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| **Project title:** | **Evaluation of the efficiency of production of winter pot chrysanthemums at 4.8 $W/m^2$ (2000 lux) and 9.6 $W/m^2$ (4000 lux) supplementary lighting** |
| **Project number:** | PC 92d |
| **Project leader:** | Dr Paul Carver<br>HRI Efford, Lymington, Hampshire, SO41 0LZ<br>Tel: 01590 673341 Fax: 01590 671553 |
| **Report:** | Final report, February 2002 |
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| **Date project commenced:** | 1 November 1999 |
| **Date completion due:** | 31 October 2000 |
| **Keywords:** | Pot Chrysanthemums, supplementary lighting, winter production, home life. |

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## 1.0 PRACTICAL SECTION FOR GROWERS

### 1.1 Background

Daily solar radiation levels in winter fall to about one tenth of those in summer, and this reduces pot chrysanthemum quality and slows down production. For this reason, pot chrysanthemum specifications set by the multiple retailers, especially for numbers of flowers and 'useful' buds per pot, are extremely difficult to meet in the UK in winter without using supplementary lighting. The challenge is to optimize winter lighting to enable growers to provide the quality and diversity of product that customers want, in numbers and on occasions to meet customers' requirements, and at a price that is competitive and still gives the grower a margin.

R&D on pot chrysanthemum lighting has been a more or less constant feature of HDC funding since about 1988 and work over this period has recently been summarized in "Supplementary lighting of pot chrysanthemums – a grower guide" (PC 92e). The final year of work covered in this grower guide is reported here (PC 92d). The work recognizes that substantial improvement of pot chrysanthemum quality requires lighting to be applied continuously during the short day (SD) phase of production, and seeks to quantify the respective benefits of lighting at two irradiance levels.

### 1.2 Objectives

- To quantify crop speed, quality and post-harvest life of a wide range of pot chrysanthemum cultivars grown with SON/T supplementary lighting applied continuously during SD at irradiances of 4.8 and 9.6 W/m$^2$ PAR and with $CO_2$ enrichment.

- To quantify the financial cost of each lighting treatment.

### 1.3 Methods

Two levels of supplementary lighting (irradiances) were combined with three stick dates and six cultivars to give 36 treatments in total:

Lighting irradiances: 4.8 W/m$^2$ and 9.6 W/m$^2$ PAR

Stick weeks: Weeks 41, 45 and 48

Cultivars: Trenton, Mirimar, Springfield, Ivory Time, Tattoo Time and Prize Time

Five cuttings were stuck in 14D pots filled with Levington M2 compost. Bottom heating was applied to give a compost temperature of about 20°C. Pots were covered with clear polythene after sticking and this remained in place for 9 days. Long days (LD) were given using night-break lighting (50% on/off cycles for 5 hours/night from tungsten lamps at an irradiance of 0.5 W/m$^2$ at canopy height). The propagation phase lasted 16 days in total, after which plants were given short-day (SD) treatment. This was achieved using supplementary lighting for 12h 15m each day, so ensuring a night length of 11h 45m. The lighting came on at 07:00 am when B/O screens were removed. Screens were drawn across again at 6.00 pm each day or at dusk, whichever was earlier. Daily PAR integrals given by the supplementary lighting treatments were: 0.21 MJ/m$^2$/d for lighting at 4.8 W/m$^2$, and 0.42 MJ/m$^2$/d for lighting at 9.6 W/m$^2$.

The heating set point for both day and night was 18°C, and venting was at 23°C. $CO_2$ enrichment was applied to reach a target level of 1000 vpm when the vents were less than 5% open, and 500 vpm when the vents were more than 5% open.

Pots were spaced at 41/m$^2$ (pot thick) during the 16-day propagation phase, decreasing to 27/m$^2$ for the first 14 SD and at 13.5/m$^2$ thereafter. Plants were soft-pinched to 7-8 leaves. Daminozide (as B-Nine) was applied to control plant height at rates specific to each cultivar and lighting treatment. Liquid feeding commenced at the start of SD; 300 mg/l N, 60 mg/l $P_2O_5$ (26 mg/l P) and 250 mg/l $K_2O$ (207 mg/l K) were applied at each irrigation.

## 1.4 Summary of results

### *Production time*

- Pots grown with supplementary lighting at an irradiance of 9.6 W/m$^2$ for 12h 15m per day reached the marketing stage 2.2 to 3.0 days ahead of pots grown with supplementary lighting at 4.8 W/m$^2$. Stick date had little obvious influence on this. Previous work has shown that crops lit at 4.8 W/m$^2$ reach the marketing stage 4-5 days ahead of unlit crops, so it seems that doubling the level of lighting from 4.8 to 9.6 W/m$^2$ gives about a 50% additional saving in production time. All cultivars were advanced by the higher irradiance treatment.

### *Plant height and spread*

- The use of supplementary lighting made it difficult to meet the minimum height specification of 16-23 cm above the pot rim, particularly for pots stuck in week 45 which received the lowest solar radiation levels. However, the problem was no greater when supplementary lighting was applied at 9.6 W/m$^2$ than at 4.8 W/m$^2$. No problems were found in reaching the minimum specification for pot spread, 25 cm.

### *Flower development*

- Doubling the irradiance of supplementary lighting from 4.8 W/m$^2$ to 9.6 W/m$^2$ increased the total number of buds and flowers per pot (averaged over cultivars and stick weeks) by 18.4%. The percentage increase in flowers per pot was smaller, averaging 12.6%. Not all cultivars benefitted equally, and the largest increases in number of flowers per pot where shown by Mirimar (+4.8 flowers, +14.7%), Tattoo Time (+6.1 flowers, +36.7%) and Prize Time (+4.6 flowers, +22.9%). There was also a smaller but useful increase in flowers per pot in Ivory Time (+1.5 flowers, +11.1%). Assuming flowers per pot is a useful yardstick of quality, then increasing the irradiance of supplementary lighting gave enhanced quality in Mirimar, Tattoo Time and Prize Time, a marginal improvement in Ivory Time, but no obvious improvement in Trenton and Springfield. In these latter two cultivars, increasing the irradiance primarily increased the numbers of large buds. There appeared to be no obvious relationship between total flower count and increase in flowers due to increased irradiance.

