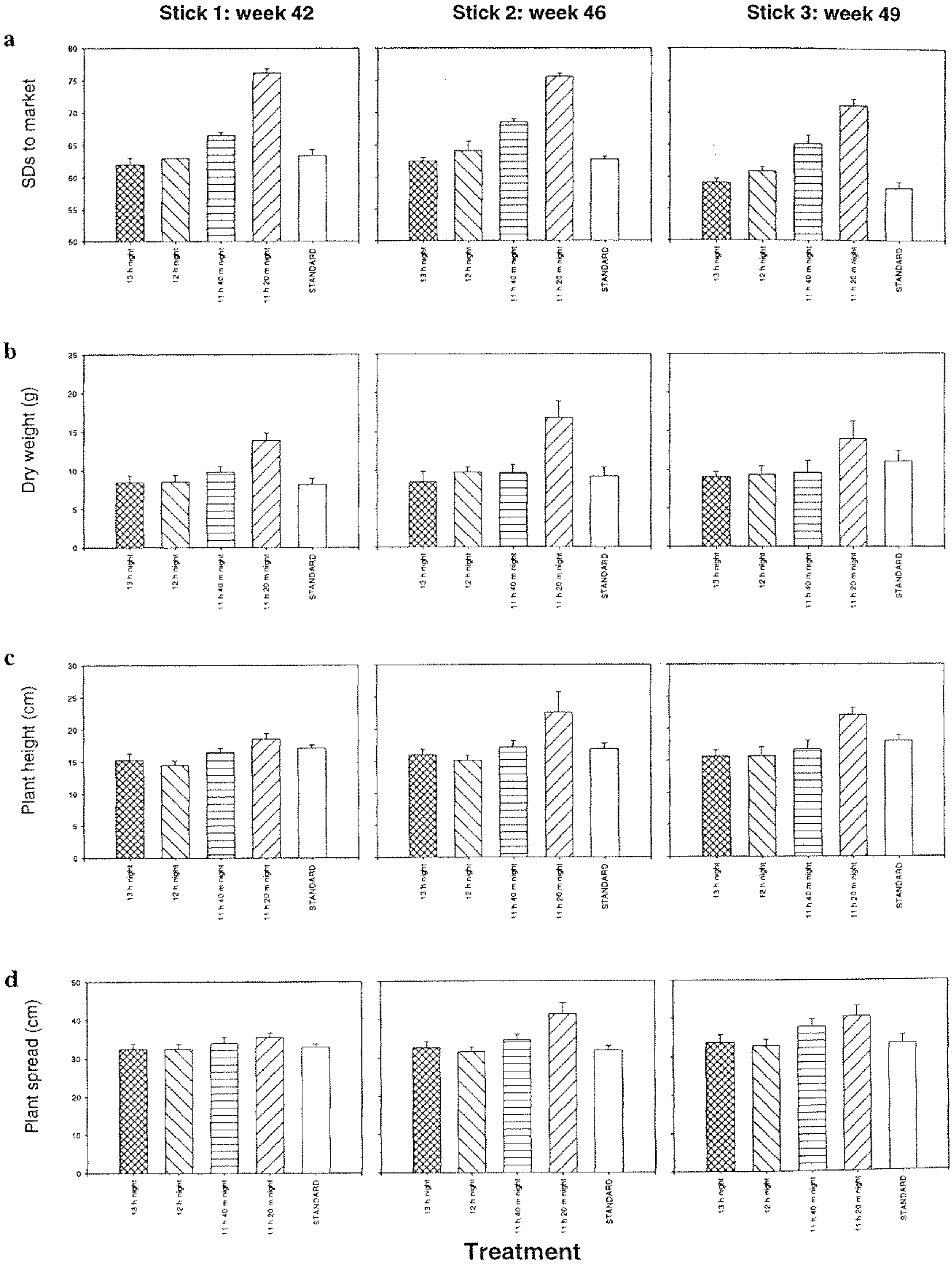
Appendix 5

Figure 6: Glow Time : Effect of reduced nightlength during the winter period (± SD)

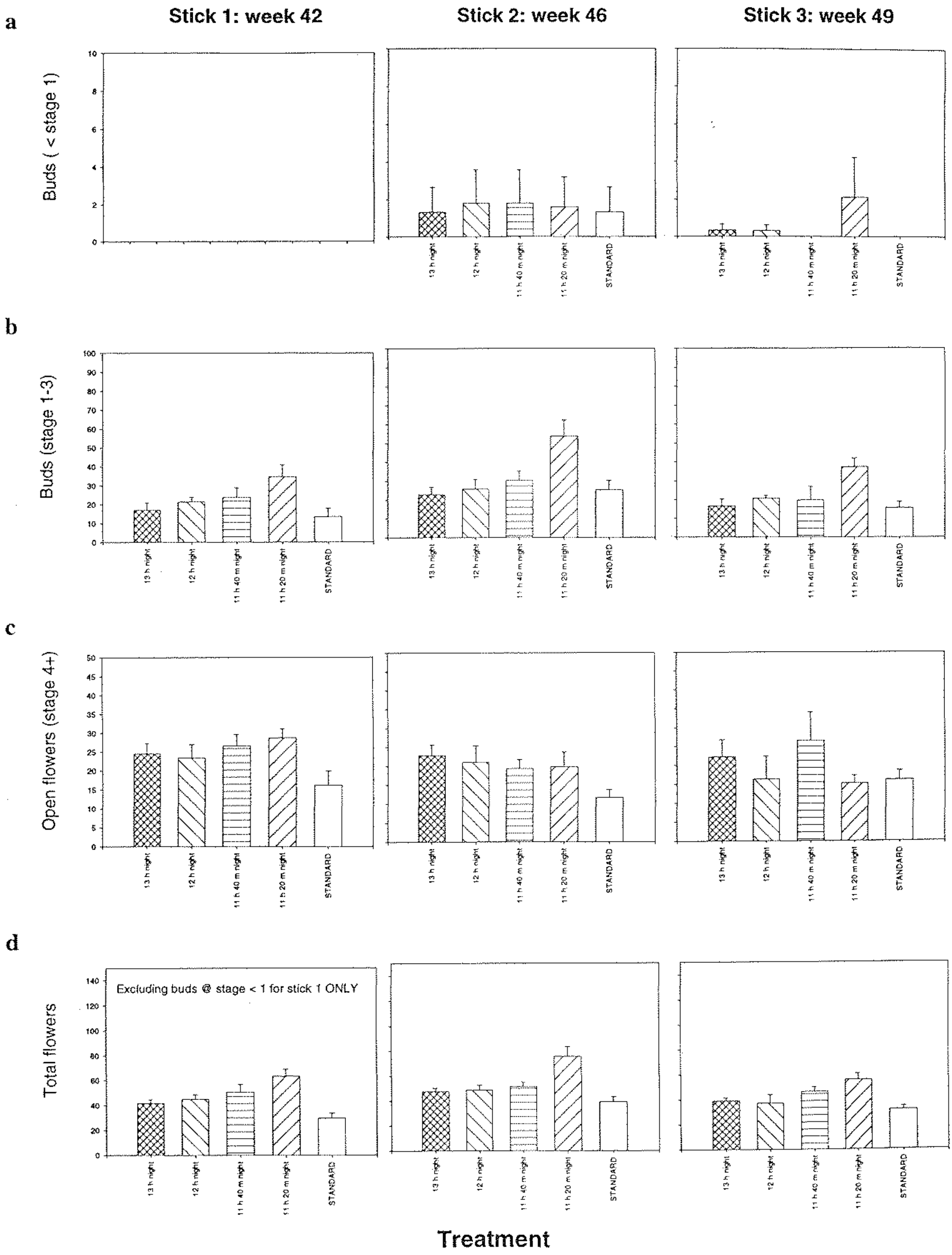


Appendix 5

Figure 7: Miramar : Effects of reduced night-length during the winter period (± SD)

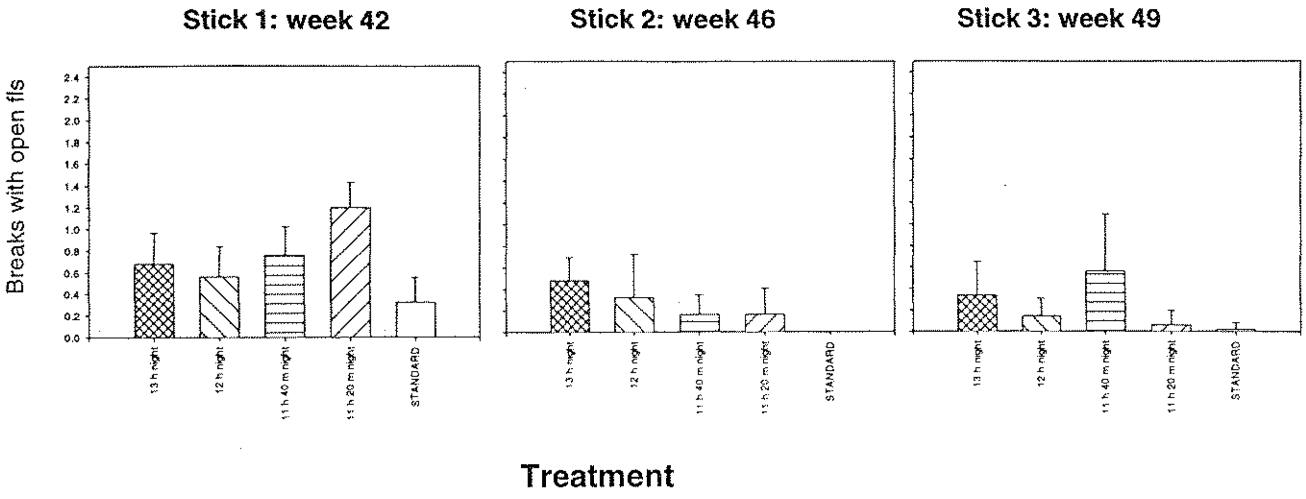


Appendix 5
Figure 8: Miramar : Effect of reduced nightlength during the winter period (± SD)



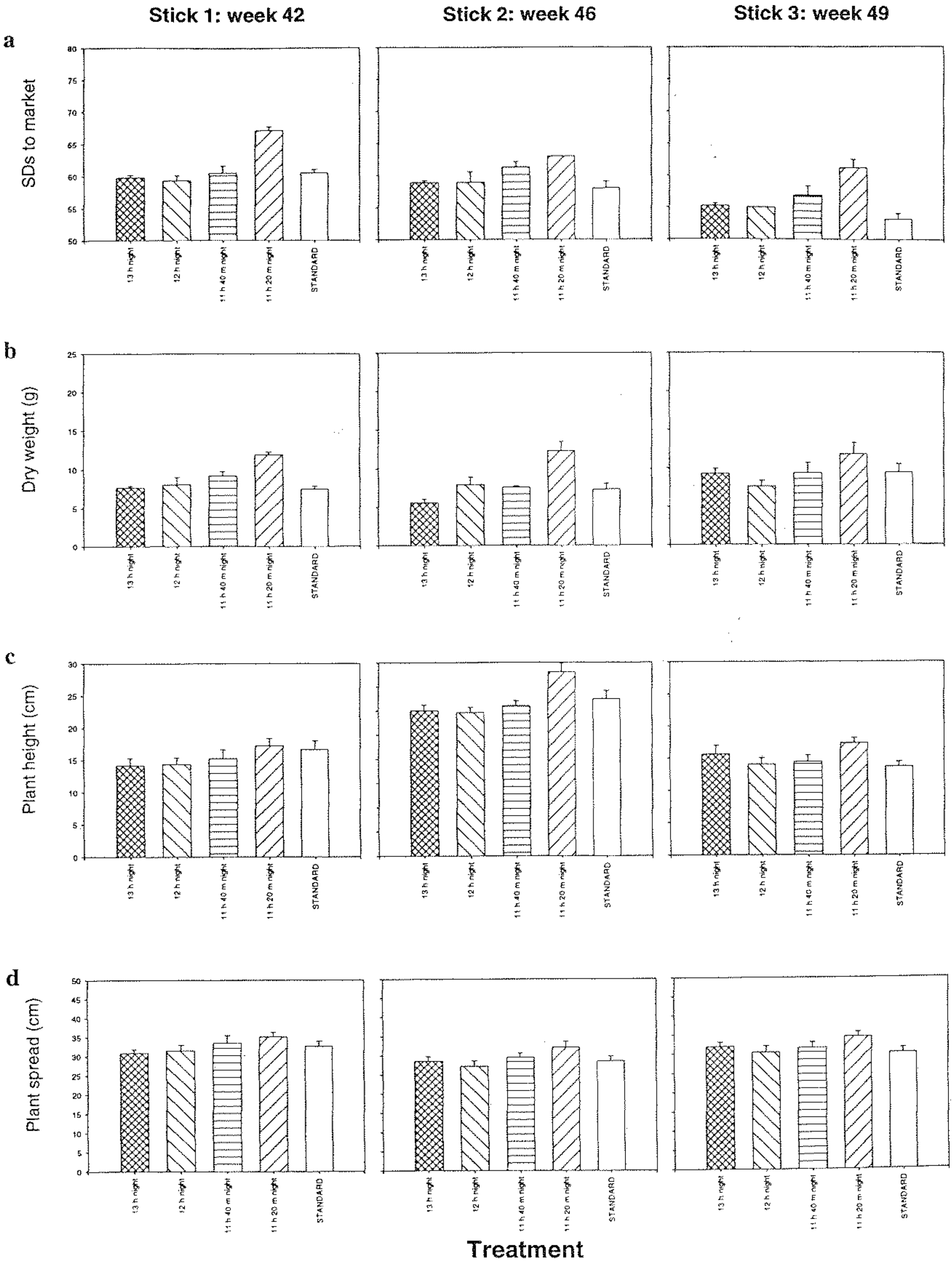
Appendix 5

Figure 9: Miramar : Effect of reduced nightlength during the winter period (± SD)



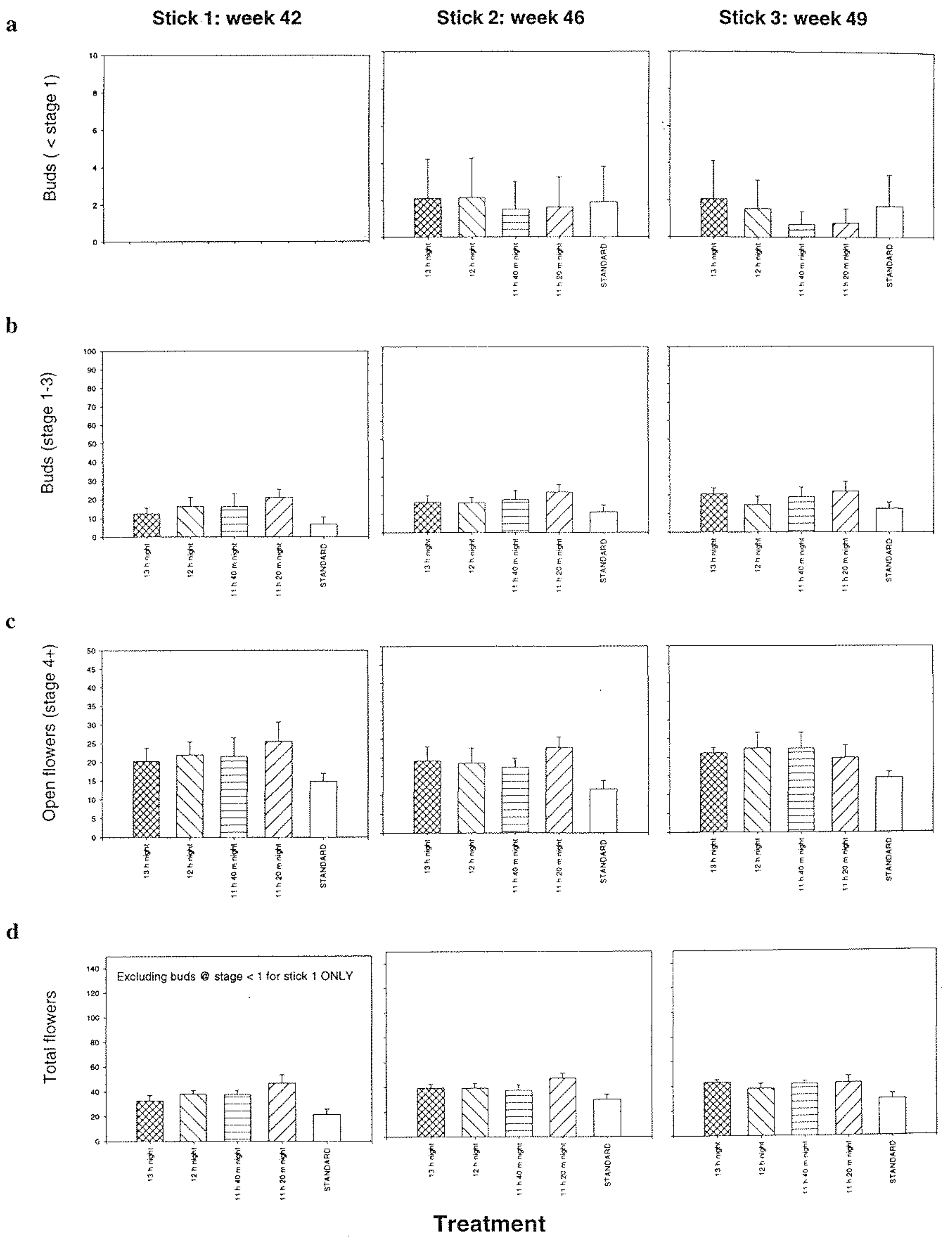
Appendix 5

Figure 10: Purple About Time : Effects of reduced night-length during the winter period (± SD)