- Previous studies have shown that flower and bud numbers tend to be greater in pots stuck in week 48 than in pots stuck in either week 41 or 45, since the week 48 pots receive the highest light integrals during the final three weeks of SD. Week 48 pots certainly had more buds and flowers than week 45 pots in this trial, but had no more buds and flowers than week 41 pots. This was probably because week 41 pots were harvested at a more mature stage than week 45 or week 48 pots.

***Plant dry weight***

- Dry weight reflects photosynthetic growth made by the plant and, in general, the higher the dry weight, the higher the quality. Lighting at 9.6 W/m$^2$ increased dry weight per pot over that given by lighting at 4.8 W/m$^2$ by about 21% on average, but by up to 34.6% for pots stuck in week 45 when natural solar radiation was lowest.

***Home life***

- Only about 20% of pots were judged still to be of reasonable quality after 4 weeks of home life, and this was not affected by prior supplementary lighting treatment.

- Pots grown at the higher light level had a greater number of open flowers at the start of home life than pots grown at the lower light level, and this difference was maintained through home life. In general, pots showed a modest increase in the number of flowers per pot during home life, reflecting some continued bud opening. However, the increase in the number of open flowers was not affected by prior lighting treatment.

- Numbers of distorted flowers per pot (which reflect uneven bud opening) were low after 2 weeks of home life, but were lowest when pots had been lit at 9.6 W/m$^2$. Since lighting conditions during home life were the same for both treatments, it is clear that lighting during production had had an influence on flower distortion, and that lighting at 9.6 W/m$^2$ can go some way to ameliorate the problem.

- Prior lighting at 9.6 W/m$^2$ also significantly reduced flower deterioration during home life. Flower deterioration scores were significantly higher in pots from the week 41 stick than from pots stuck later, indicating that it is primarily light during the later stages of production that is important. There was no obvious effect of prior lighting treatment on foliage quality after 2 weeks of home life.

***Economic evaluation***

- It was calculated that lighting at 4.8 W/m$^2$ increased the cost per lit pot by between 7.54 and 11.12 pence depending on assumptions made regarding glasshouse area lit per lamp. This cost was doubled when lighting was increased to 9.6 W/m$^2$ using the same wattage lamps (400 W SON/T). The increased cost of the higher irradiance was, however, reduced by 24-29% when 600 W lamps were used (assuming sufficient available headroom to mount 600 W lamps). These costs take account of the contribution that supplementary lighting makes to heating costs, and assume that 50% Climate Change Levy is paid on electricity used.

- A cost-benefit analysis was done taking into account the slightly faster cropping (and greater throughput) given by lighting at 9.6 W/m$^2$ as against 4.8 W/m$^2$. It was further assumed that wastage is reduced from 1.0% to 0.5% when the irradiance is increased from 4.8 W/m$^2$ to 9.6 W/m$^2$ but that return per marketed pot will remain unchanged at £1.10. This showed that lighting at 9.6 W/m$^2$ is likely to be as cost effective as lighting at 4.8 W/m$^2$ so long as 600 W lamps are used to achieve the increased irradiance. Raising the irradiance using 400 W lamps will require an extra 1-3 pence per pot to be achieved to cover the additional costs.

- On a more positive note, lighting at the higher irradiance should give the grower a greater assurance of meeting market quality requirements, especially for buds and flowers per pot in low light years, will enable the grower to produce a wide range of flower types to meet continuously changing market needs, and will enable the grower to compete with the very best of overseas producers.

## 1.5 Action points for growers

The higher the level of light reaching the pots in winter, the higher the quality is likely to be and the greater the range of cultivars that can be grown to retail specifications. In practice supplementary lighting is essential to provide a sufficient level of quality to meet the needs of the multiple retailers, even given a southerly UK location and good glasshouse transmission characteristics (PC 92e). An irradiance of 4.8 W/m$^2$ applied throughout SD increases quality greatly compared to unlit crops, but it is shown here that raising the level above 4.8 $W/m^2$ will enhance pot quality further. It is unlikely that supplementary lighting installations could ever give too much light from the standpoint of plant growth in the UK in winter, so the only limits to the irradiance installed should be those determined by engineering practicalities and cost benefit analysis. Plants respond to the total light integral (solar plus supplementary) and considerably more supplementary lighting would be needed in Lincolnshire, for example, than at Efford to achieve similar plant responses (see PC 92e). It follows from this that:

- Lamps, luminaires and the glasshouse cladding need to be regularly cleaned to ensure that the irradiance reaching the pots is as high as possible. It is generally said, for example, that each year that lamps and reflectors are not cleaned reduces light output by about 2.5%.

- Even with a well-managed cleaning and maintenance programme, irradiance will still fall with time as the lamps age. It is essential, therefore, that a planned lamp replacement policy is adopted (see PC 92e). Consider on a regular basis whether the existing installation is adequate for current and future needs. Use cost-benefit analysis to aid this decision making process.

- If upgrading an existing lighting installation, consider whether the new installation can be planned around the use of 600 W lamps. These are more efficient than 400 W lamps and increasing the irradiance using these can be effectively cost neutral. However, greater headroom is required for 600 W lamps than for 400 W lamps to ensure that light is uniformly distributed over the cropped area.

- 600 W lamps should certainly be installed in any new glasshouse installation.

## 2.0 SCIENCE SECTION

### 2.1 Introduction and objectives

Daily solar radiation integrals in winter fall to about one tenth of those in summer, and low solar radiation levels depress pot chrysanthemum quality and slow down production. For this reason, pot chrysanthemum specifications set by the multiple retailers, especially for numbers of flowers per pot, are extremely difficult to meet in the UK in winter without using supplementary lighting. The challenge is to optimize winter lighting to enable growers to provide the quality and diversity of product that customers want, in numbers and on occasions to meet customers' requirements, and at a price that is competitive and still gives the grower a margin.

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***Objectives***

- To quantify crop speed, quality and post-harvest life of a wide range of pot chrysanthemum cultivars grown with SON/T supplementary lighting applied continuously during SD at irradiances of 4.8 and 9.6 $W/m^2$ PAR and with $CO_2$ enrichment.

- To quantify the financial cost of each lighting treatment.