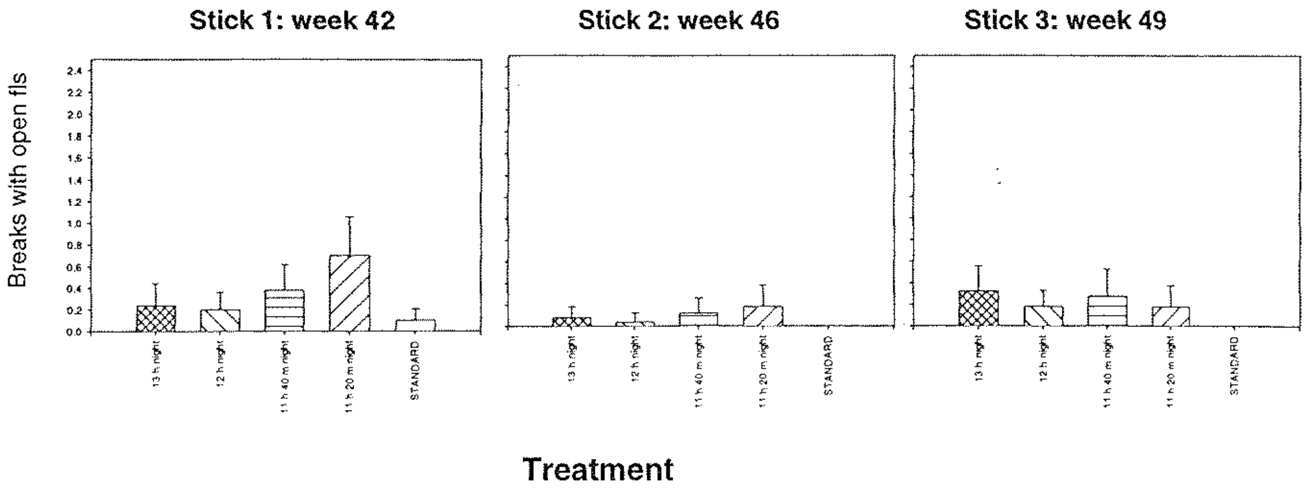
Appendix 5

Figure 11: Purple About Time : Effect of reduced nightlength during the winter period (± SD)



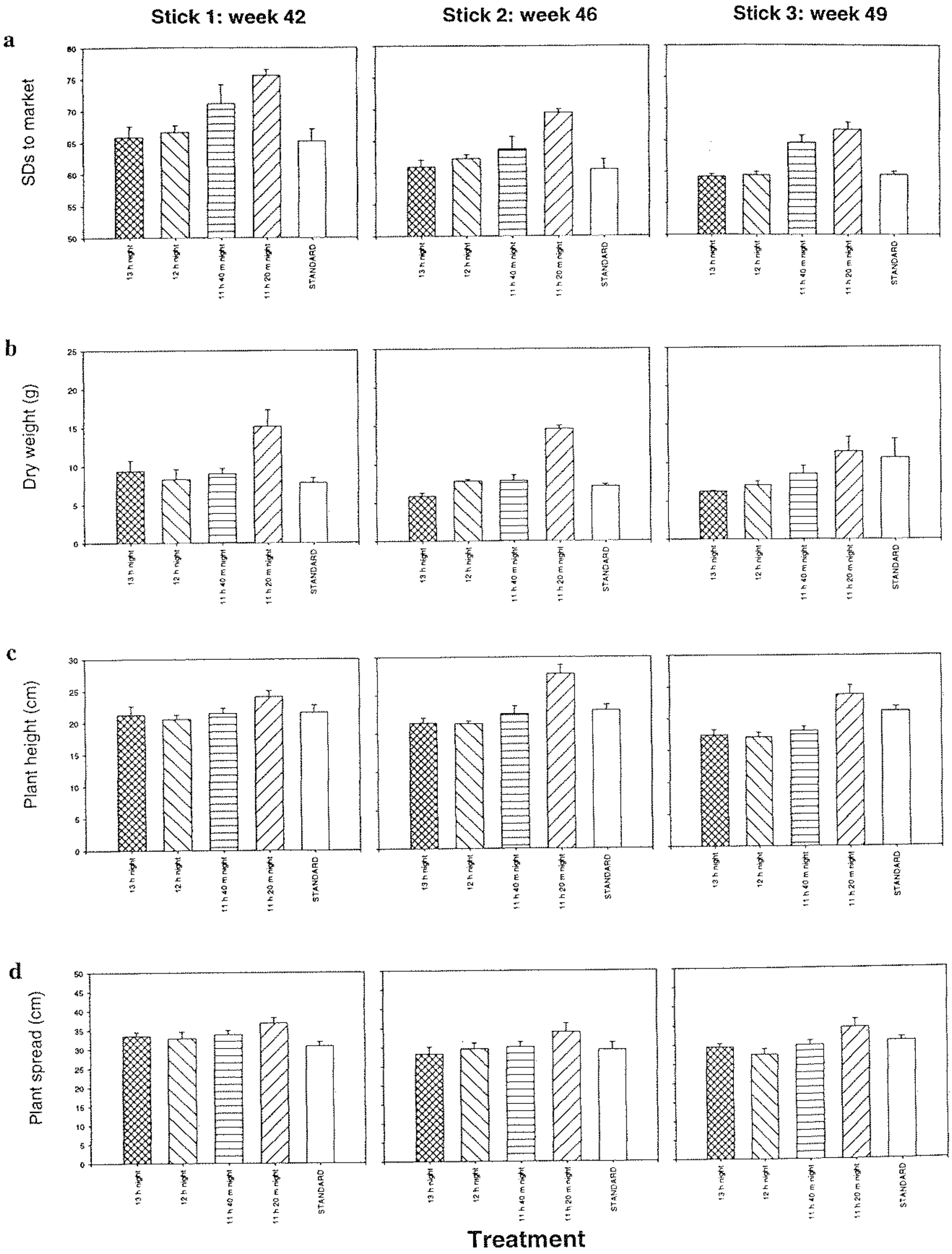
Appendix 5

Figure 12: Purple About Time : Effect of reduced nightlength during the winter period (± SD)



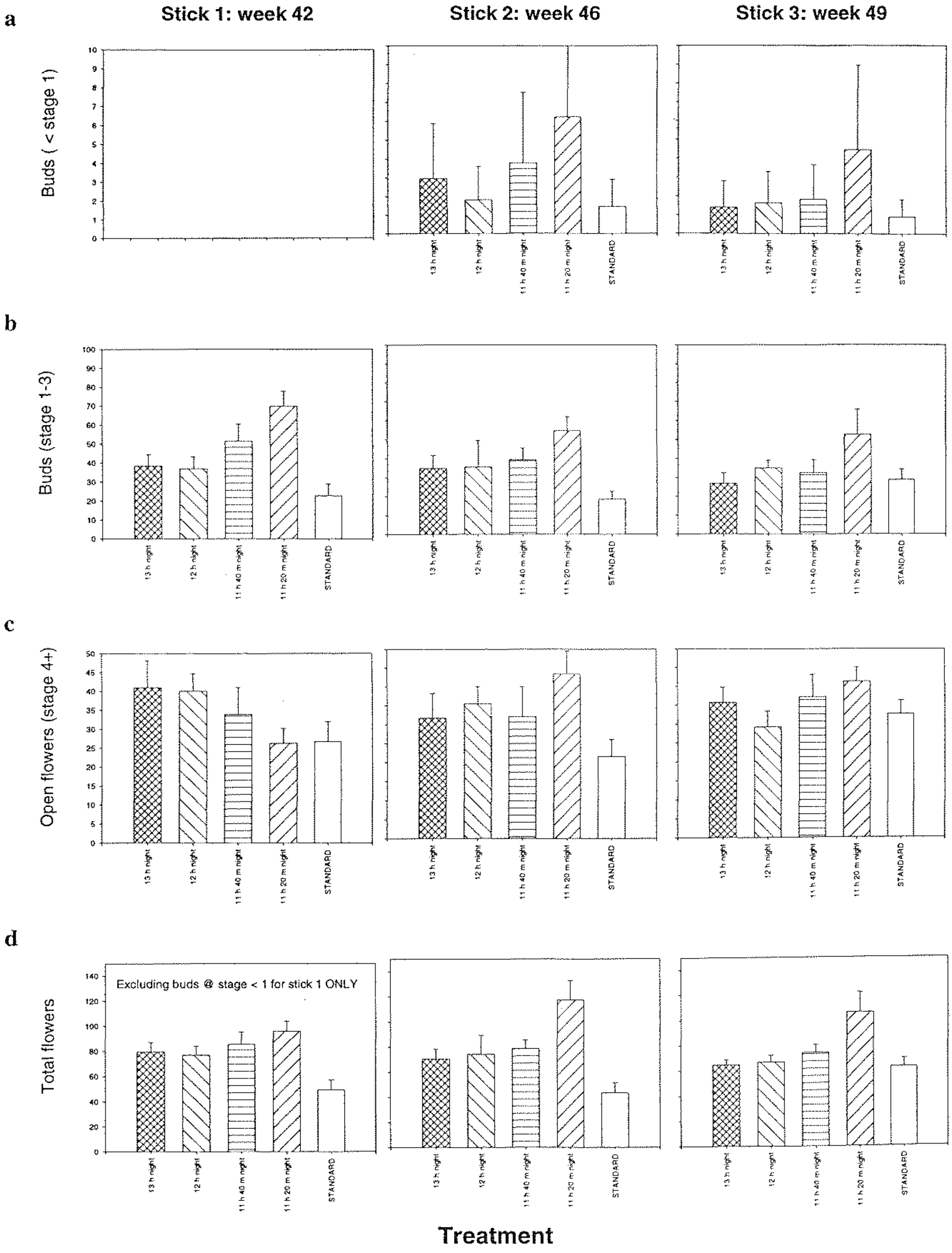
Appendix 5

Figure 13: Purple Lucky Time : Effects of reduced night-length during the winter period (± SD)



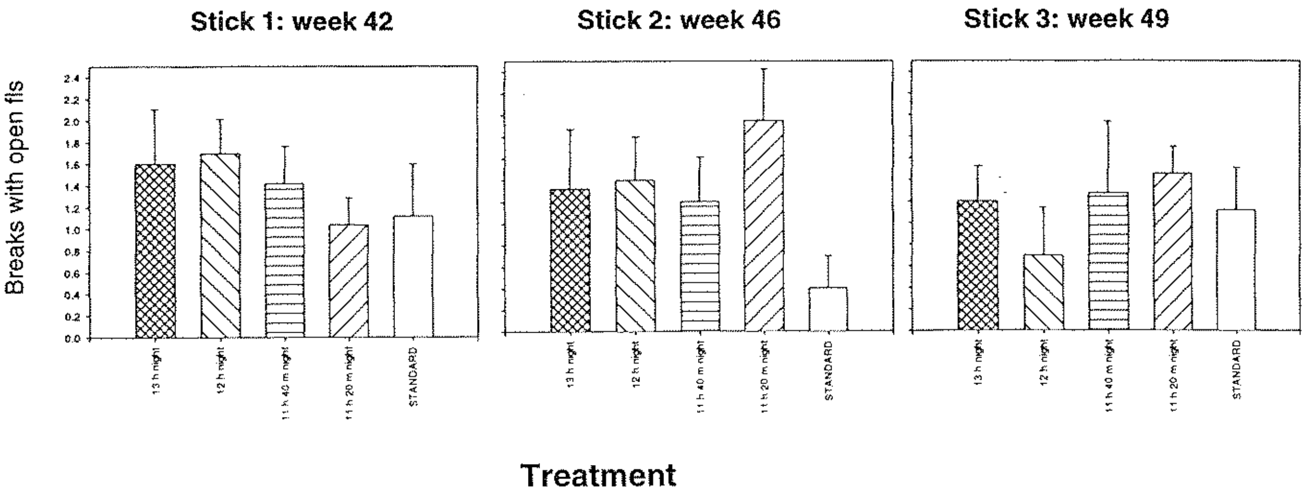
Appendix 5

Figure 14: Purple Lucky Time : Effect of reduced nightlength during the winter period (± S

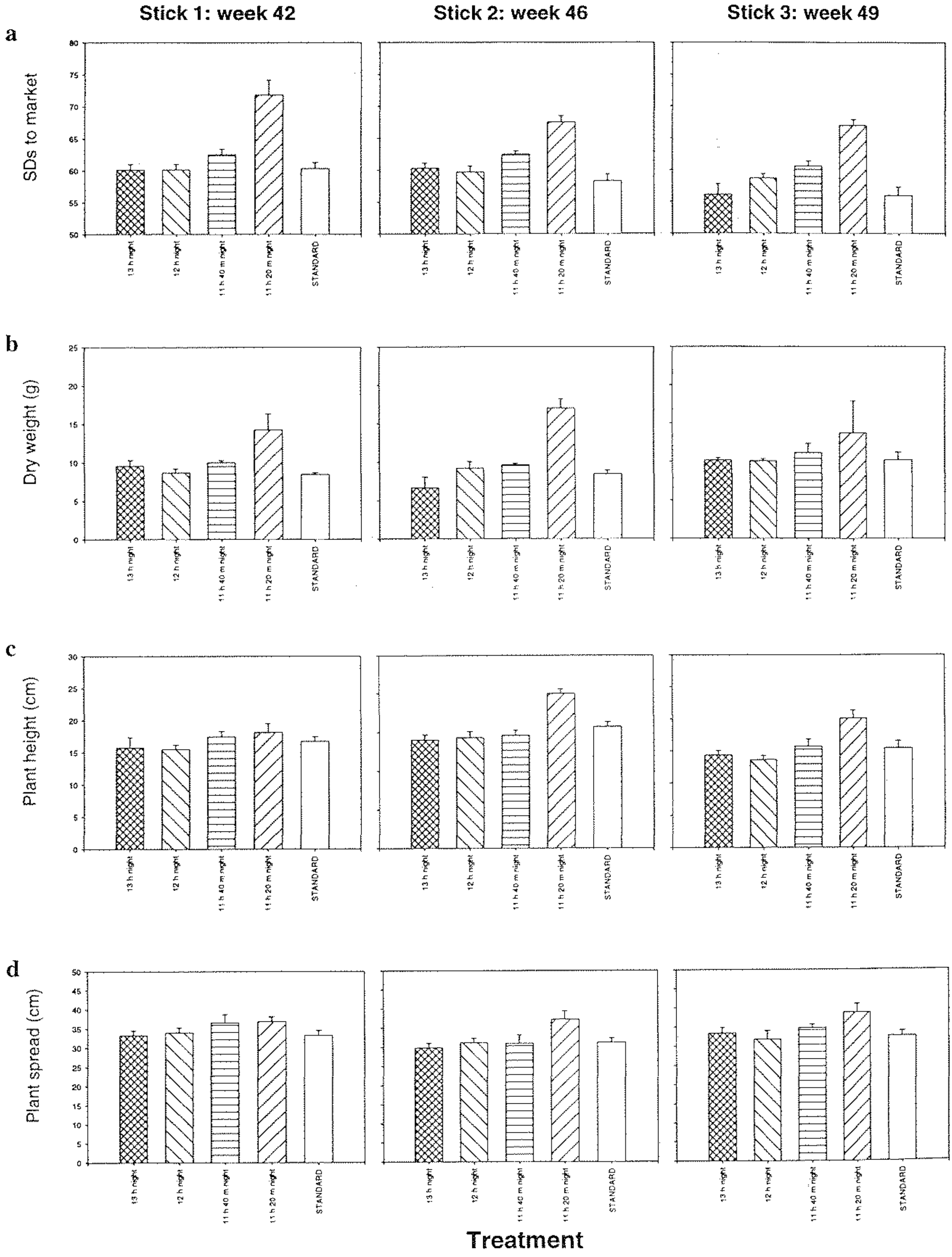


Appendix 5

Figure 15: Purple Lucky Time : Effect of reduced nightlength during the winter period (± SD)

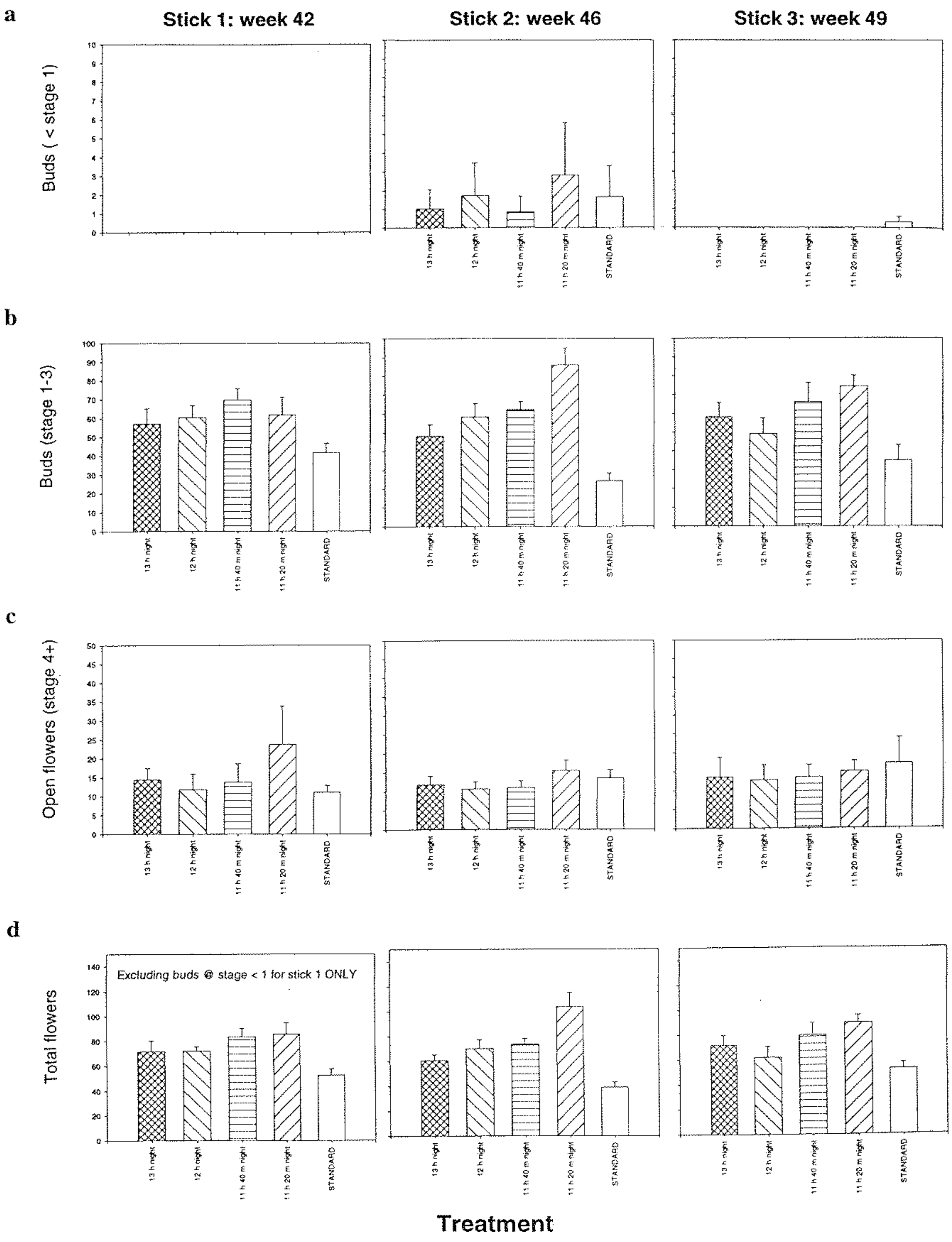


Appendix 5
Figure 16: Regal Davis : Effects of reduced night-length during the winter period (± SD)