### 2.2 Materials and methods

#### 2.2.1 Treatments

Two lighting treatments (irradiances) were combined with three stick dates and six cultivars to give 36 treatments in total:

| | |
|---|---|
| Lighting irradiances: | 4.8 $W/m^2$ and 9.6 $W/m^2$ PAR |
| Stick weeks: | Weeks 41, 45 and 48 |
| Cultivars: | Trenton, Mirimar, Springfield, Ivory Time, Tattoo Time and Prize Time |

Supplementary lighting was given using Philips 400 W SON/T lamps for 12h 15m each day during the SD phase of production. A relatively low gutter height precluded the use of 600 W lamps.

### 2.2.2 Cultural details

***Plant material***

Unrooted cuttings of the six cultivars were obtained from two suppliers as listed in Table 2.1. Cultivars nominated by the suppliers as being borderline for winter producton are indicated by ($\psi$).

**Table 2.1 Cultivars used**

| Cultivar | Supplier | Flower Colour | Height class | Response (Weeks) |
|---|---|---|---|---|
| Trenton | Yoder Toddington Ltd | White | Medium | 8 |
| Miramar ($\psi$) | Yoder Toddington Ltd | Yellow | Medium | 9 |
| Springfield | Yoder Toddington Ltd | Salmon | Small | 8 |
| Ivory Time | Cleangro Ltd | White | Medium | 7 |
| Tattoo Time ($\psi$) | Cleangro Ltd | Burgundy/Yellow | Medium/Tall | 7.5 |
| Prize Time | Cleangro Ltd | Yellow | Medium/Tall | 7.5 |

***Propagation and long-day (LD) phase***

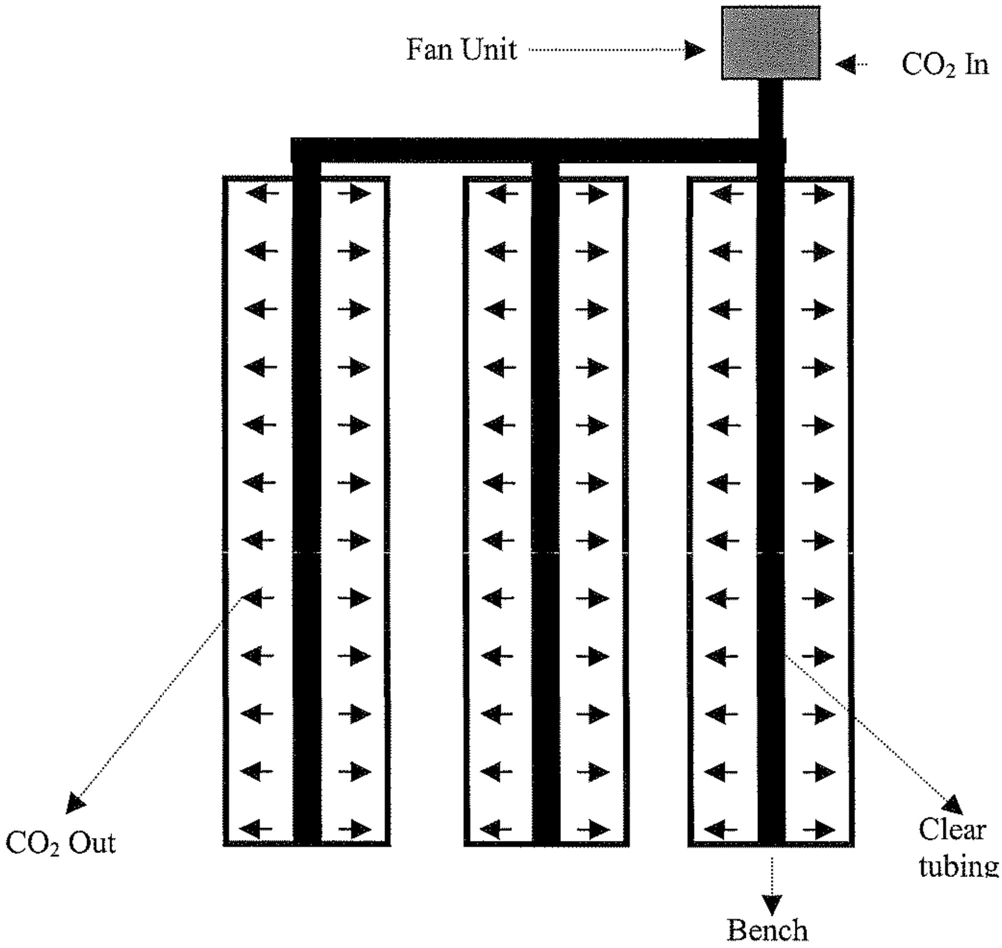
Five cuttings were stuck in 14D pots filled with Levington M2 compost. Bottom heating was applied to give a compost temperature of about 20°C. Pots were covered with clear polythene after sticking and this remained in place for 9 days. LD were given from sticking using night-break lighting (50% on/off cycles for 5 hours/night using tungsten lamps at an irradiance of 0.5 W/m$^2$ at canopy height). This continued for 16 days when pots went into SD.

***Short day environment***

Supplementary lighting was given continuously for 12h 15m each day, ensuring a night length of 11h 45m. The lighting came on at 07:00 am when blockout (B/O) screens were removed. Screens were drawn across again at 6.00 pm each day or at dusk, whichever was earlier. Daily PAR integrals given by the supplementary lighting treatments were: 0.21 MJ/m$^2$/d for lighting at 4.8 W/m$^2$, and 0.42 MJ/m$^2$/d for lighting at 9.6 W/m$^2$.

The heating set point for both day and night was 18°C, and venting was at 23°C. $CO_2$ enrichment was applied to reach a target level of 1000 vpm when the vents were less than 5% open, and 500 vpm when the vents were more than 5% open. $CO_2$ was applied in each compartment via perforated, clear plastic tubing (125mm diameter) laid down each bench (at pot height). Perforations were at 300mm intervals facing towards the pots on either side (Fig 2.1). The tubing was kept inflated with air using a fan, and the Priva environmental computer regulated the introduction of $CO_2$ into the airflow near the fan. The perforations released the $CO_2$ enriched air within the plant canopy.

**Fig 2.1 – Diagram of forced air $CO_2$ distribution system**




### *Growth regulation*

Pots were soft-pinched in SD to 7-8 leaves as soon as this became possible. Daminozide (as B-Nine) was applied to control plant height according to the specific requirements of each variety and as detailed in the crop diary (Appendix 5). Applications were the same in the two lighting treatments for a given cultivar.

### *Pot spacing*

Pots were spaced at 41 pots/m$^2$ (pot thick) during the propagation and LD phases. They were re-spaced to 27 pots/m$^2$ (20.6 cm between pots in the row and 17.9 cm between rows) at the start of SD, and to 13.5 pots/m$^2$ (29.8 cm between pots in the row, and 25.8 cm between rows) 14 days later.

### *Nutrition*

Liquid feeding was given at each irrigation beginning at the start of SD. The nutrient solution comprised: 300 mg/l N, 60 mg/l $P_2O_5$ (26 mg/l P) and 250 mg/l $K_2O$ (207 mg/l K).

*Pest and disease control*

A routine, preventative spray programme was maintained against Western Flower Thrips. In addition, crops were monitored daily and spot treatments of an appropriate pesticide applied as necessary (see crop diary, Appendix 5).

*Home-life phase*

Six pots per treatment at marketing stage were put through a simulated transport run (21 hours) and store life phase (10 days). This was then followed by up to four weeks in simulated home life. The procedure was as follows:

Plants were sleeved, boxed and held at 15°C for 15 hours, before undergoing a simulated transport run of 6 hours at 12°C. Holding area simulation: 12 hours at 18°C, sleeved in boxes. Store-life phase: Plants taken out of boxes but remained sleeved for 10 days. Lighting was given at 600 lux (tungsten lamps) for 12 hours/day. Temperature was controlled to a continuous 18-20°C. The home-life environment which followed was the same as the store life environment except that pots were not sleeved.

### 2.2.3 Assessments

*At marketing*

The effects of treatments on production time and plant quality were assessed on 12 pots per plot at marketing stage 3 (PC 13c). This is defined as when pots have a minimum of 12 flowers, all with reflexing petals, and 50% with petals at least 20 mm long. The following records were taken (see Appendix 3):

1. Number of SD to marketing stage 3
2. Total number of buds and flowers per pot
3. Number of 'small' buds not contributing to floral display (stage <1)
4. Number of 'large' buds contributing to floral display (stages 1-3)
5. Number of flowers per pot from the 'paint brush' stage to fully open (stages 4-8)
6. Average plant height above the rim of the pot (cm).
7. Average plant spread (cm) (diameter) before sleeving.
8. Average pot dry weight (g) (based on 3 pots per treatment, each comprising 5 plants).

*During home life*

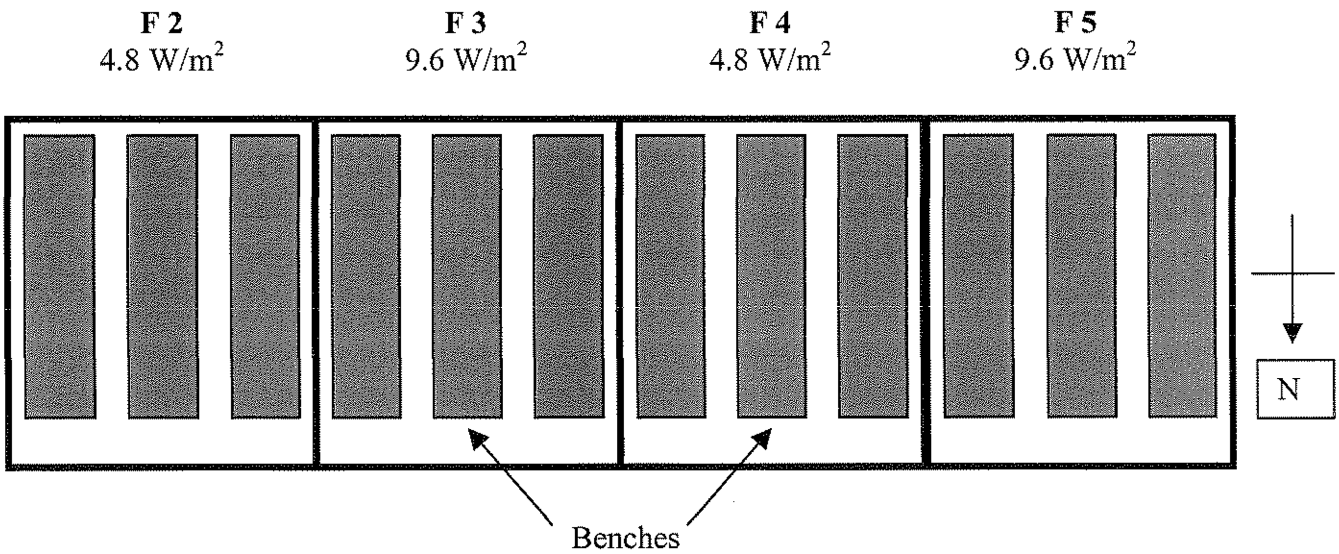
Assessments were made at de-sleeving and weekly thereafter for 4 weeks or until plants deteriorated to the stage where it was judged useful home life had ended. The following assessments were made (see Appendix 4):

1 Number of flowers per pot at stage 4 (paintbrush) or beyond.
2 Number of distorted flowers per pot.
3 Qualitative assessment of flower quality as an average of pots in a treatment:
  0 = No deterioration
  1 = Degeneration visible in the centre of the flower.
  2 = Flower wilting or necrotic.
4 Qualitative assessment of foliage quality as an average of pot scores for the upper canopy, the mid canopy, and the lower canopy:
  0 = All leaves green
  1 = Some leaves tinged with yellow
  2 = About half the leaves tinged with yellow
  3 = Most leaves yellow/brown
  4 = Extensive leaf death and abscission

### 2.2.4 Experimental design and trial layout

The trial was carried out using 4 similar compartments of F-Block North (F2-5), each measuring 12 m x 6.7 m (see Fig 2.2, Plate 1 in Appendix 1, and Appendix 2). Two of the compartments had supplementary lighting at 4.8 W/m$^2$ (F2 & F4) and two had supplementary lighting at 9.6 W/m$^2$ (F3 & F5). Three benches, each 1.25 m x 10 m, were arranged in a north-south alignment within each compartment, and on each were plots of all six cultivars for each sticking. Each plot comprised 24 pots, and a fully randomized statistical design was employed. Statistical analysis was by ANOVA. Differences were judged significant if the probability of the difference occurring by chance was 1 in 20 or less (i.e. $P<0.05$).