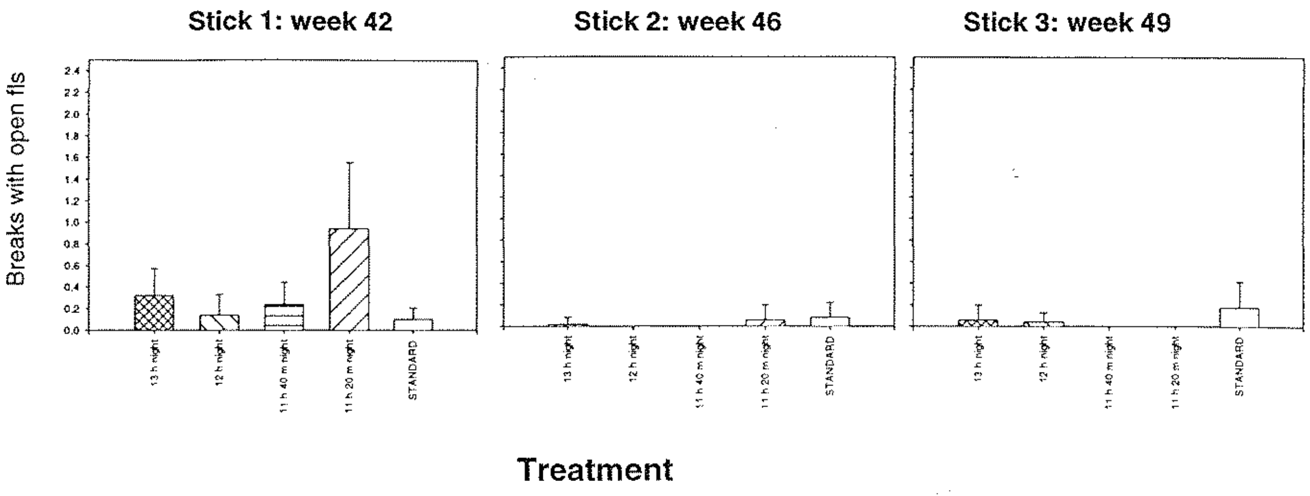
Appendix 5

Figure 17: Regal Davis : Effect of reduced nightlength during the winter period (± SD)



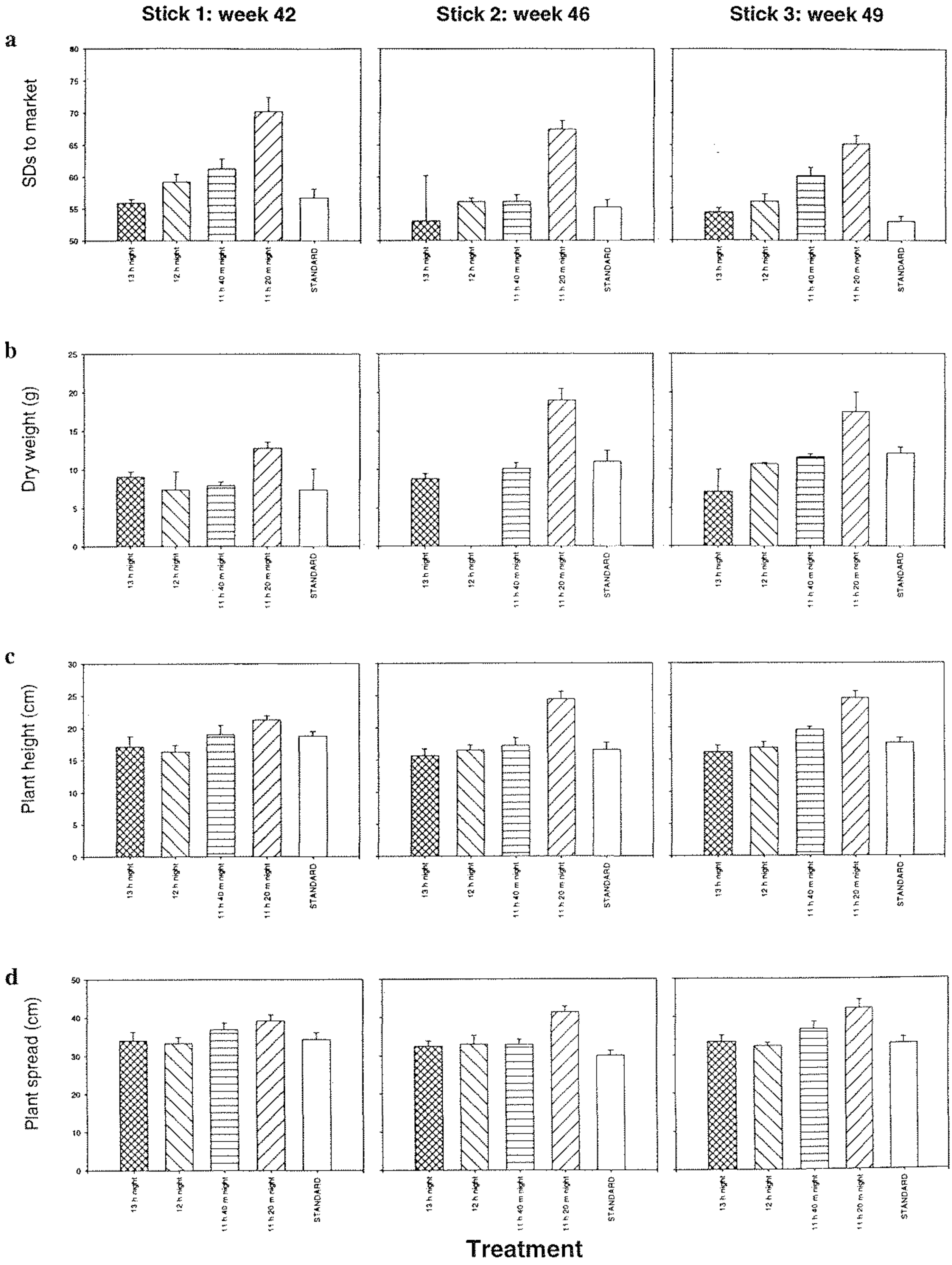
Appendix 5

Figure 18: Regal Davis : Effect of reduced nightlength during the winter period (± SD)



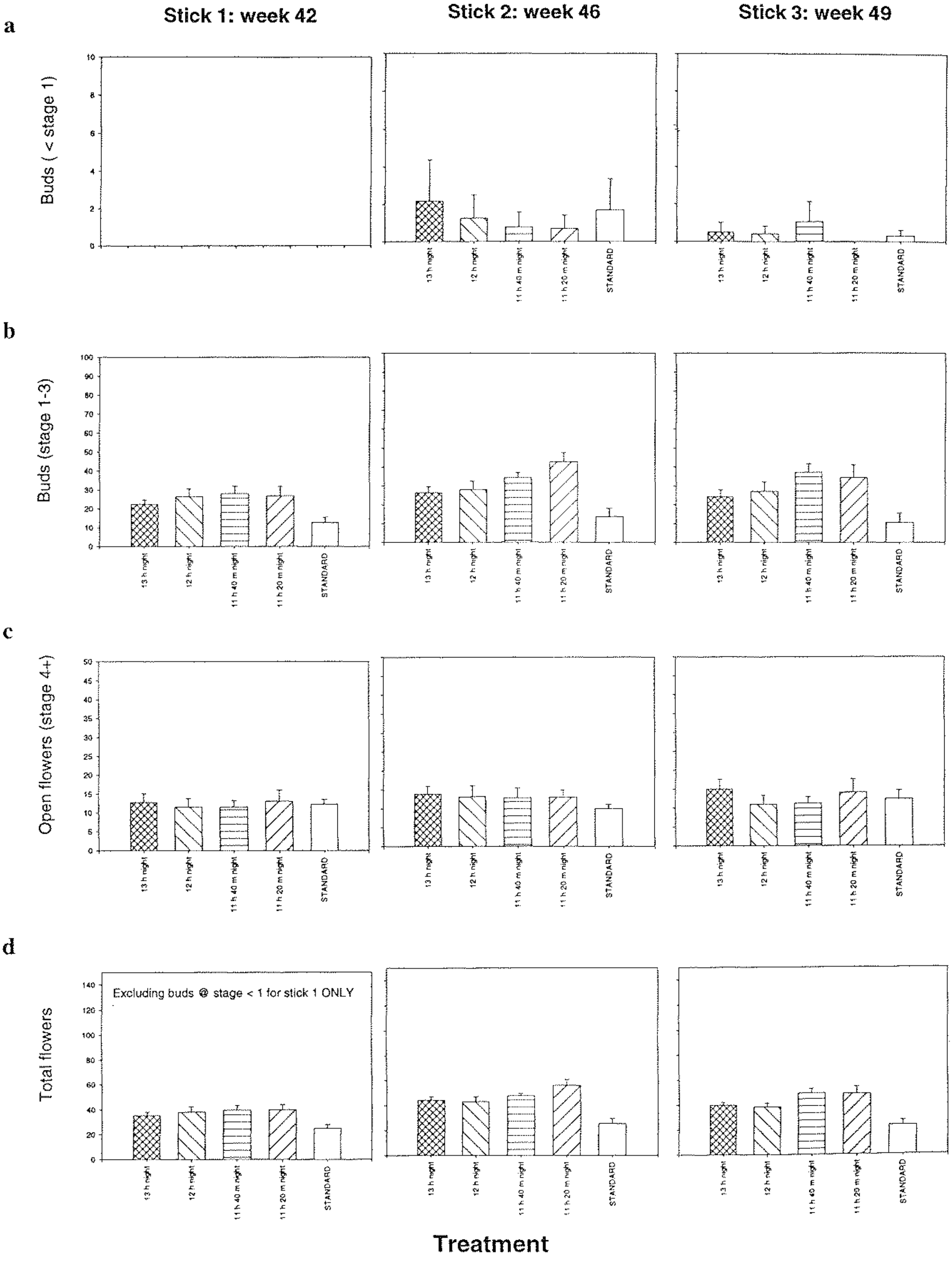
Appendix 5

Figure 19: Surf : Effects of reduced night-length during the winter period (± SD)



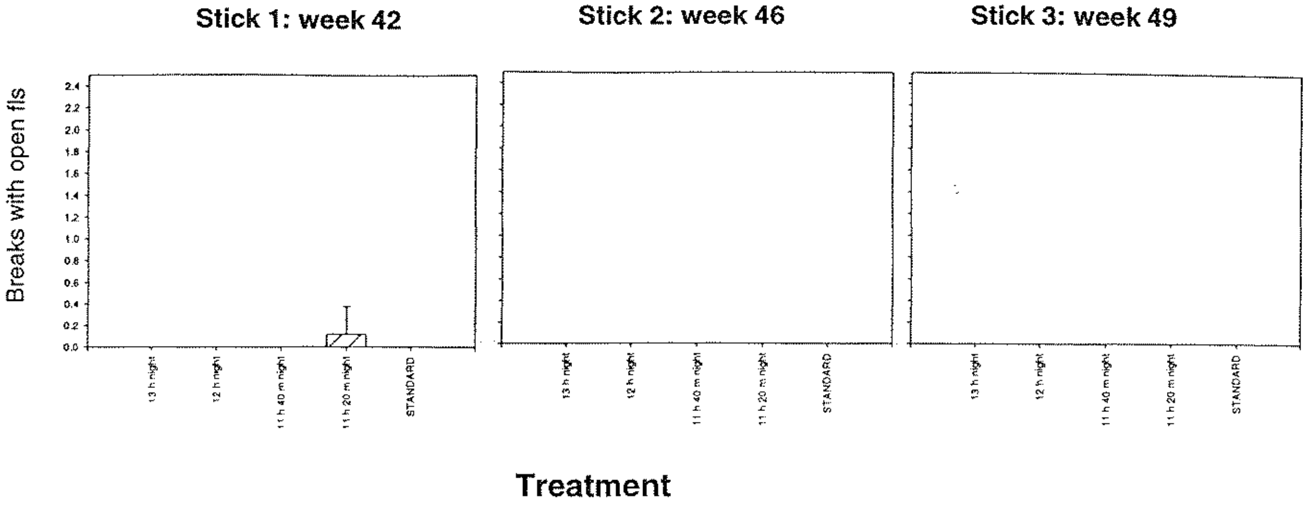
Appendix 5

Figure 20: Surf : Effect of reduced nightlength during the winter period (± SD)



Appendix 5

Figure 21: Surf : Effect of reduced nightlength during the winter period (± SD)

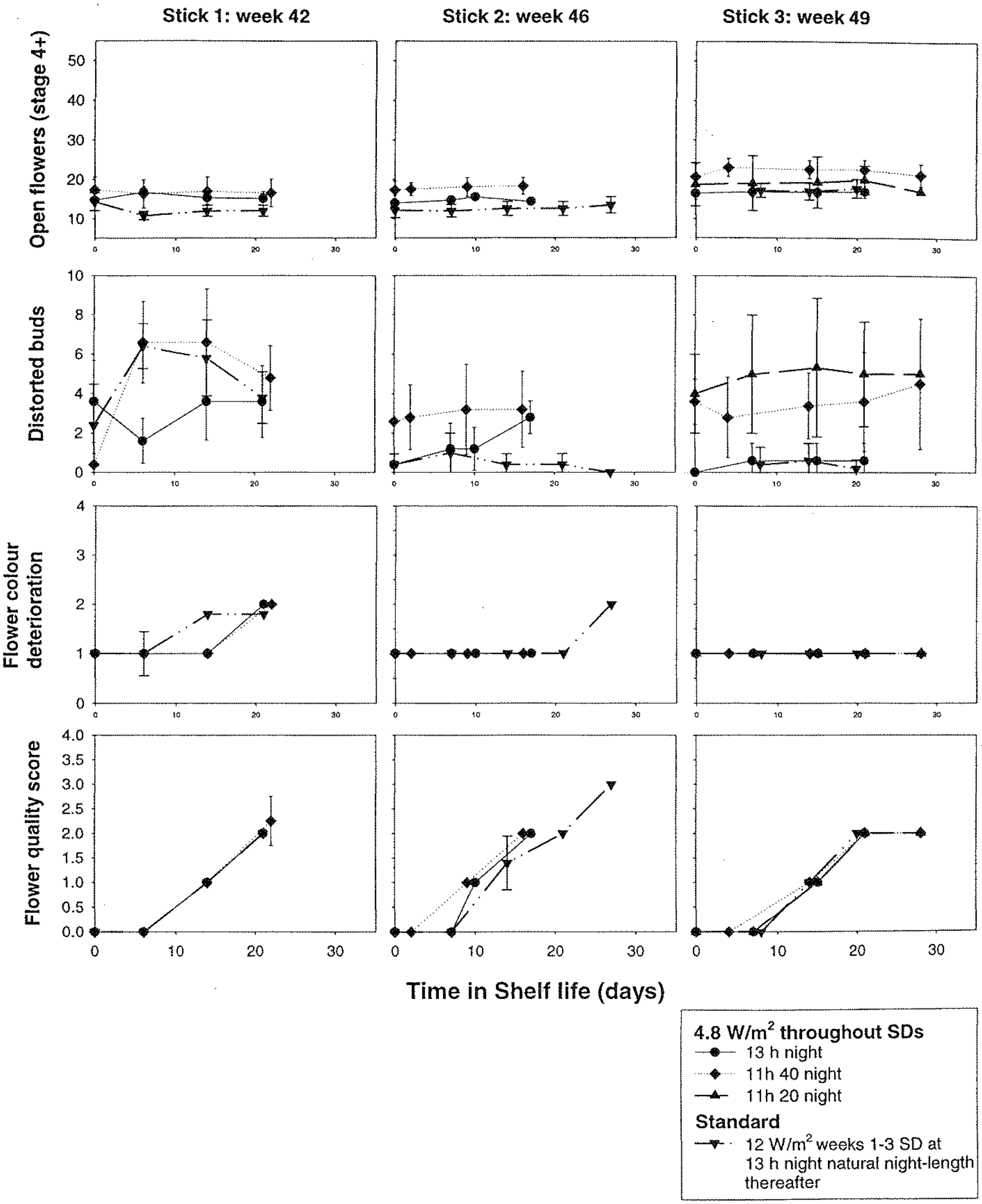


Appendix 6

Effects of reduced night-length On post-harvest performance

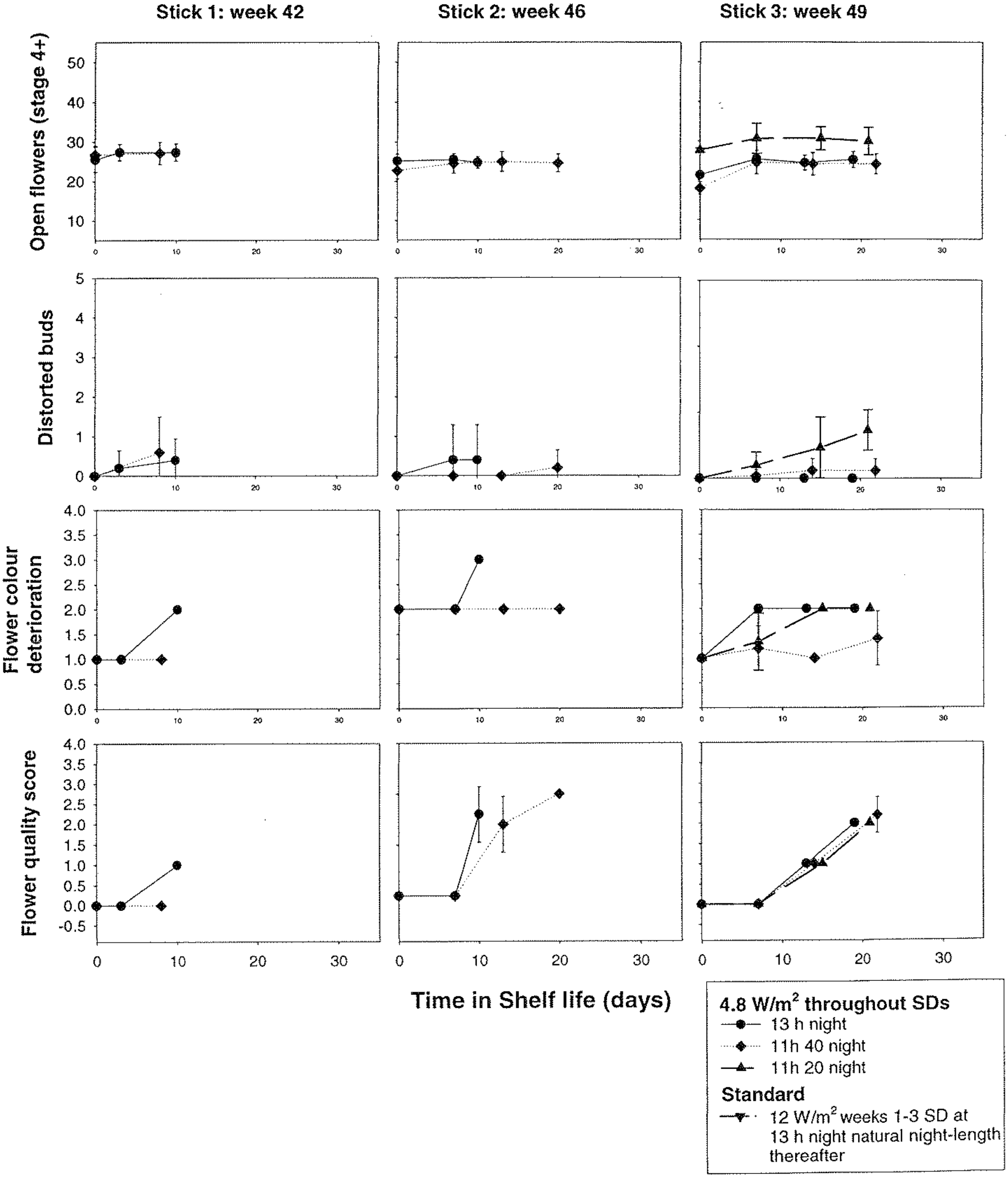
Appendix 6

Figure 1: Effects of reduced nightlength treatment on shelf-life performance in Charm (±SD)



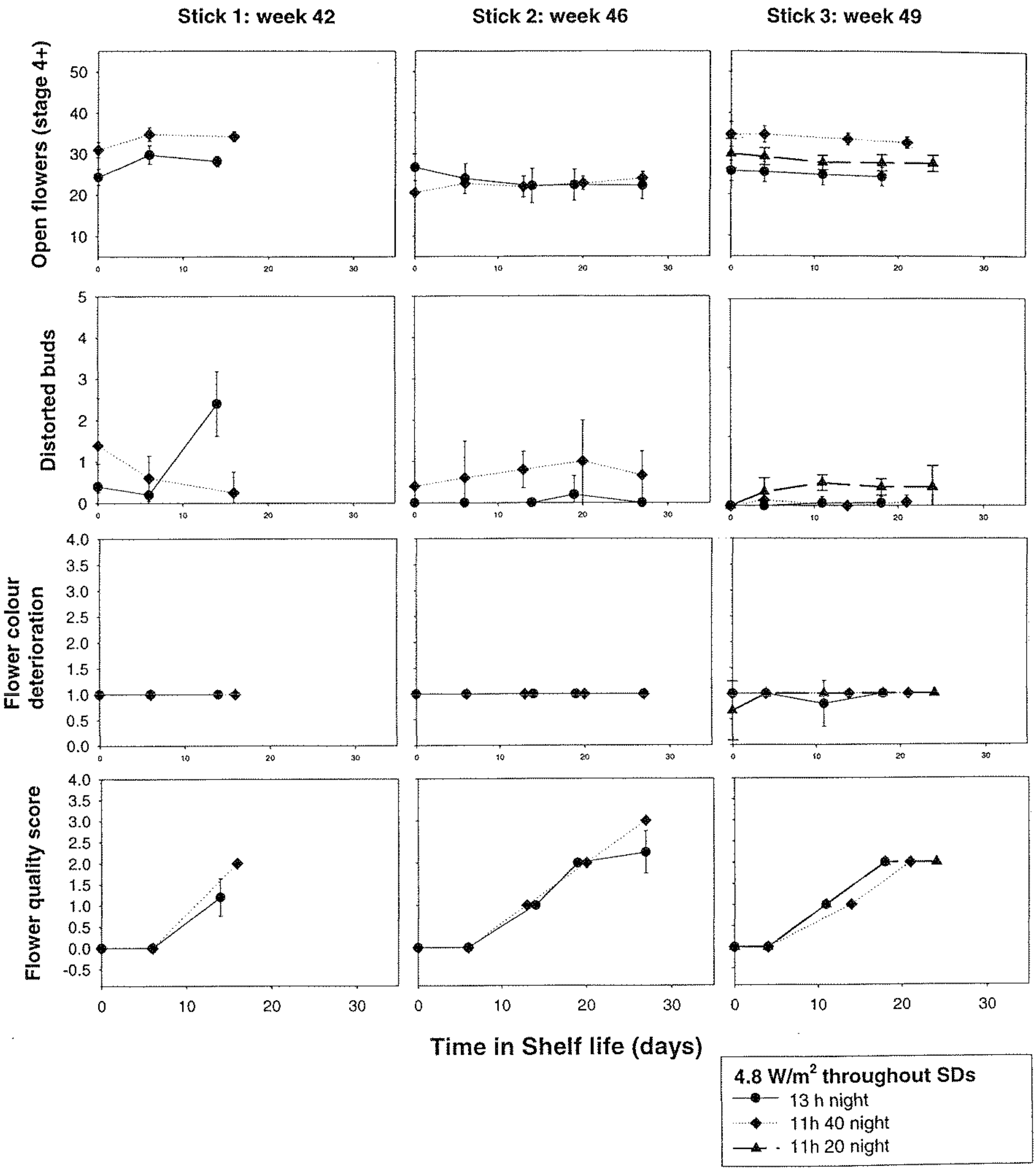
Appendix 6

Figure 2: Effects of reduced nightlength treatment on shelf-life performance in Glow Time (±SD)



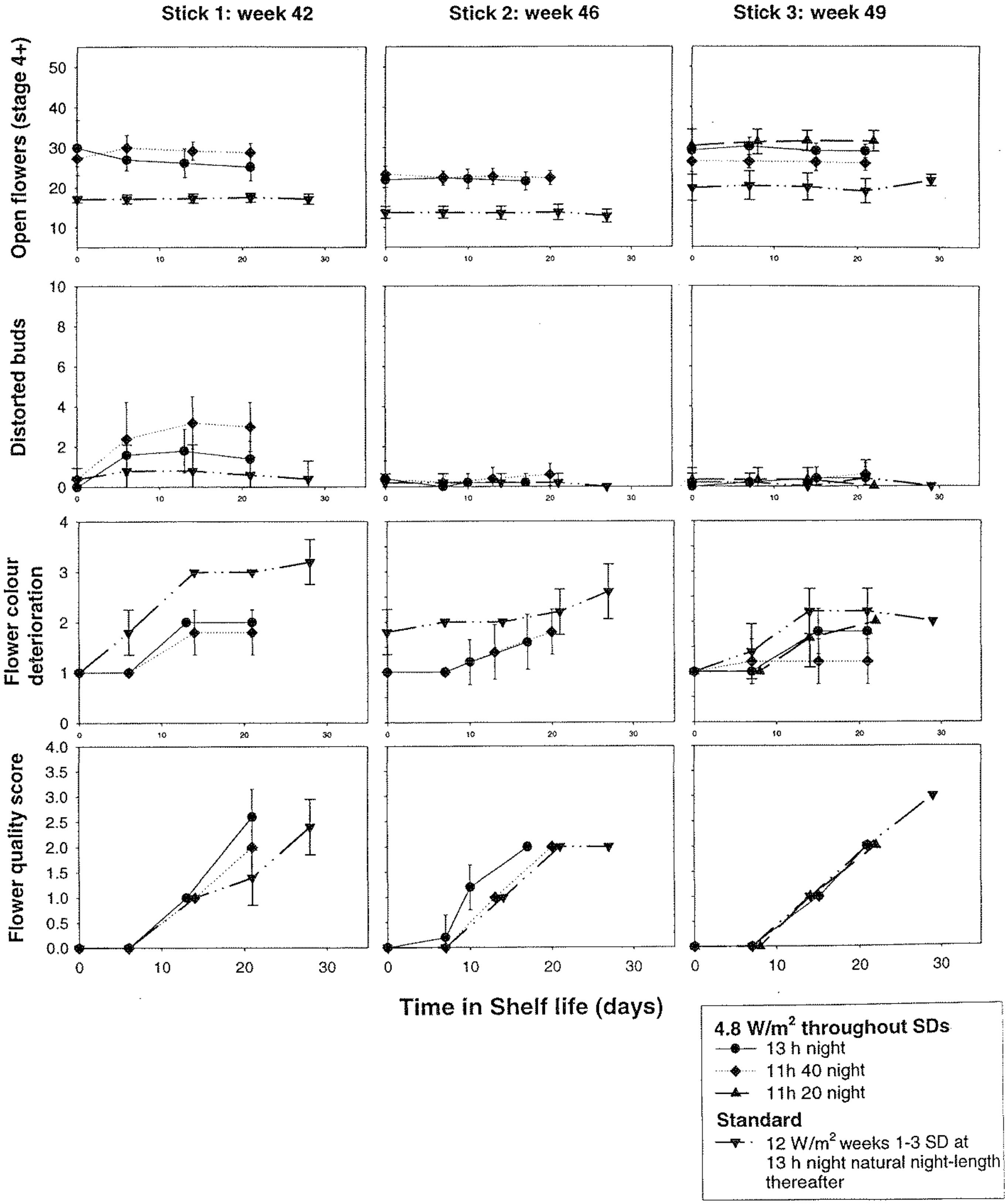
Appendix 6

Figure 3: Effects of reduced nightlength treatment on shelf-life performance in Miramar (±SD)



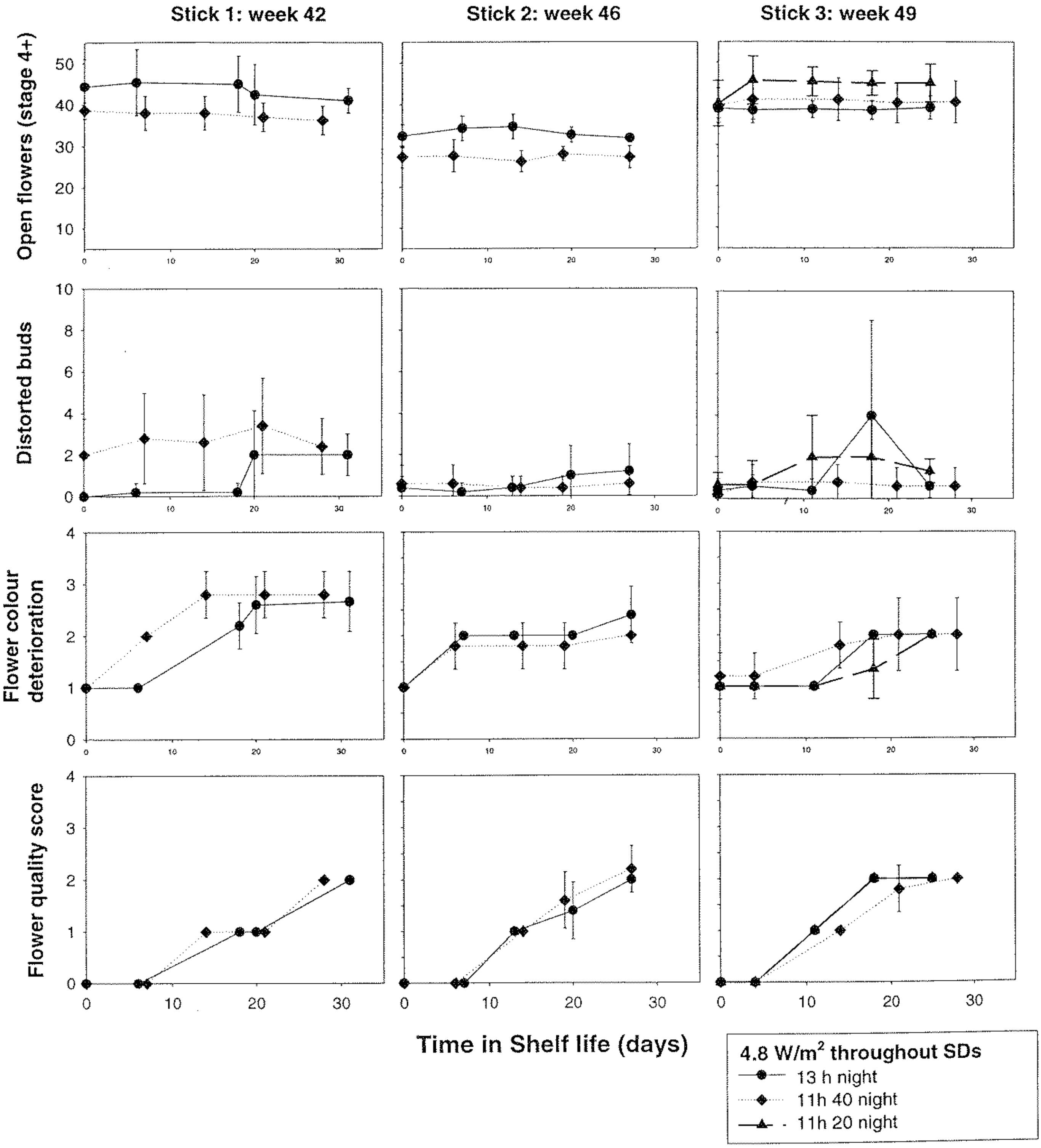
Appendix 6

Figure 4: Effects of reduced nightlength treatment on shelf-life performance in Purple About Time (±SD)



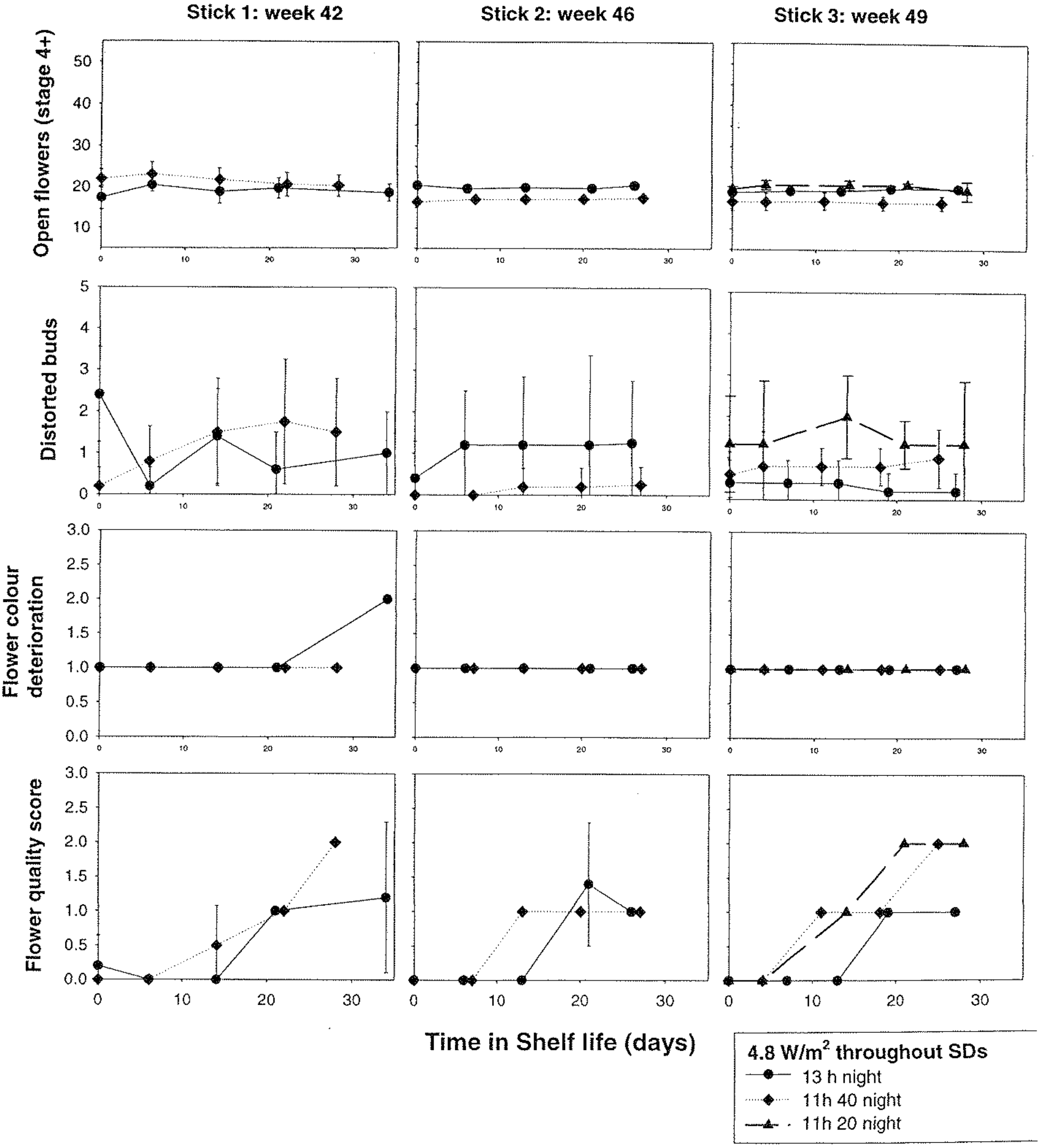
Appendix 6

Figure 5: Effects of reduced nightlength treatment on shelf-life performance in Purple Lucky Time (±SD)