**Fig 2.2 Lighting treatments within the F-Block compartments**

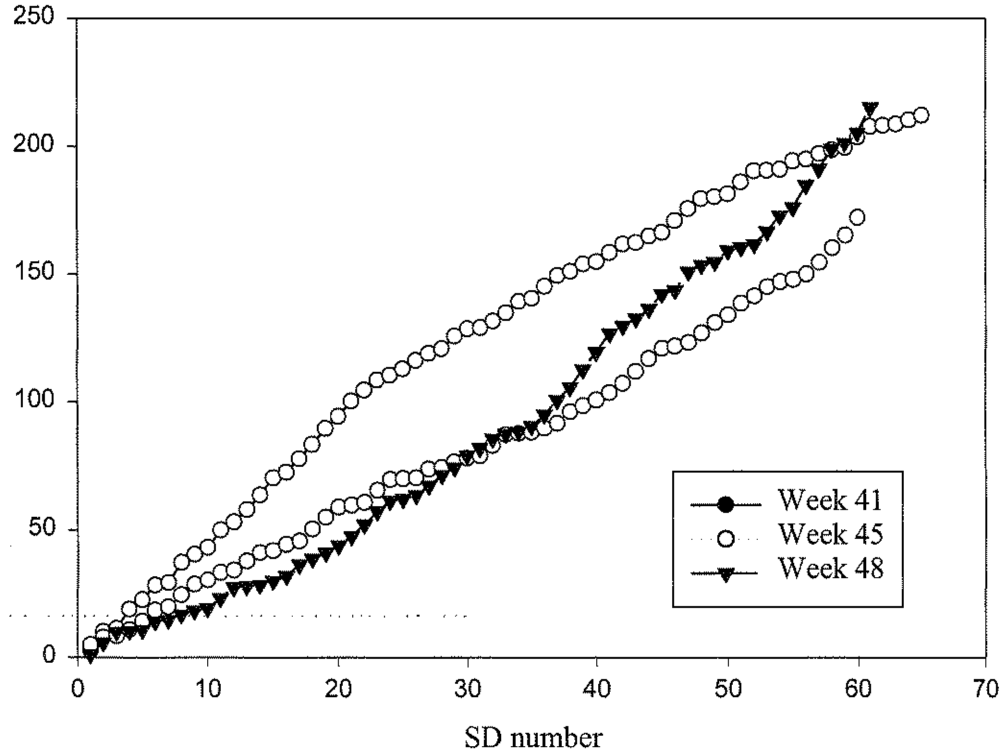


## 2.3 RESULTS AND DISCUSSION

### 2.3.1 Light levels

Fig. 2.3 shows cumulative outside solar radiation integrals (total radiation) during the SD phase of cropping for pots stuck in weeks 41, 45 and 48. The trends show that pots stuck in week 41 started SD in relatively high light conditions, but grew into ever declining light. Thus, they received the highest daily solar radiation integrals during the first weeks of SD but the lowest integrals during the final weeks of SD. In contrast, pots stuck in week 48 received the lowest solar radiation integrals during the first weeks of SD but the highest integrals during the final weeks. Pots stuck in week 45 received relatively constant solar radiation integrals through production, and these tended to be intermediate between those received by week 41 and 48 pots.

**Fig. 2.3 Cumulative outside solar radiation ($MJ/m^2$) during the SD phase of cropping for pots stuck in weeks 41, 45 and 48 (1999-2000)**




These trends are further shown up in Table 2.2 which shows average daily photosynthetically active radiation (PAR) integrals received within the glasshouse during the SD phase of cropping. The data assume that 45% of solar radiation is PAR, and that 60% of solar radiation is transmitted into the glasshouse. To this has been added the daily PAR integrals given by the use of supplementary lighting at either 4.8 or 9.6 $W/m^2$ for 12h 15m per day (0.21 and 0.42 $MJ/m^2/d$ respectively). Only the pots stuck in week 41 (both supplementary lighting treatments) experienced daily PAR integrals during the first 3 weeks of SD that are above the threshold that is generally believed to prevent delays in bud initiation (1.25 $MJ/m^2/d$, see PC 92e). However, pots stuck in week 45 and grown with the higher level of supplementary lighting received light levels very close to this threshold. All other things being equal, one would expect the week 41 pots and the week 45 high supplementary lighting pots to reach the marketing stage in fewer SD than other pots. High light at the end of production has generally been found to benefit pot quality, particularly numbers of buds and flowers per pot (PC 92e), and one might also expect that this would show up in pots stuck in week 48.

**Table 2.2 Average daily PAR radiation integrals ($MJ/m^2/d$ - solar plus supplementary) during SD (assuming 60% transmission of solar radiation)**

| | Week 41 | | Week 45 | | Week 48 | |
|---|---|---|---|---|---|---|
| | 4.8 $W/m^2$ | 9.6 $W/m^2$ | 4.8 $W/m^2$ | 9.6 $W/m^2$ | 4.8 $W/m^2$ | 9.6 $W/m^2$ |
| **First 3 weeks of SD** | 1.50 | 1.71 | 0.98 | 1.19 | 0.82 | 1.03 |
| **Total SD period** | 1.09 | 1.31 | 0.98 | 1.15 | 1.16 | 1.34 |
| **Final 3 weeks of SD** | 0.82 | 1.02 | 1.16 | 1.25 | 1.44 | 1.65 |

### 2.3.2 Short days (SD) to marketing

Table 2.3 shows average numbers of SD to the marketing stage for pots growing in the two lighting treatments for each of the three stick dates. These data are averaged over cultivars (full data are shown in Appendix 3).