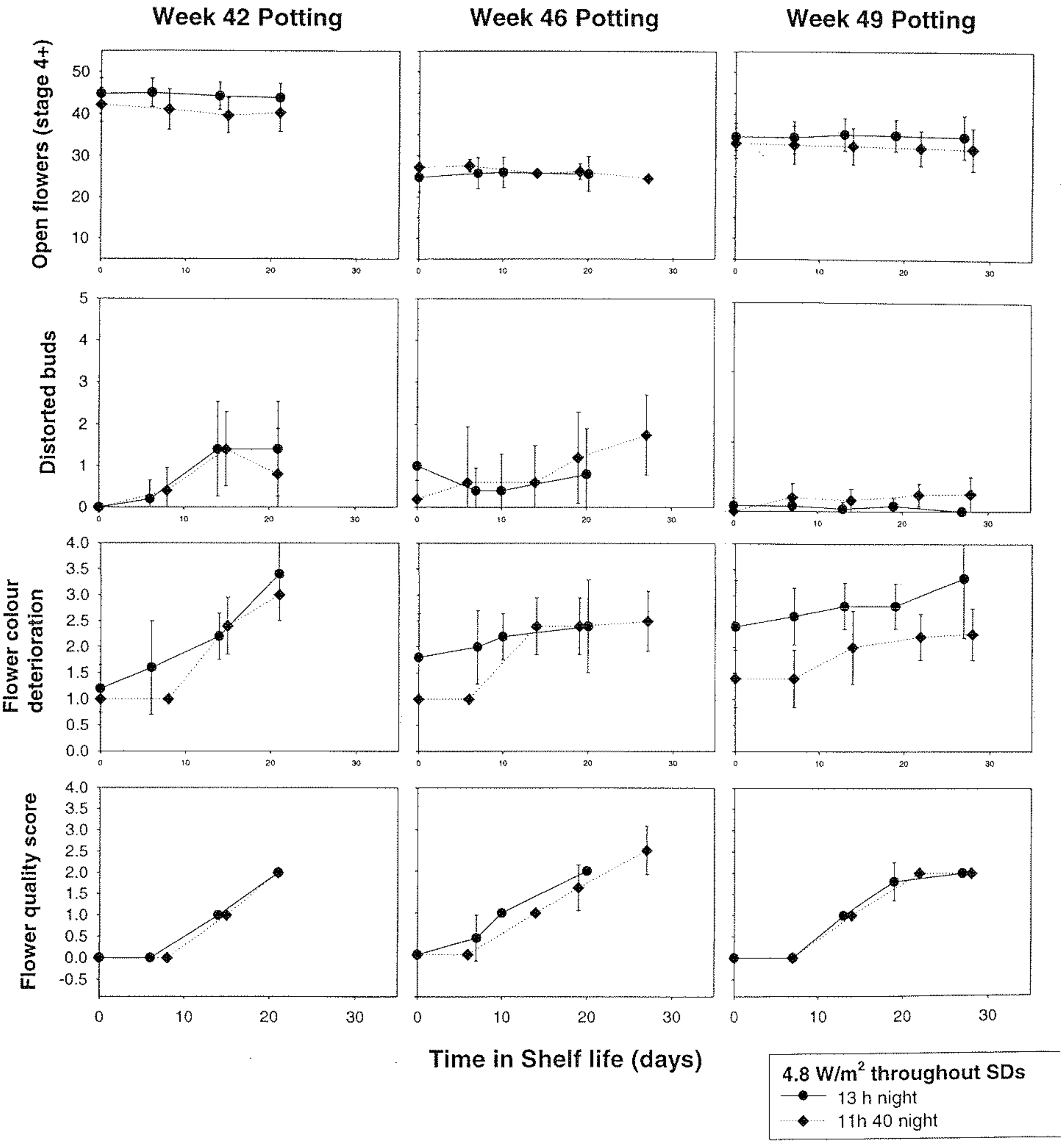
Appendix 6

Figure 6 : Effect of nightlength treatment on shelf-life in Surf (±SD)



Appendix 6

Figure 7: Effects of reduced nightlength treatment on shelf-life performance in Regal Davis (±SD)

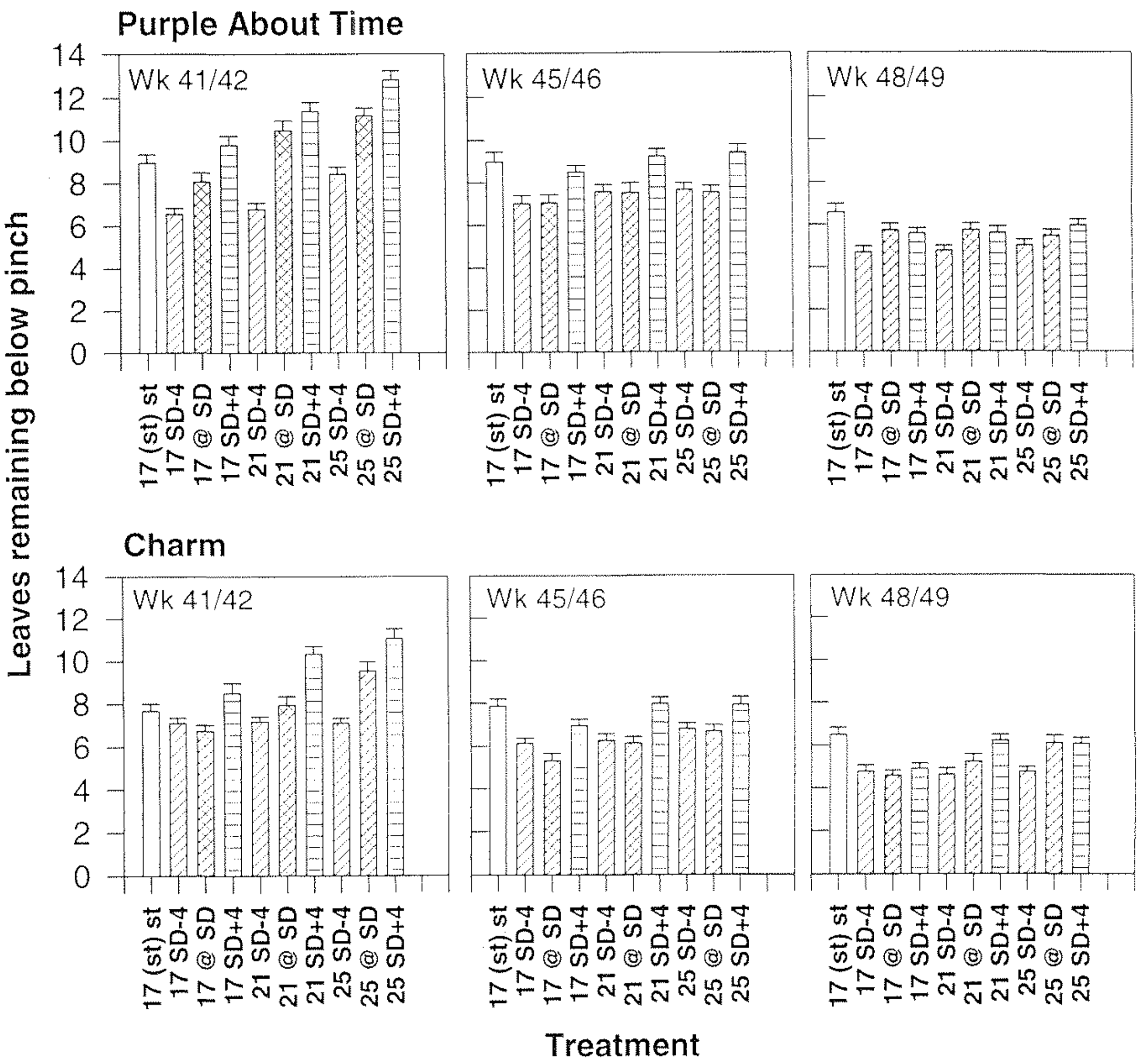


Appendix 7

Effects of manipulating the number of long days and timing of the pinch

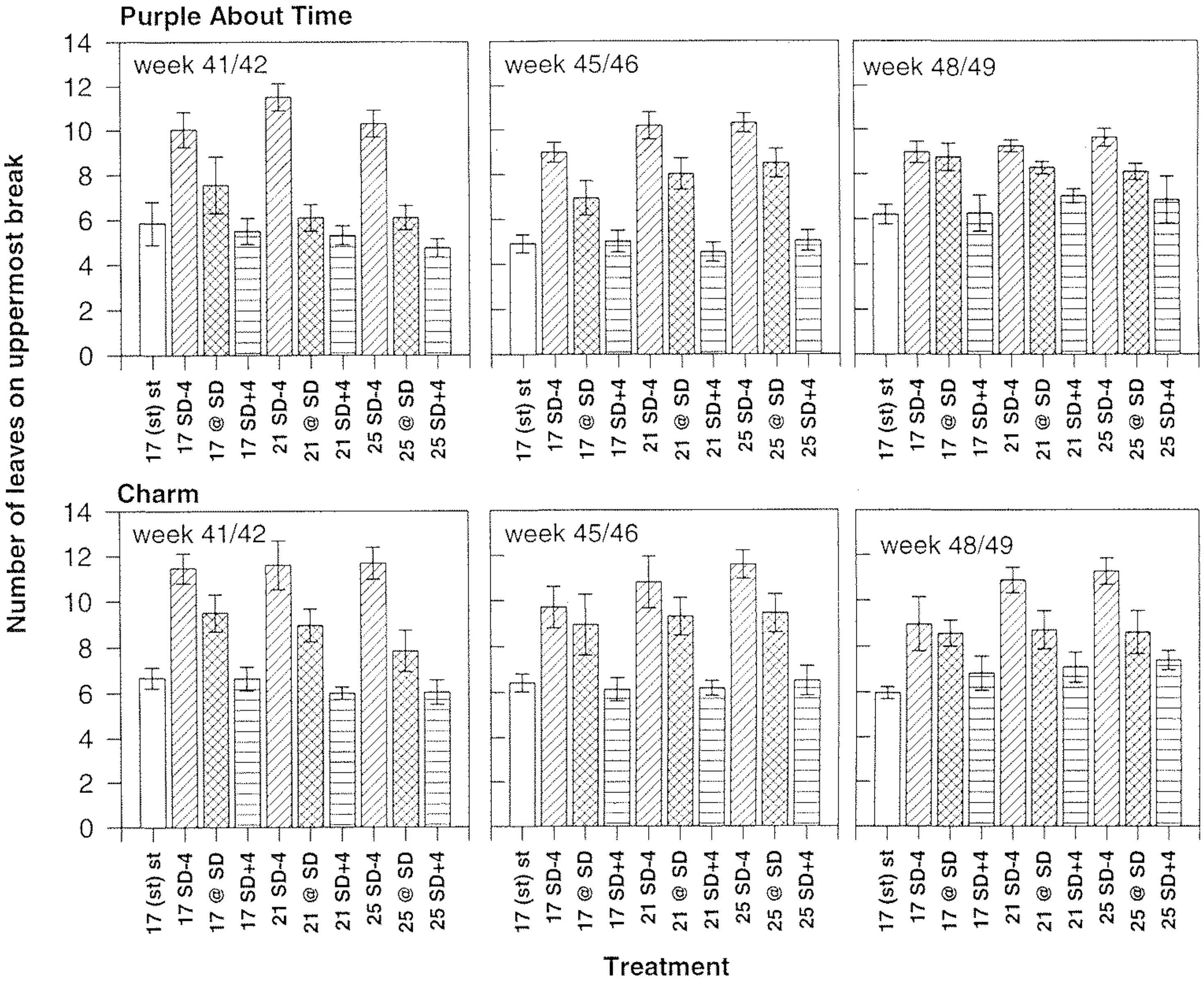
Appendix 7

Figure 1: Effect of number of long days and timing of the pinch on leaf number remaining below the pinch in Purple About Time and Charm.



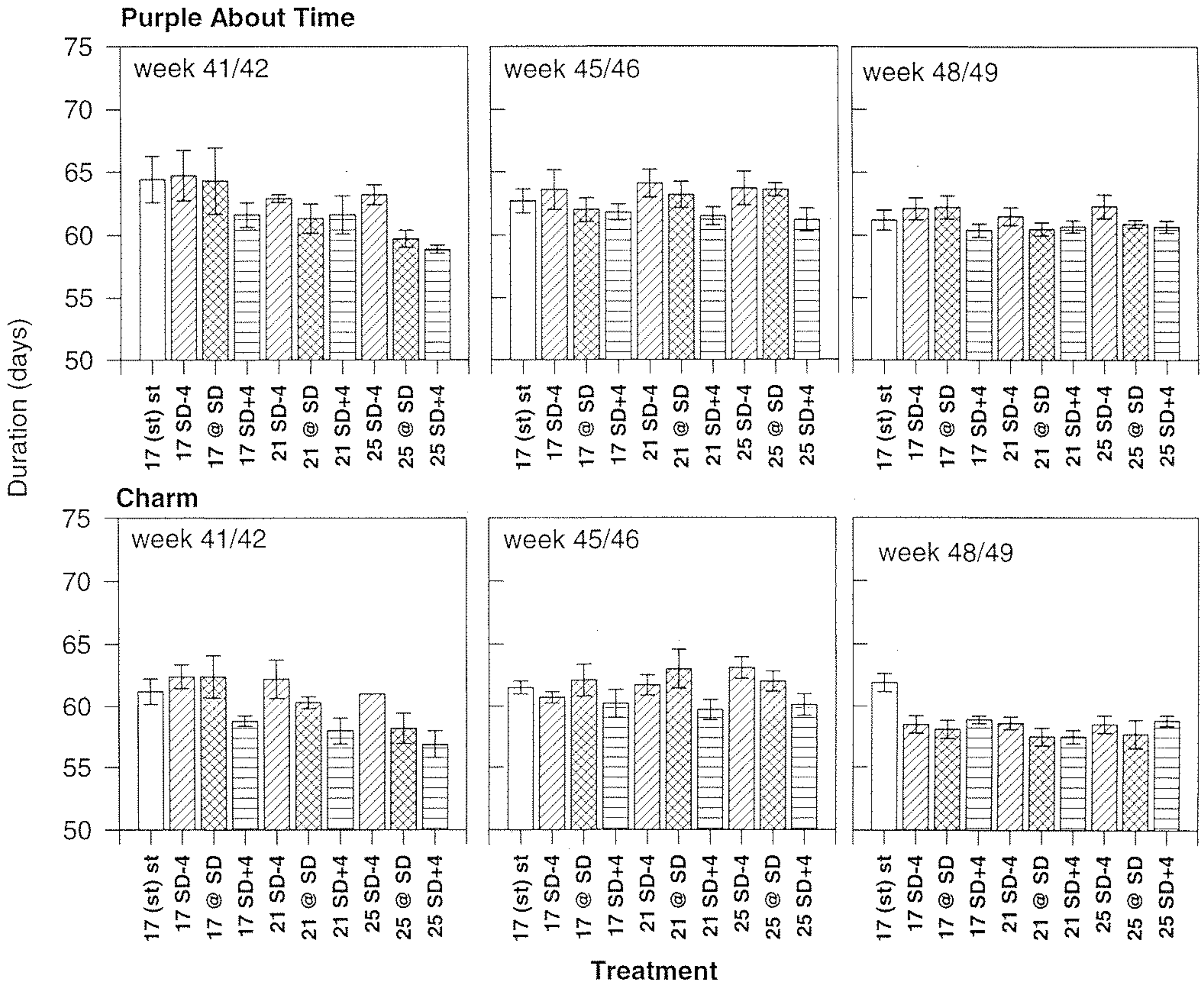
Appendix 7

Figure 2: Effect of number of long days and timing of the pinch on number of leaves on the uppermost break at marketing (± standard deviation)



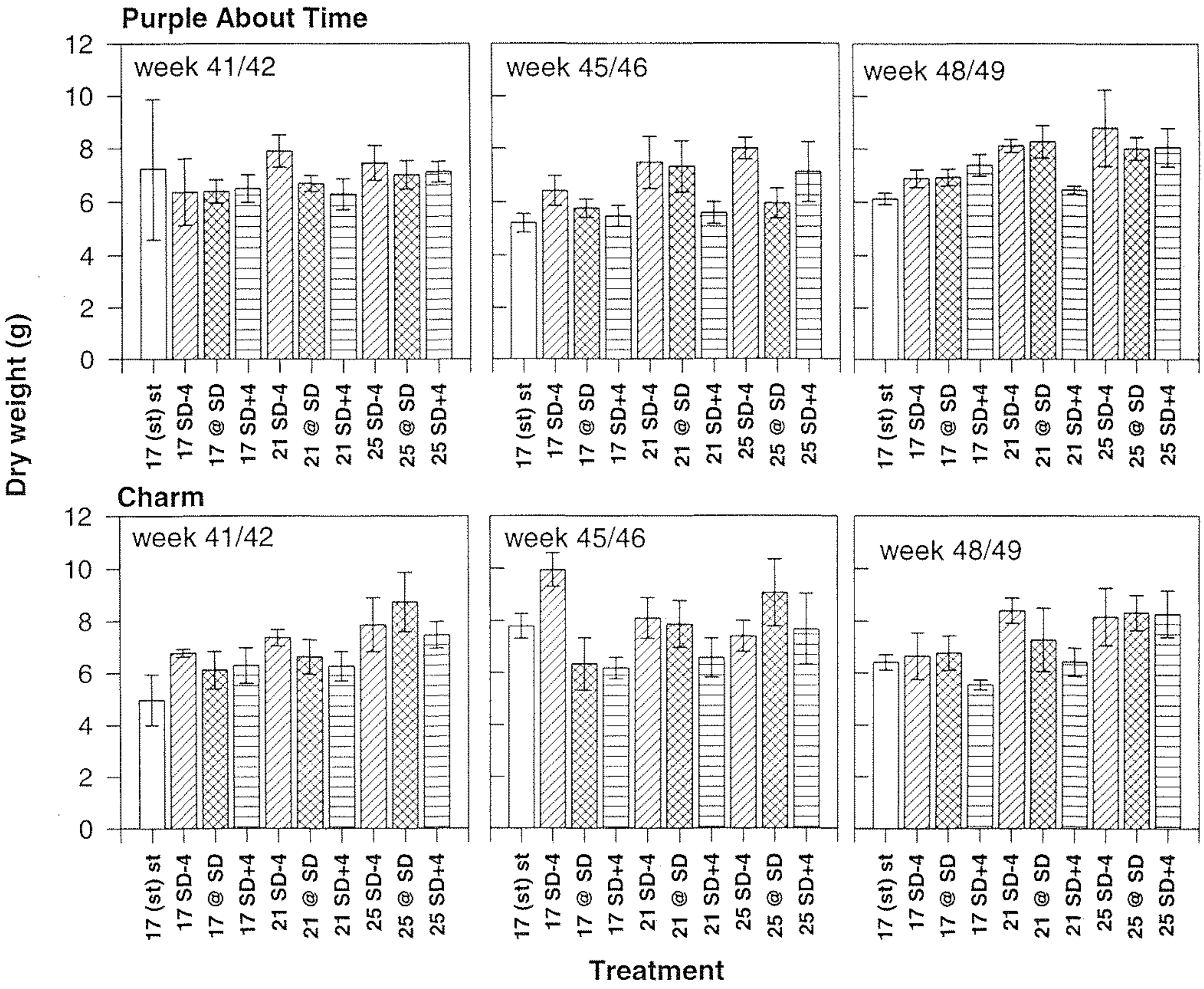
Appendix 7

Figure 3: Effect of number of long days and timing of the pinch on SDs to marketing (± standard deviation)



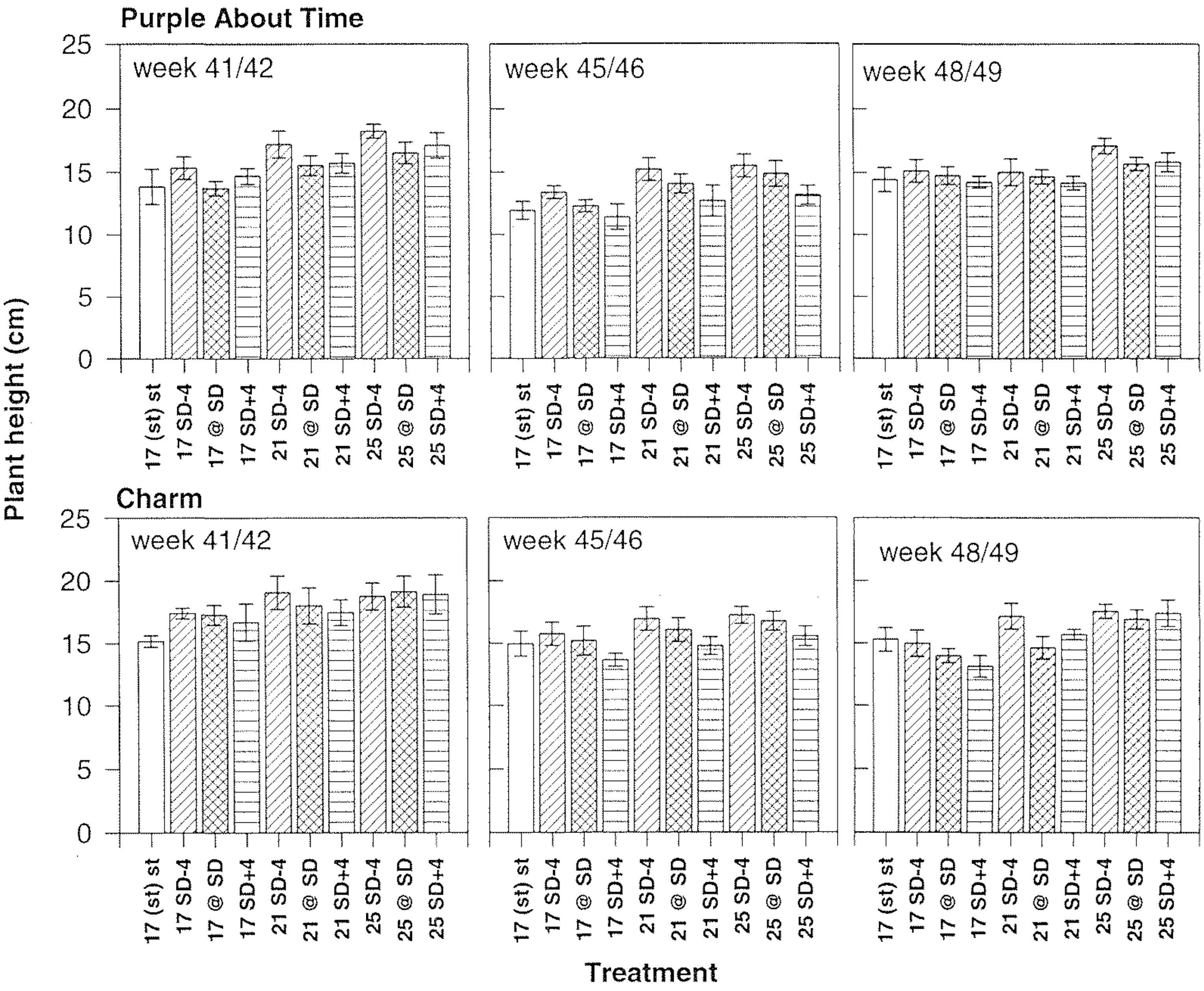
Appendix 7

Figure 4: Effect of number of long days and timing of the pinch on plant dry weight at marketing (± standard deviation)



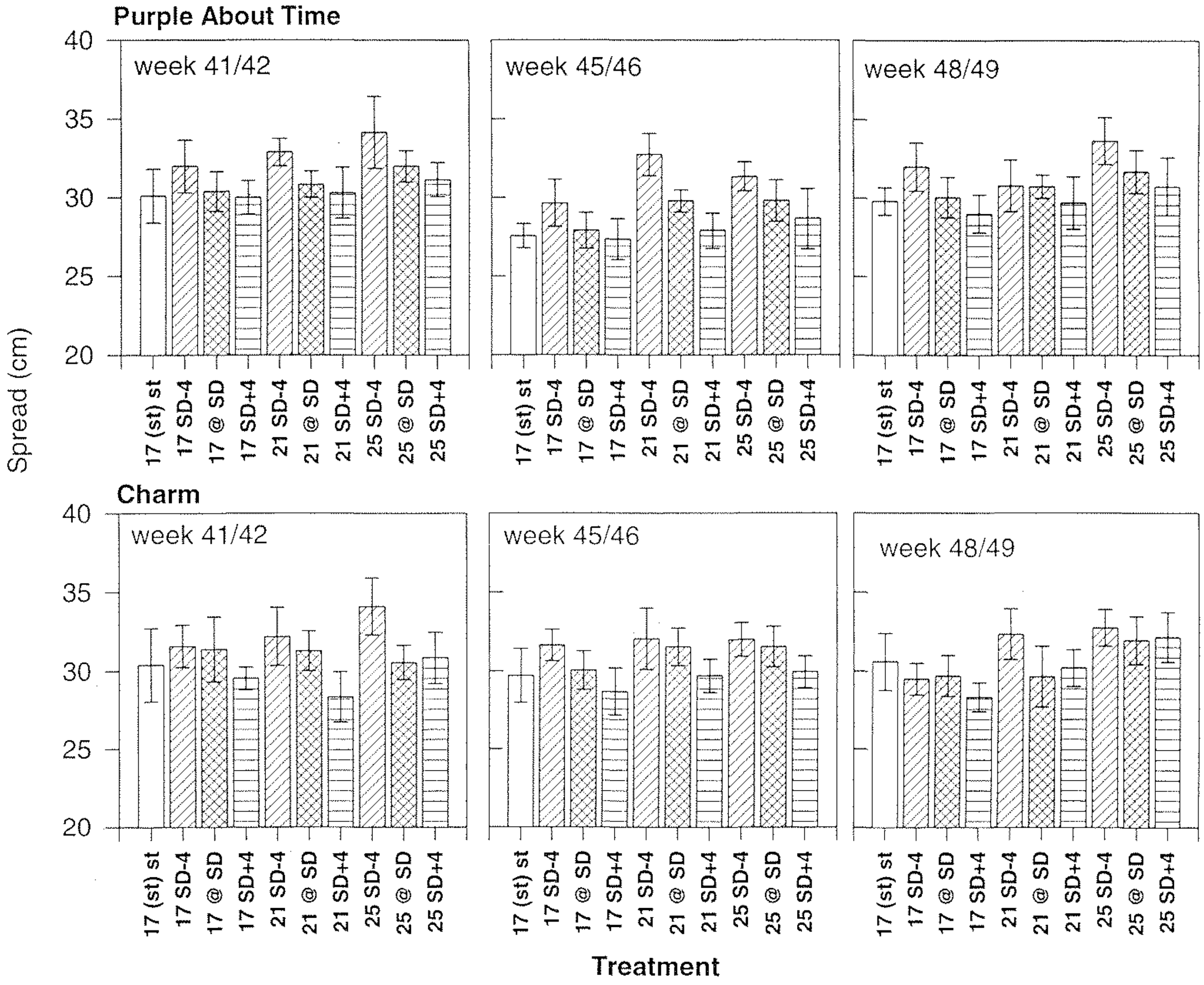
Appendix 7

Figure 5: Effect of number of long days and timing of the pinch on plant height at marketing (± standard deviation)



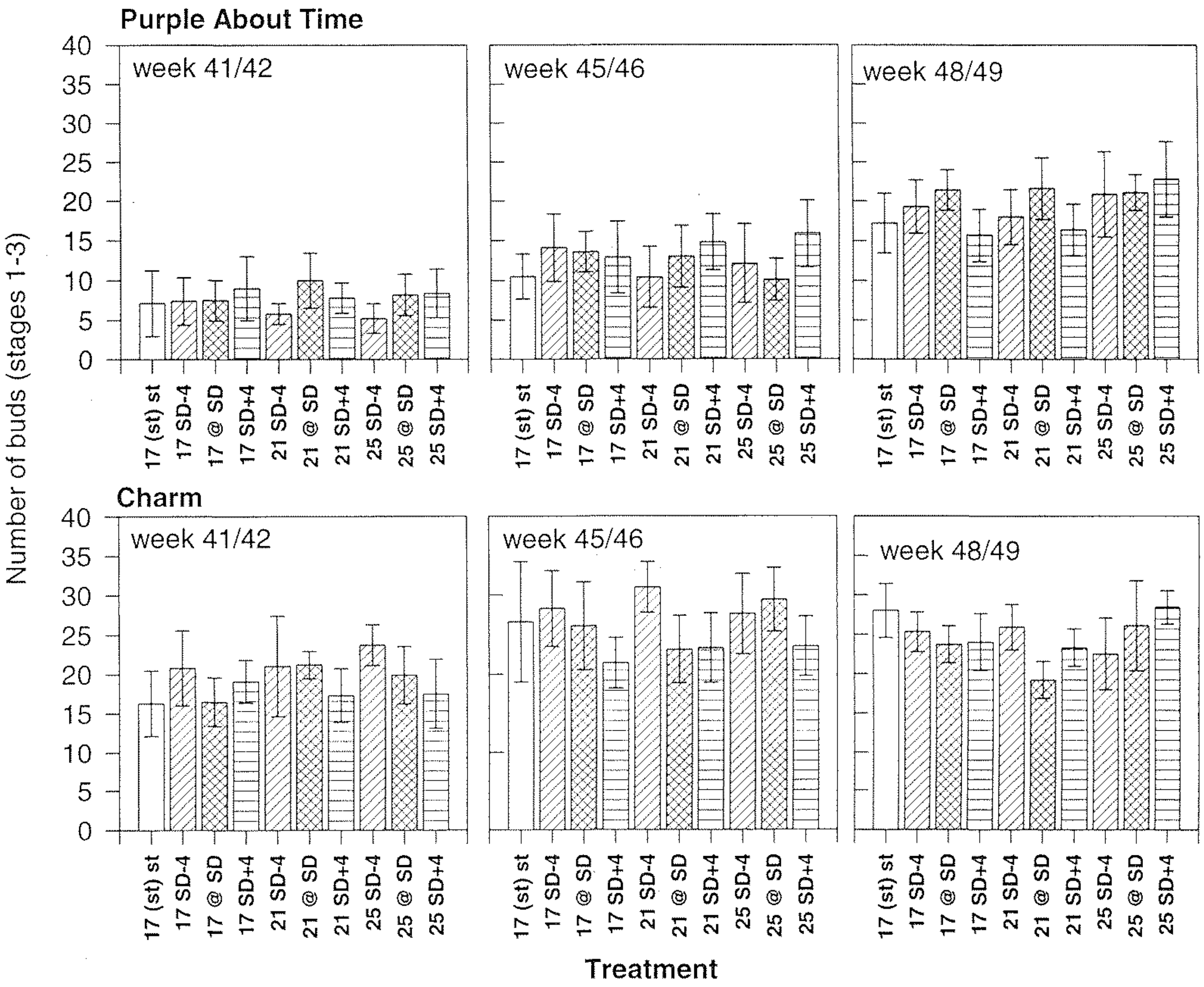
Appendix 7

Figure 6: Effect of number of long days and timing of the pinch on plant spread at marketing (± standard deviation)



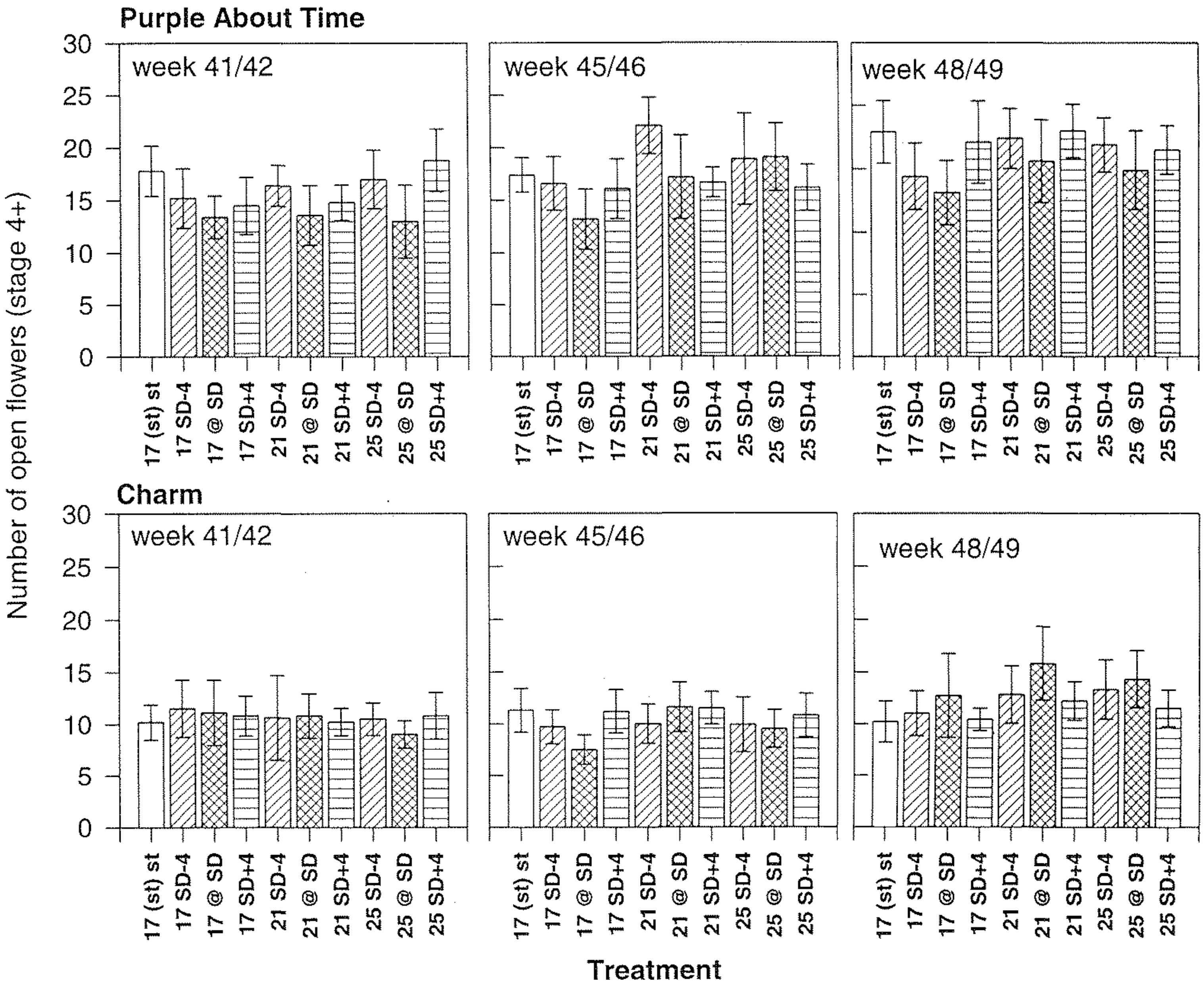
Appendix 7

Figure 7: Effect of number of long days and timing of the pinch on number of buds at stages 1 - 3 at marketing (± standard deviation)



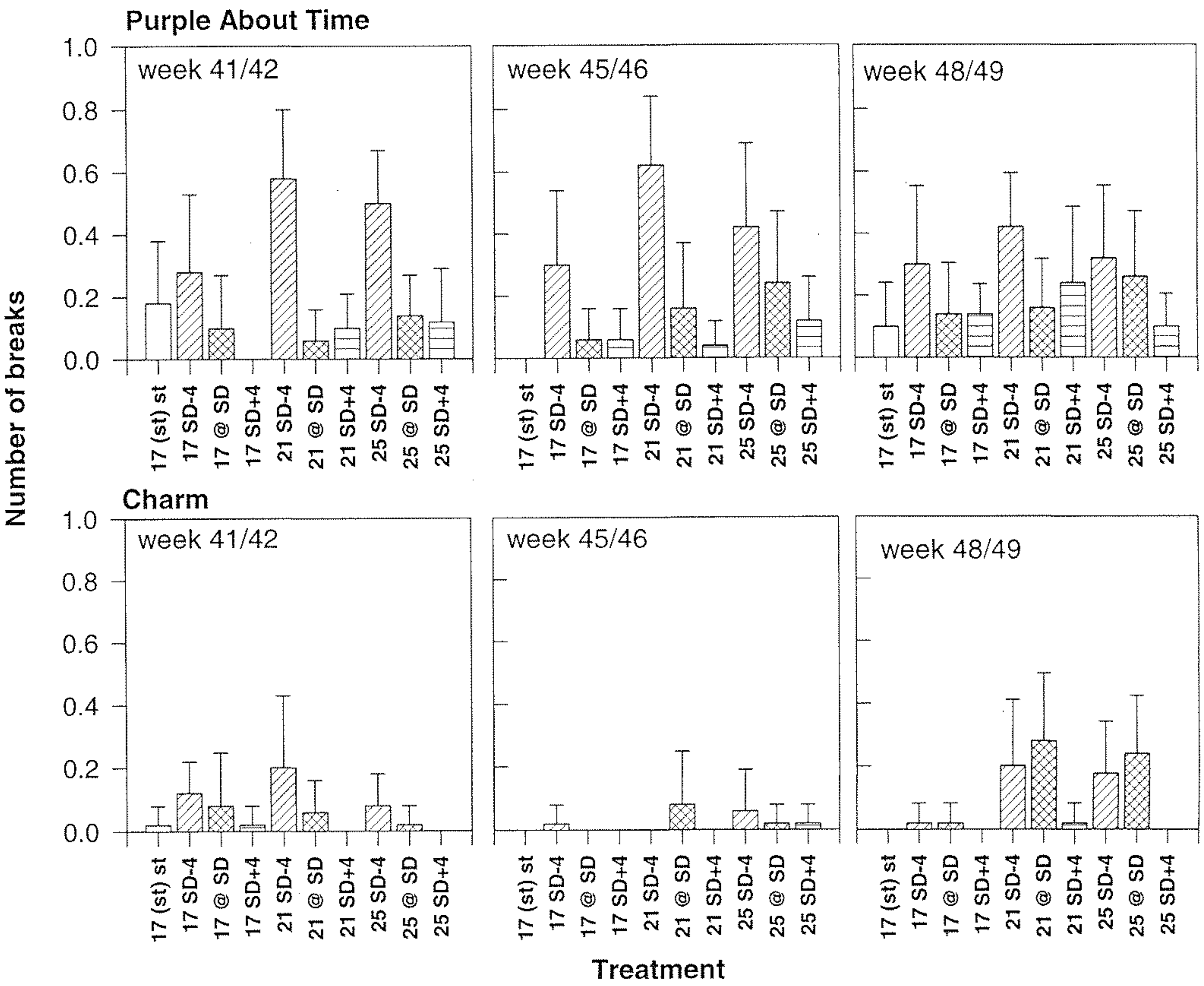
Appendix 7

Figure 8: Effect of number of long days and timing of the pinch on number of open flowers (stage 4+) at marketing (± standard deviation)