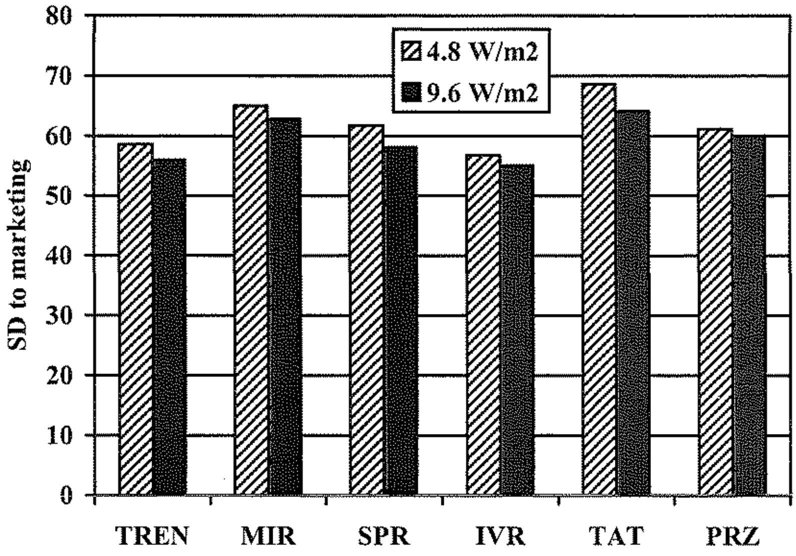
**Table 2.3 Effects of lighting treatment on number of SD to the marketing stage**

| | Stick week | | |
|---|---|---|---|
| **Lighting treatment** | **41** | **45** | **48** |
| **4.8 $W/m^2$** | 65.3 | 59.5 | 61.0 |
| **9.6 $W/m^2$** | 62.8 | 56.5 | 58.8 |
| **Significance of difference** | ** | ** | * |

* significant at $P<0.05$; ** significant at $P<0.01$

Pots grown with the higher level of supplementary lighting (9.6 $W/m^2$) reached the marketing stage 2.2 to 3.0 days ahead of pots grown with the lower level of supplementary lighting (4.8 $W/m^2$), with little obvious influence of stick date. The advancement for pots from stick week 2 is seen in Plate 2a – f (Appendix 1). It has been shown in the past that winter crops lit throughout SD at 4.8 $W/m^2$ generally reach the marketing stage 4-5 days ahead of unlit crops (PC 92e). So, it can be generalized that doubling the level of supplementary lighting (from 4.8 to 9.6 $W/m^2$) gives about a 50% greater increase in the saving to be made in SD cropping duration. All cultivars were advanced by the higher irradiance treatment, and there was no apparent relationship between response group (Table 2.1) and the advance given by raising the irradiance (Fig. 2.4).

**Fig. 2.4 Effects of supplementary lighting on number of SD to marketing for six cultivars (averaged over stick week). L.s.d. 5% for treatment comparisons within cultivars = 1.7 SD.**




It had been expected that cropping would be fastest for pots stuck in week 41 since these received the highest PAR integrals during the first weeks of SD (see earlier, Section 2.3.1). However, pots stuck in week 41 actually took longer to reach the marketing stage than those stuck in either week 45 or 48. The reason for this is unclear, but it is likely that pots from the week 41 stick were harvested at a relatively later stage of maturity compared to pots from weeks 45 and 48. This explanation is suggested by the observation that plants from the week 41 stick averaged 0.62 breaks with 3 or more open flowers, as compared to only 0.04 breaks for week 48 pots that had received a generally similar total light integral but higher integrals during flower maturation.

### 2.3.3 Plant height and spread

Pots were grown to a winter height specification of 16-23 cm above the pot rim. However, the minimum specification proved difficult to achieve for all cultivars stuck in week 45, except Trenton and Prize Time, and for two of the cultivars stuck in week 48, Ivory Time and Mirimar (see Fig. 2.5).

The crop diary (Appendix 5) shows that no cultivar received more than two applications of B-Nine (generally at final spacing and about one month before harvest) and that one or no applications were not uncommon. It is clear, therefore, that the environments in which the pots grew were conducive to compact (or overly-compact) growth. Compact habit has generally proved to be a characteristic of pots grown in winter under continuous supplementary lighting (see PC 92e), reflecting the low far-red content of SON/T radiation (which promotes plant extension growth) at a time of year when natural solar radiation is at its lowest. Compact habit is generally perceived as being a positive benefit, but only when this is shown in pots reaching minimum height specifications! Particular care will need to be taken, therefore, to ensure that adequate LD are given, and that growth regulant treatments and other cultural aspects that affect height, such as irrigation, are optimized to ensure that minimum height specifications are met when supplementary lighting is used on naturally short cultivars such as Mirimar and Ivory Time stuck around week 45. No problems were found in reaching the minimum specification for pot spread, 25 cm.

**Fig. 2.5. Pot height averaged over lighting treatments, for 6 cultivars stuck in weeks 41. 45 and 48. Dashed lines indicates minimum and maximum height specifications**

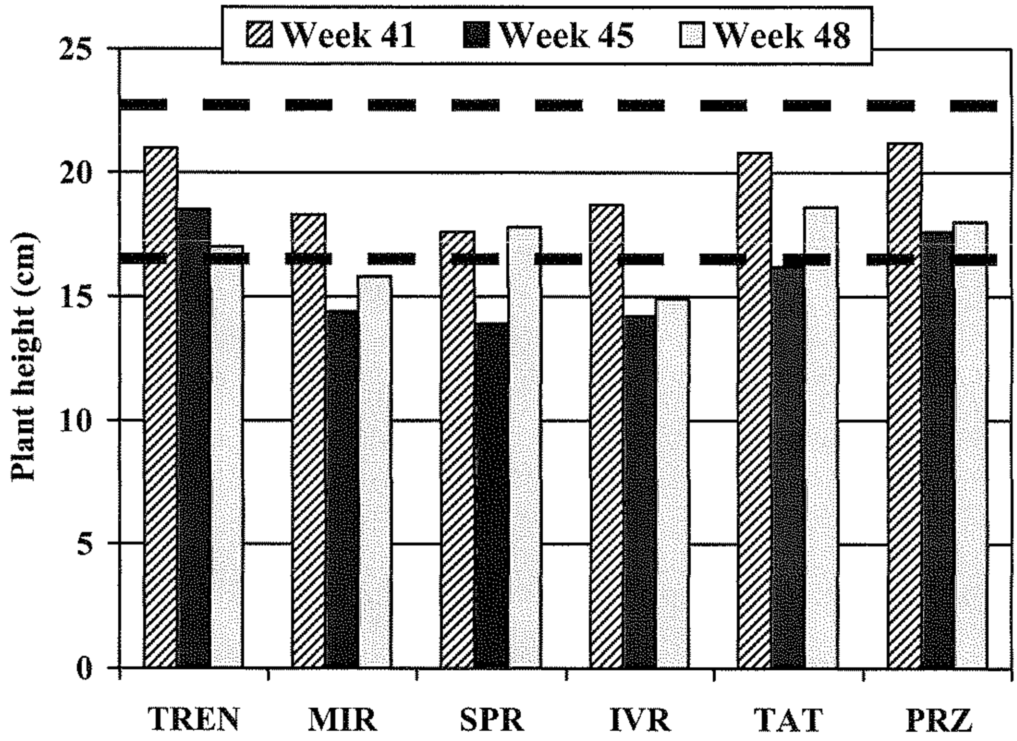



Table 2.4 shows the effects of lighting treatment on average plant height and plant spread (diameter), averaged over cultivars (full data are shown in Appendix 3). As can be seen, there were no significant differences in plant height or in plant spread due to lighting treatment. Such differences as were shown could clearly be ascribed to random pot-to- pot variation. Thus, doubling the irradiance from 4.8 $W/m^2$ to 9.6 $W/m^2$ gave no extra reduction in extension growth, and is likely to give no additional difficulty in reaching height or spread specifications in commercial production.