Appendix 7

Figure 9: Effect of number of long days and timing of the pinch on number of breaks with 3 or more open flowers at marketing (± standard deviation)

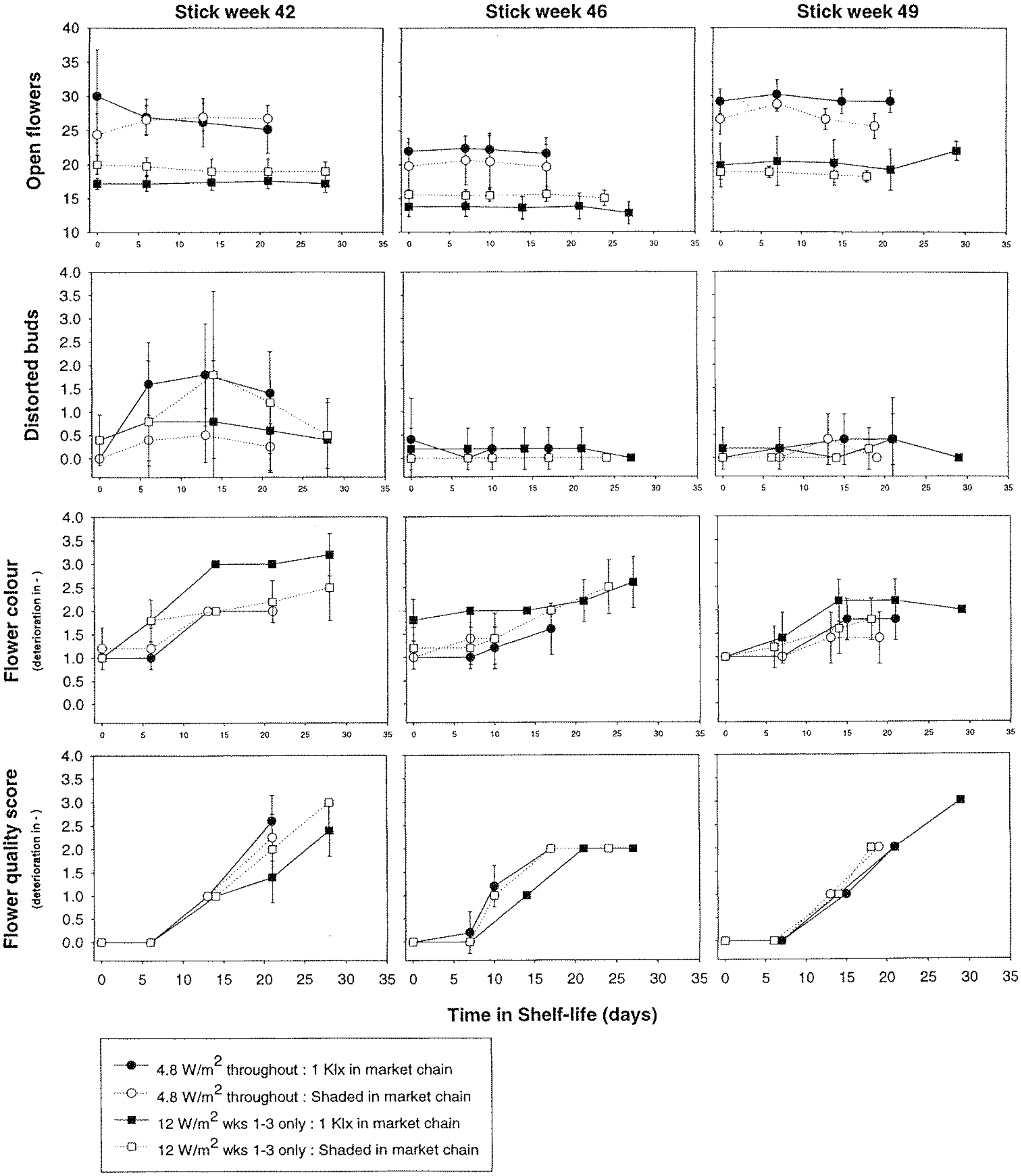


Appendix 8

Effects of production and retail light levels on post-harvest performance

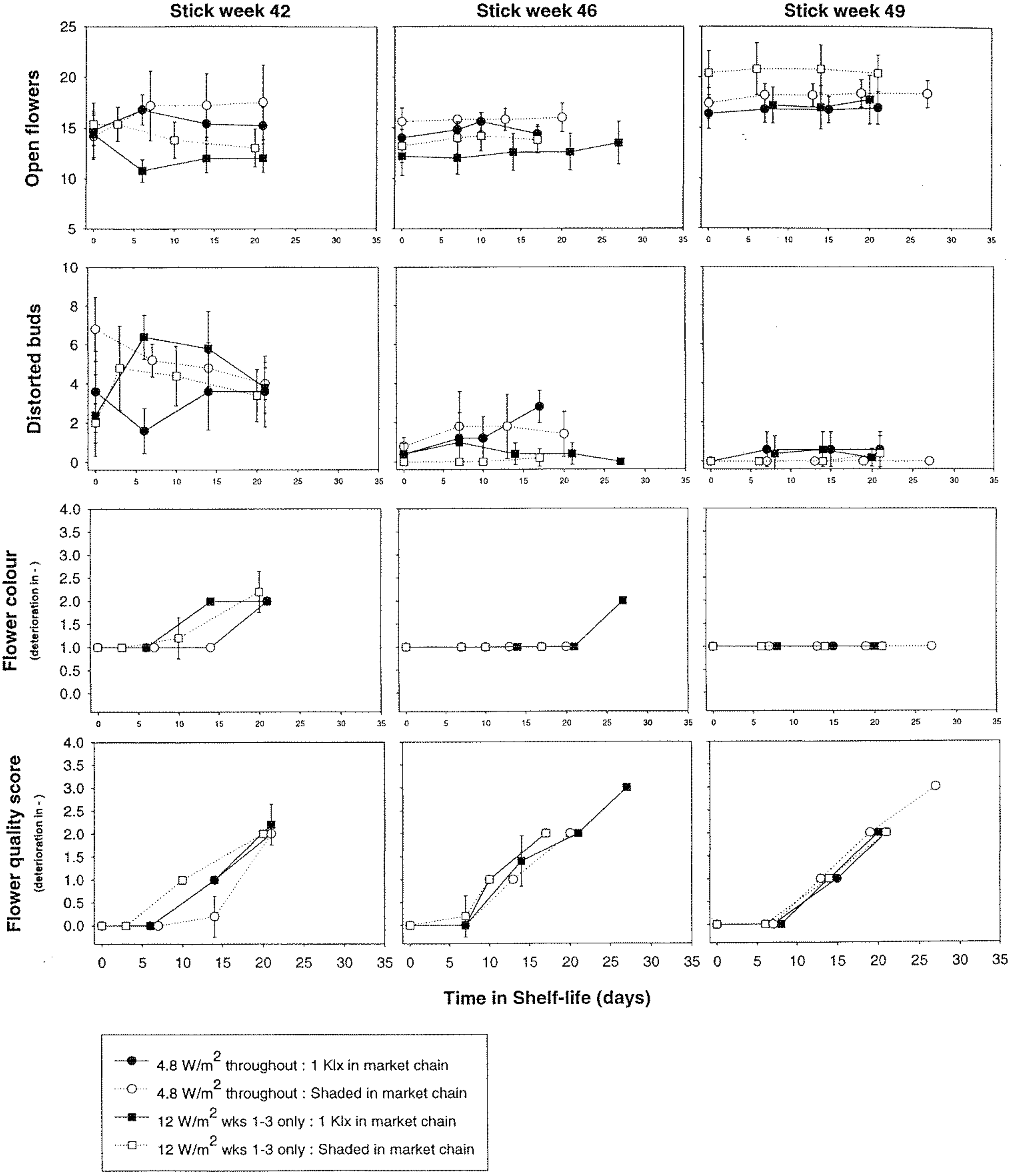
Appendix 8

Figure 1 : Effect of low light levels during the market chain on post-harvest performance in plants produced with and without supplementary lighting at the end of production under different lighting regimes : Purple About Time



Appendix 8

Figure 2 : Effect of low light levels during the market chain on post-harvest performance in plants produced with and without supplementary lighting at the end of production under different lighting regimes : Charm



Appendix 9

Photographic plates

Plate 1: Effect of reduced night-length in Charm (a), Purple About Time (b), Miramar (c) and Surf (d)

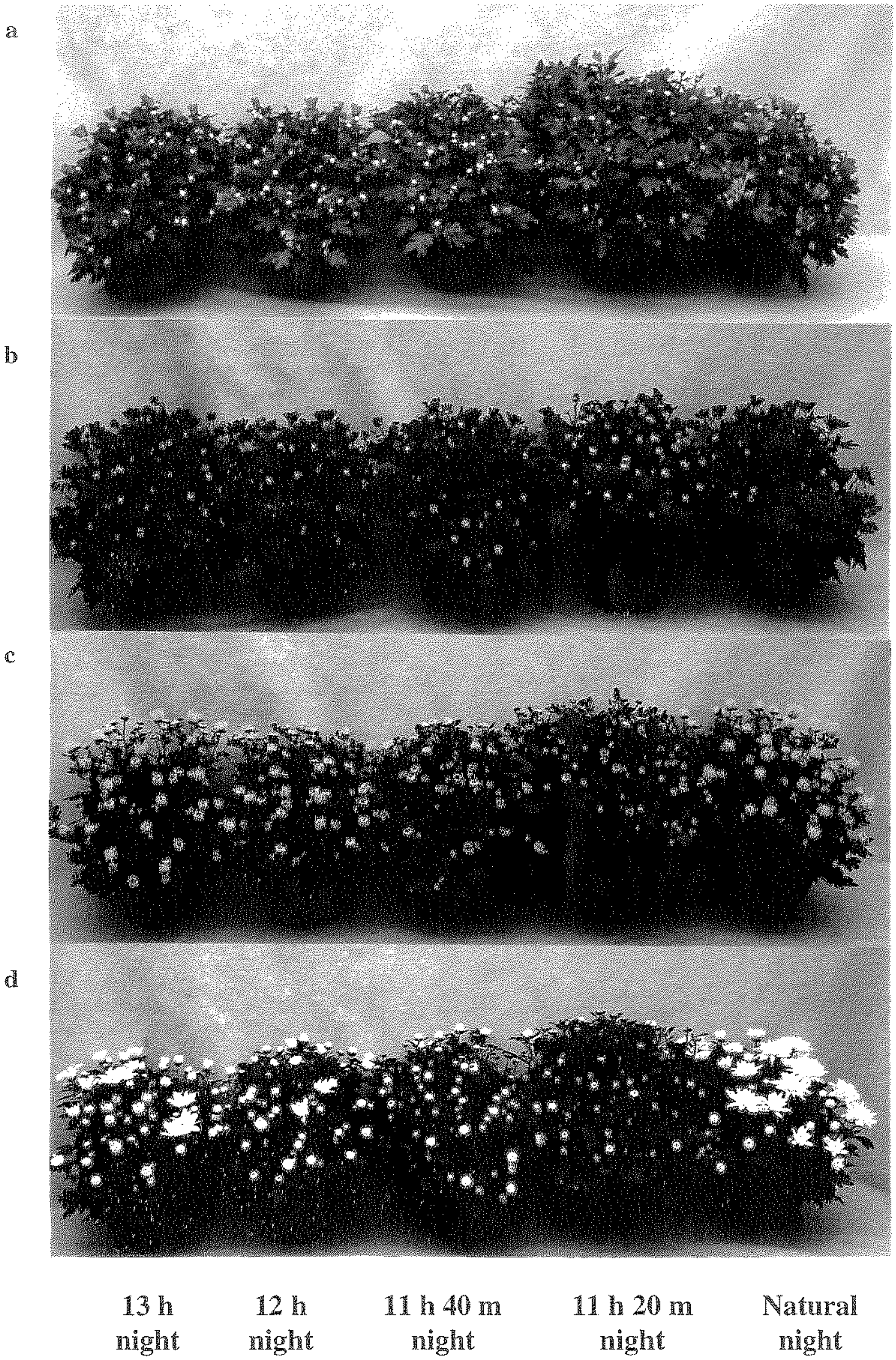


Plate 2: Effect of reduced night-length in Glow Time (a), Regal Davis (b) and Purple Lucky Time (c)

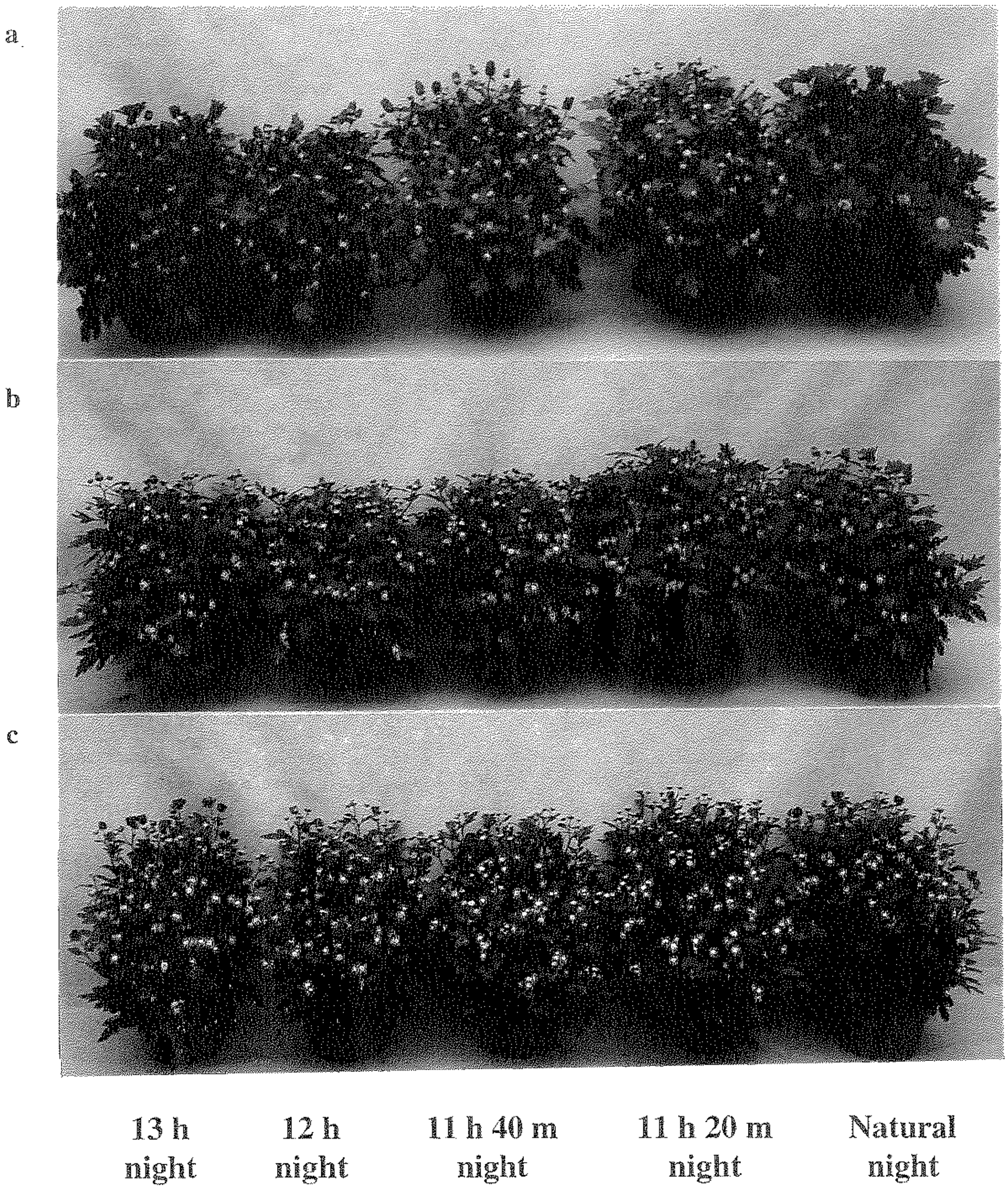


Plate 3: Effects of the number of long days and timing the pinch relative to the start of short days on growth and flowering in Charm : Stick 1

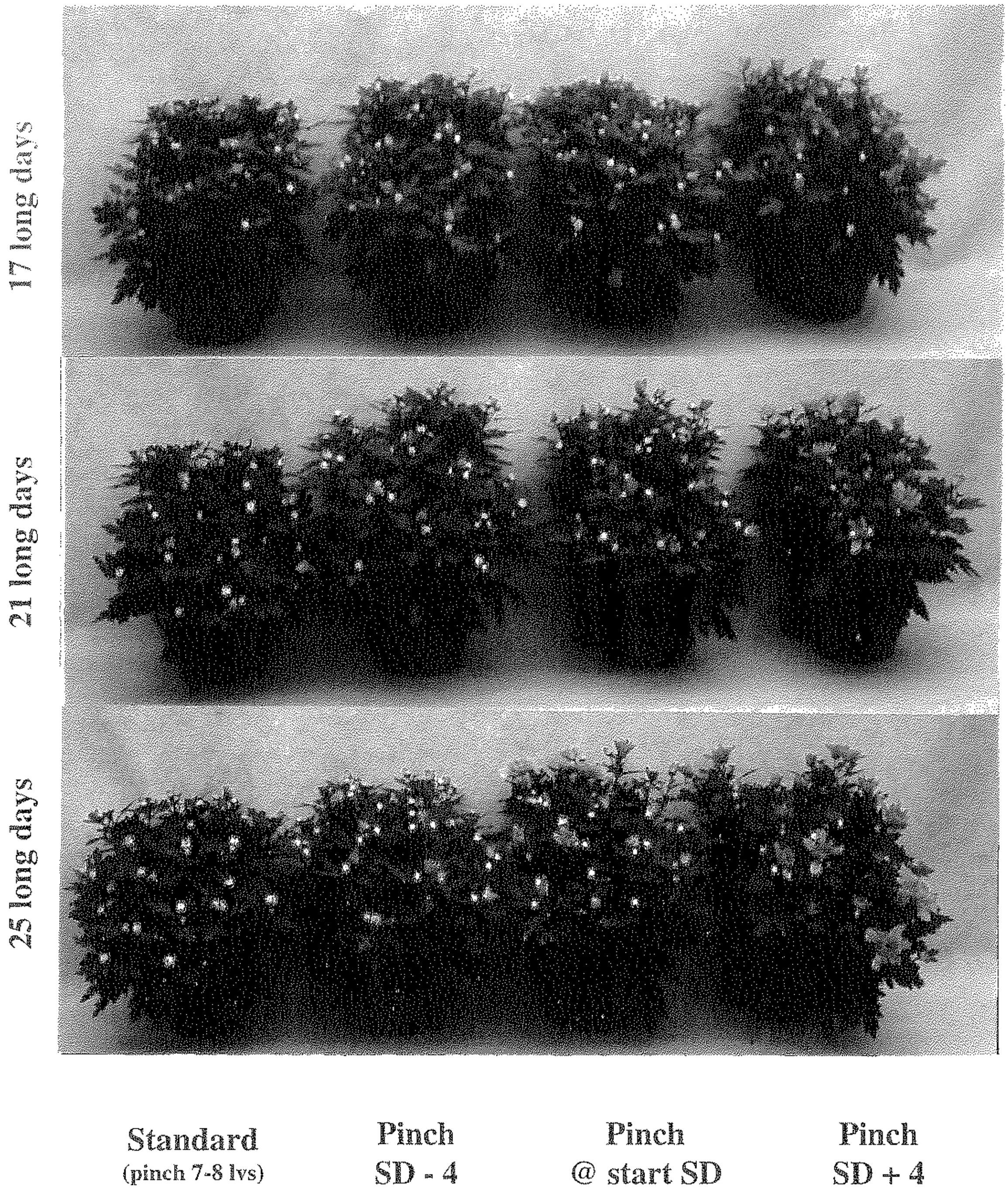


Plate 4: Effects of the number of long days and timing the pinch relative to the start of short days on growth and flowering in Charm : Stick 2

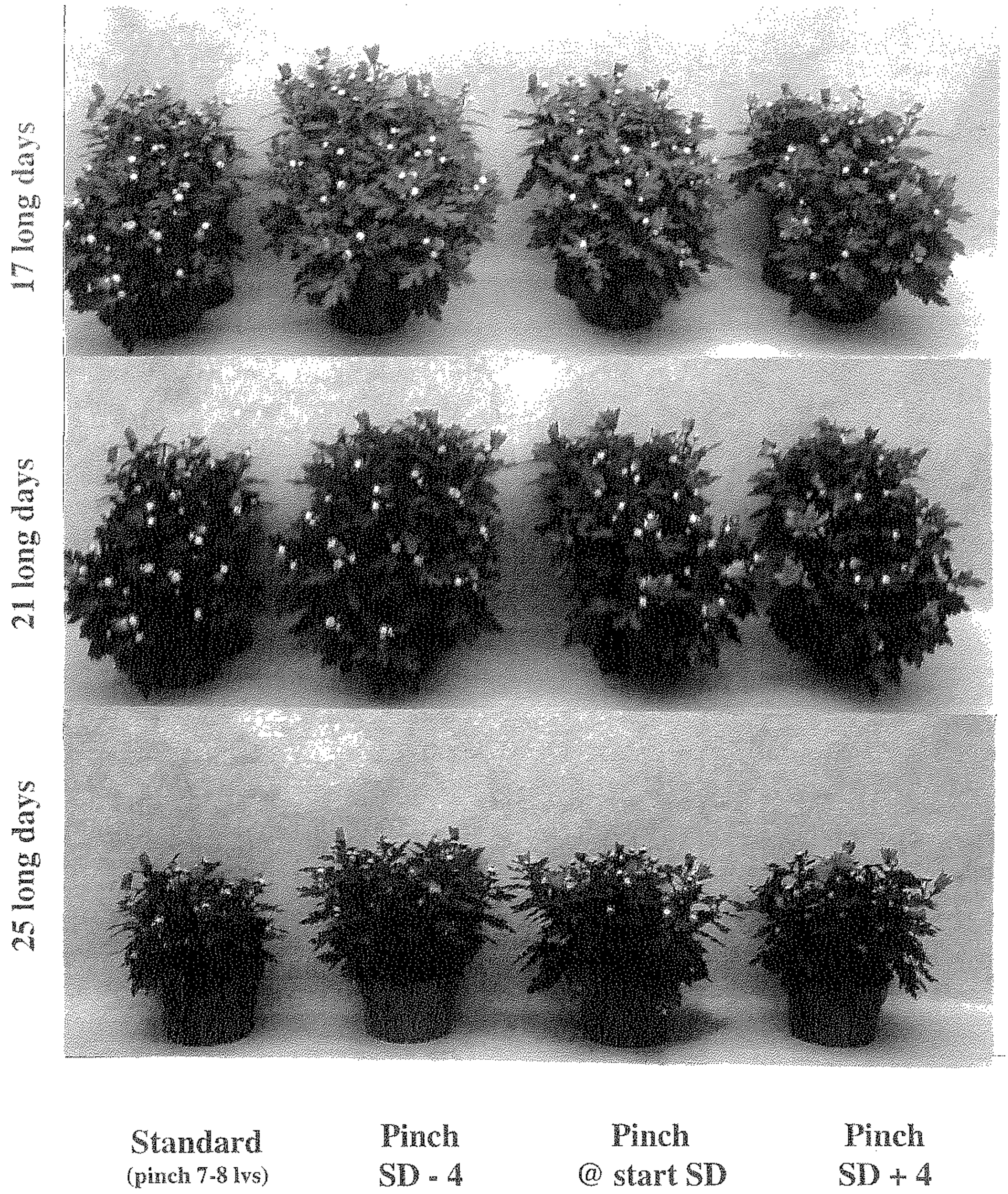


Plate 5: Effects of the number of long days and timing the pinch relative to the start of short days on growth and flowering in Charm : Stick 3

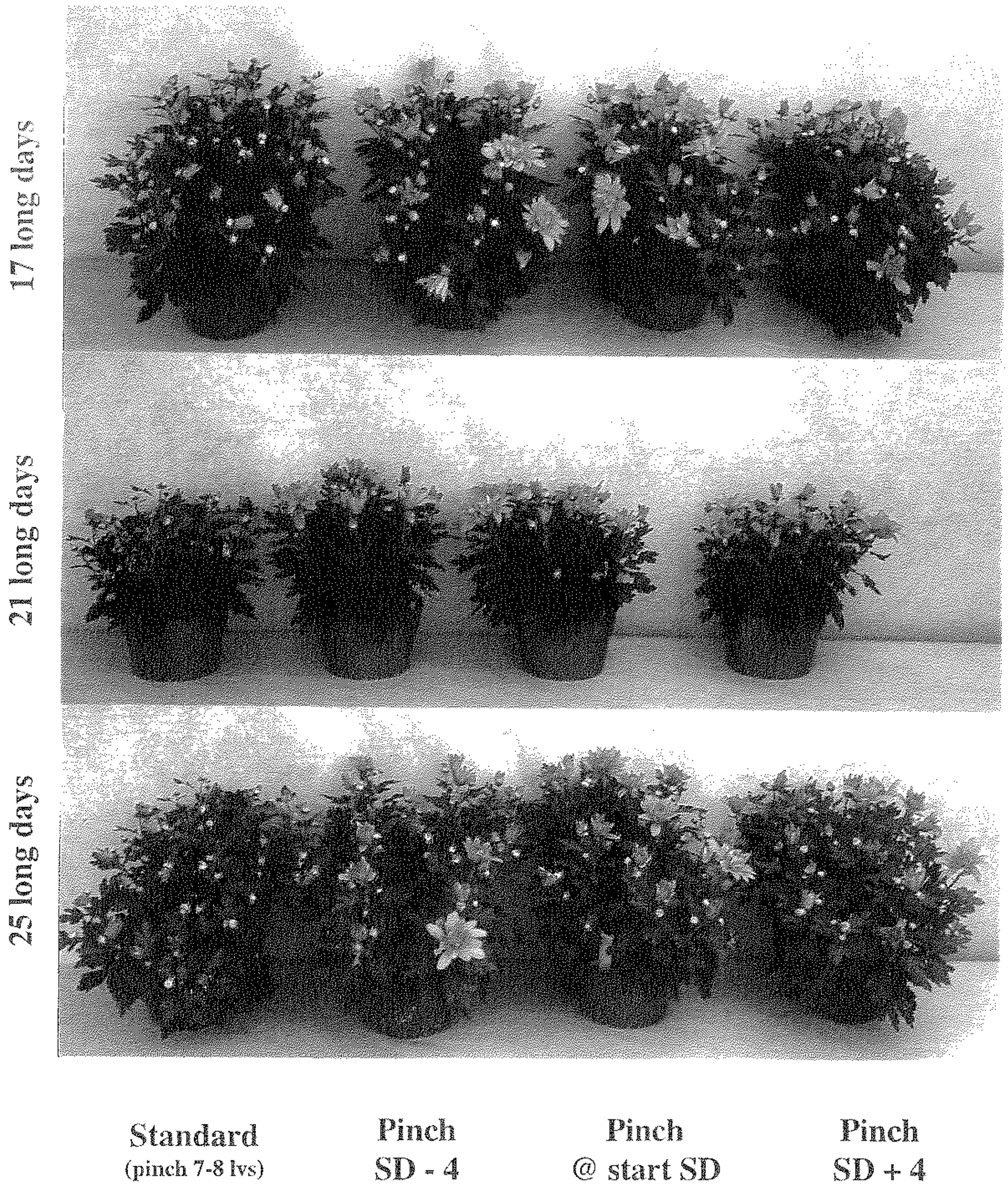


Plate 6: Effects of the number of long days and timing the pinch relative to the start of short days on growth and flowering in Purple About Time : Stick 1

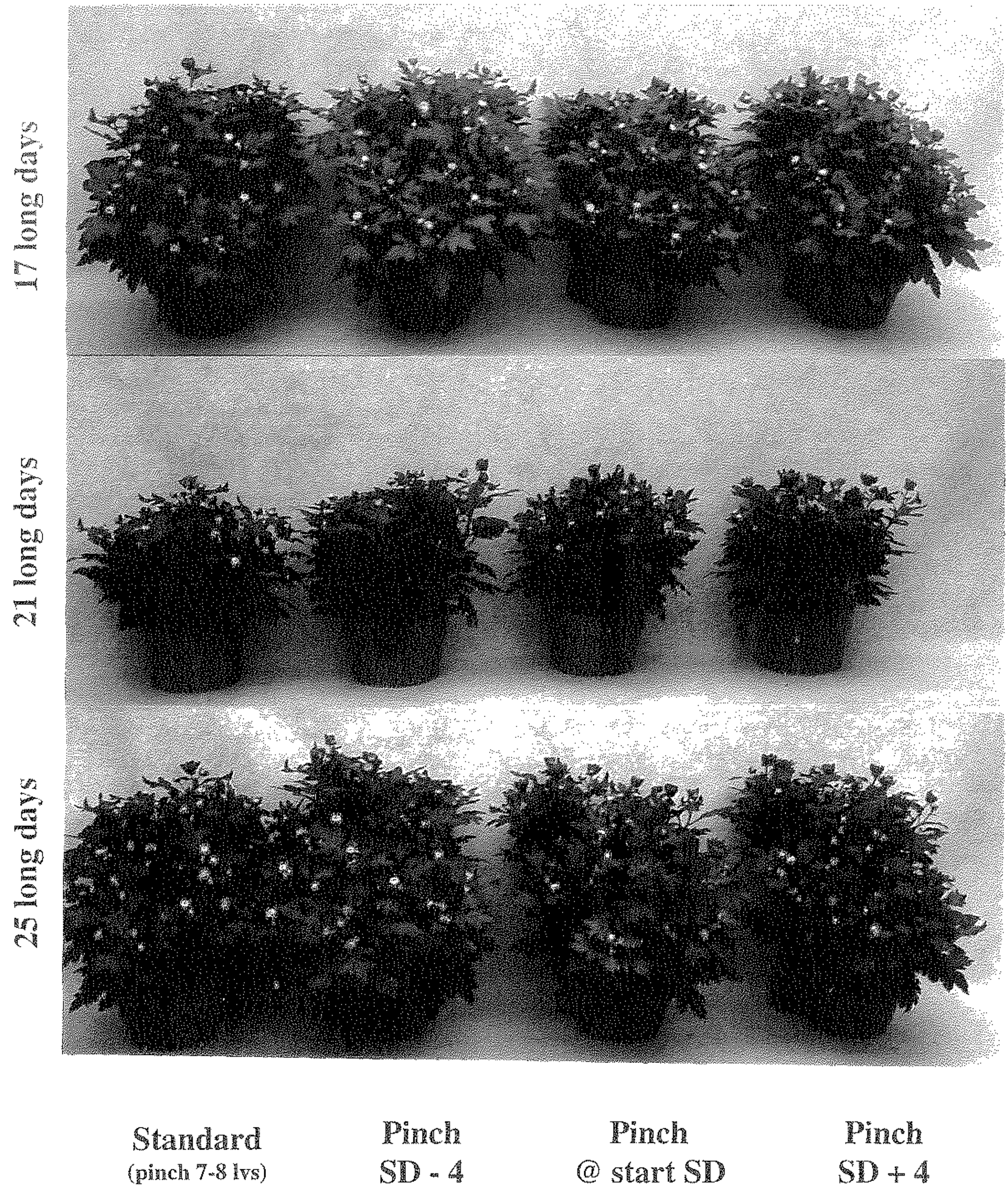


Plate 7: Effects of the number of long days and timing the pinch relative to the start of short days on growth and flowering in Purple About Time : Stick 2

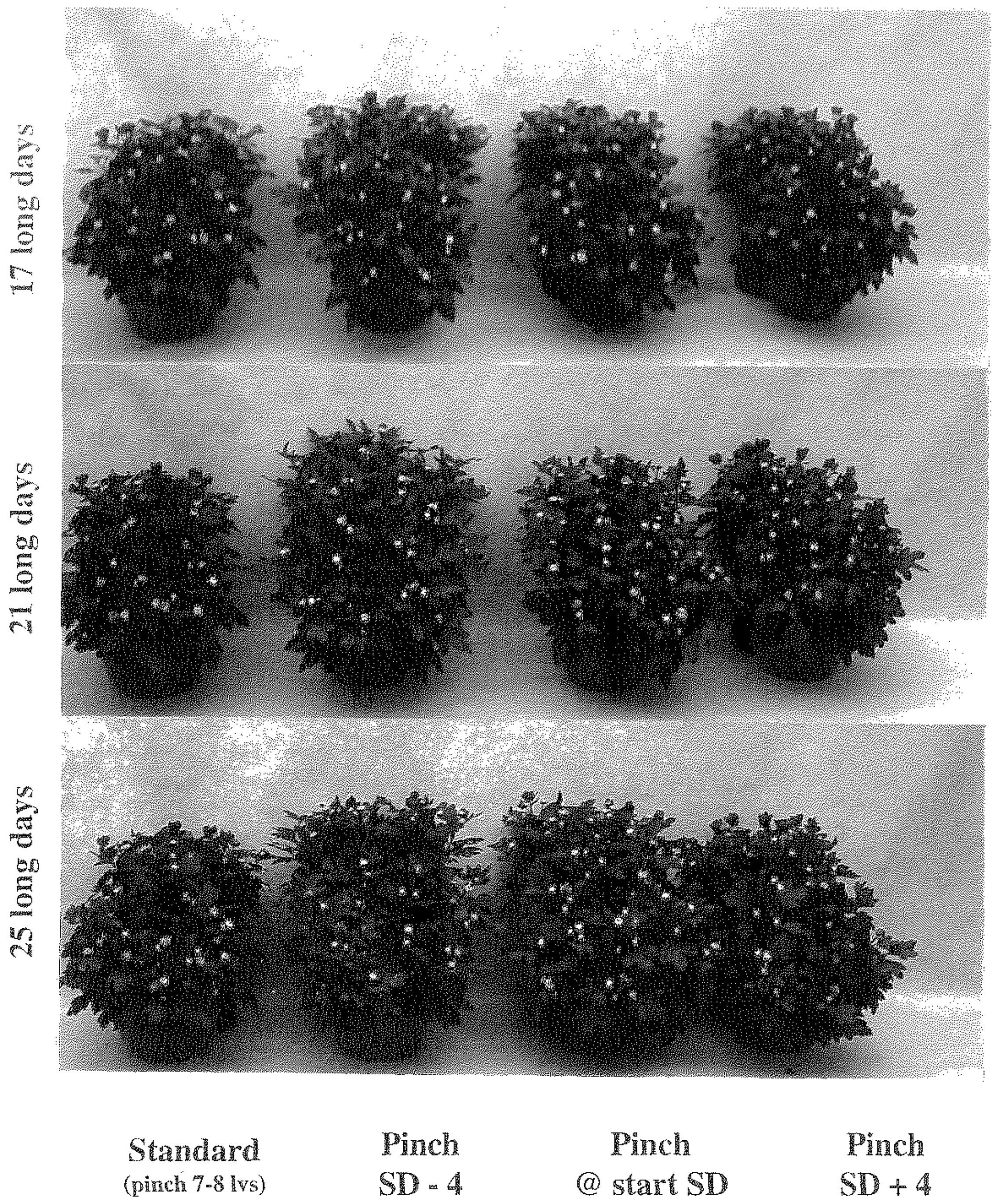


Plate 8: Effects of the number of long days and timing the pinch relative to the start of short days on growth and flowering in Purple About Time :   Stick 3