**Table 2.4 Average plant height (cm) and plant spread (cm) at marketing**

| | Stick week | | | | | |
|---|---|---|---|---|---|---|
| | 41 | | 45 | | 48 | |
| **Lighting treatment** | **Height** | **Spread** | **Height** | **Spread** | **Height** | **Spread** |
| **4.8 $W/m^2$** | 19.8 | 34.3 | 15.4 | 33.8 | 17.4 | 35.8 |
| **9.6 $W/m^2$** | 19.4 | 33.8 | 16.1 | 33.7 | 16.9 | 35.2 |
| **Significance of difference** | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. |

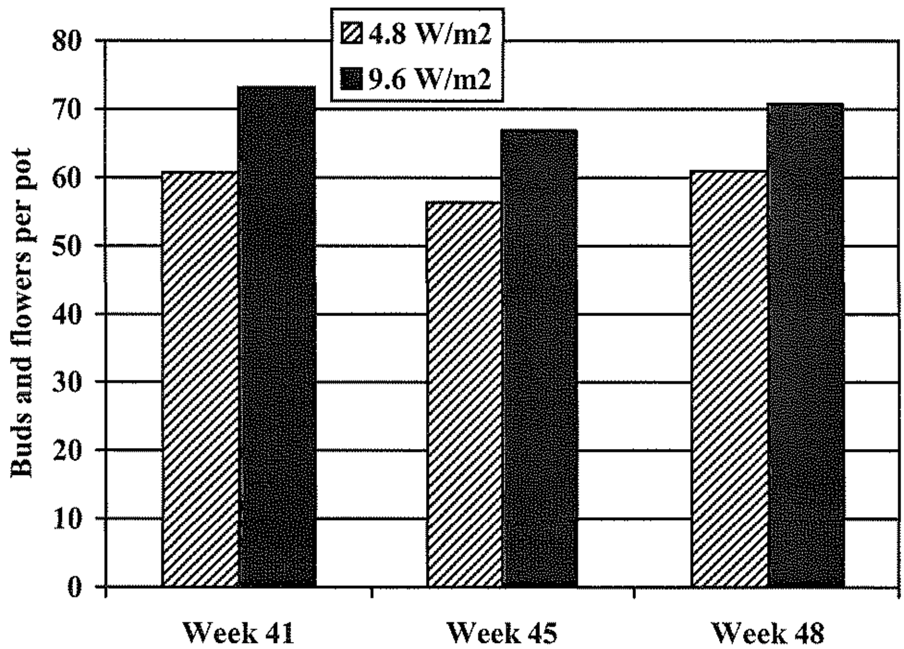
n.s. = non-significant difference

### 2.3.4 Buds and flowers at marketing

The expectation based on previous experimentation (see PC 92e) was that total bud and flower numbers (averaged over lighting treatments) would be highest in pots stuck in week 48 since these received the highest light integrals during the final three weeks of SD (see earlier, Section 2.3.1). Week 48 pots certainly had more buds and flowers than week 45 pots (+6.5%, 65.8 versus 61.5; P<0.01), but had no more buds and flowers than week 41 pots (65.8 versus 66.8). This was probably because week 41 pots were harvested at a more mature stage than week 48 pots (see earlier).

As shown in Fig. 2.6, doubling the irradiance from 4.8 $W/m^2$ to 9.6 $W/m^2$ increased the total number of buds and flowers per pot (averaged over cultivar) by an average of 18.4% with little obvious effect of stick week (range from +16.0% in week 48 to +20.4% in week 41).

**Fig 2.6 Effects of lighting treatments on buds and flowers per pot for three stick weeks (averaged over cultivars). All differences within stick weeks significant at P<0.01.**



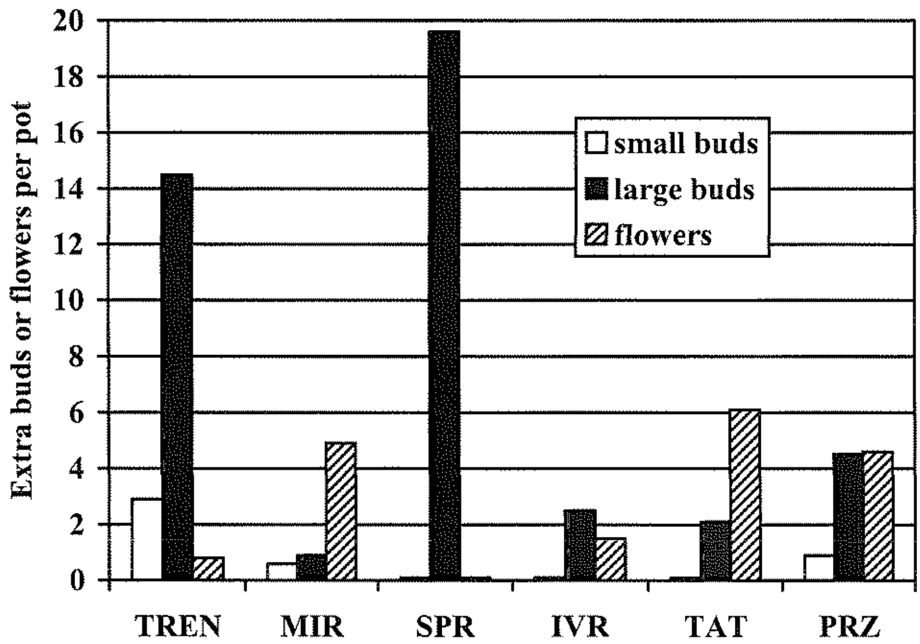

The increase in total buds and flowers varied between cultivars, ranging from +11.4% for Tattoo Time to +28.0% for Springfield (averaged over stick week) (see Appendix 3). However, increases in flowers has more obvious impact on visual quality and, presumably, on commercial value, than increases in buds and, as seen in Fig. 2.7, increases in the three bud and flower categories for a given cultivar were rarely equal. The average increase (over all cultivars) in flowers per pot due to increased irradiance was 2.4 flowers (+12.6%), but this was primarily due to significant increases (P<0.001) for Mirimar (+4.8 flowers, +14.7%), Tattoo Time (+6.1 flowers, +36.7%) and Prize Time (+4.6 flowers, +22.9%). There was also a smaller but useful increase in flowers per pot (P<0.05) for Ivory Time (+1.5 flowers, +11.1%). Assuming that flowers per pot is a useful yardstick of quality, then increasing the irradiance gave enhanced quality in Mirimar, Tattoo Time and Prize Time, a marginal improvement in

Ivory Time, but no obvious improvement in Trenton and Springfield. In the case of these latter two cultivars, increasing the irradiance primarily increased the numbers of large buds ($P<0.001$ in each case).

The potential for increasing flowers in Mirimar and Tattoo Time by increasing the irradiance might be particularly useful in that these cultivars were judged at the outset to be marginal for winter production in the UK (Table 2.1). Overall, however, there appeared no obvious relationship between total flower count and increase in flowers due to increased irradiance. Thus, Springfield and Ivory Time had the smallest numbers of flowers per pot when lit at 4.8 $W/m^2$ (15.4 and 13.4 respectively), but the former showed no increase in flowers when lit at 9.6 $W/m^2$, and the latter showed only a small increase in flowers (as detailed above).

It is not clear why some cultivars developed many additional buds whilst others developed extra flowers when the irradiance of supplementary lighting was raised. This may reflect differences between the cultivars in the speed with which the total complement of flowers and buds were set. Thus, cultivars that set all of their buds quickly, developed these together and finished with more open flowers, whilst cultivars that set their buds more slowly ended with few extra flowers, but many extra buds. However, this is purely speculation.

**Fig. 2.7 Increases in numbers of small buds (stage <1), large buds (stage 1-3) and flowers (stage 4-8) per pot due to increasing the irradiance from 4.8 to 9.6 $W/m^2$**




### 2.3.5 Plant dry weight per pot

Dry weight reflects photosynthetic growth made by the plant and, in general, the higher the dry weight, the higher the pot quality. Analysis showed that, averaging over all stick dates and cultivars, lighting at 9.6 $W/m^2$ increased dry weight per pot over that given by lighting at 4.8

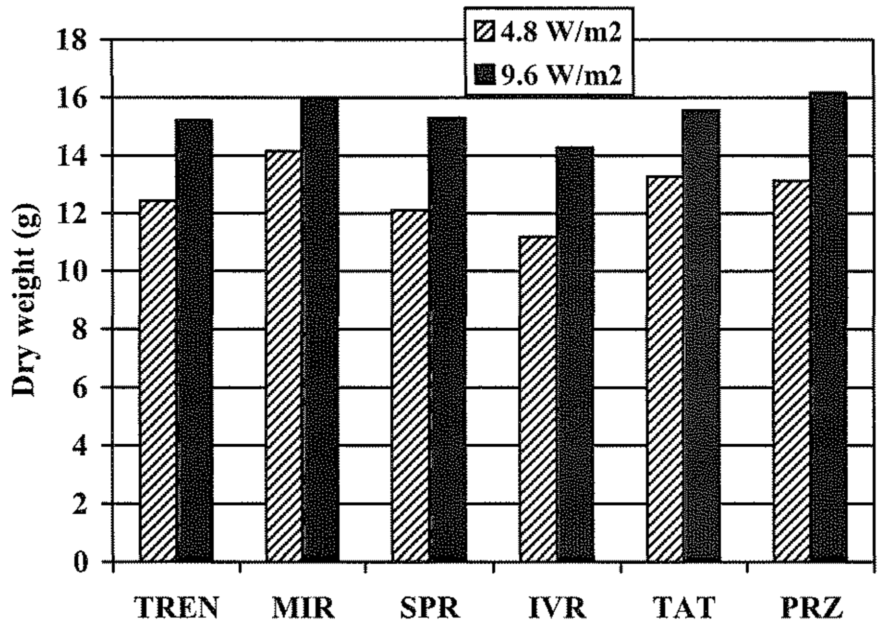
$W/m^2$ by about 21% (P<0.01). However, the % dry weight increase varied between stick dates (Table 2.5) with the greatest increase being given for the week 45 stick when natural solar radiation was lowest. In this case, pot dry weight was increased by 34.6% for an increase in total PAR radiation received of 11.1%. Significant increases in dry weight due to the higher level of supplementary lighting were shown by all cultivars (Fig. 2.8), ranging from 12.9% for Mirimar to 27.4% for Ivory Time.

**Table 2.5 Effects of lighting treatment on dry weight per pot (g)**

| | Stick week | | |
|---|---|---|---|
| **Lighting treatment** | **41** | **45** | **48** |
| **4.8 $W/m^2$** | 13.87 | 10.73 | 13.55 |
| **9.6 $W/m^2$** | 16.44 | 14.44 | 15.34 |
| **Significance of difference** | n.s. | * | n.s. |

n.s. non-significant; * significant at P<0.05

**Fig. 2.8 Effects of lighting treatments on dry weight per pot for six cultivars (averaged over sticking date). L.s.d. 5% for treatment comparisons within cultivars = 0.88 g**




### 2.3.6 Home-life performance

*Survival in home life*

Pots remained in home life until it was judged that their useful home life had ended. As shown in Fig 2.9, only about 20% of pots survived to the end of the 4-week home-life trial, and there was no effect of lighting treatment on survival. For pot number statistics see Appendix 4a.

*Flowers per pot*

Pots raised at the higher light level had a greater number of flowers (stage 4 and above) at the start of home life than pots grown at the lower light level, and this difference was maintained through home life. This is shown in Fig. 2.10 for Ivory Time, chosen because only about 5% of pots had been lost by the end of week 3, and being typical in showing a small increase in flowers per pot during home life, reflecting some continued bud opening. However, there was no indication that the degree of bud opening was affected by prior lighting treatment.

**Fig. 2.9 Survival in home life (numbers of pots remaining expressed as a percentage of those at de-sleeving).**

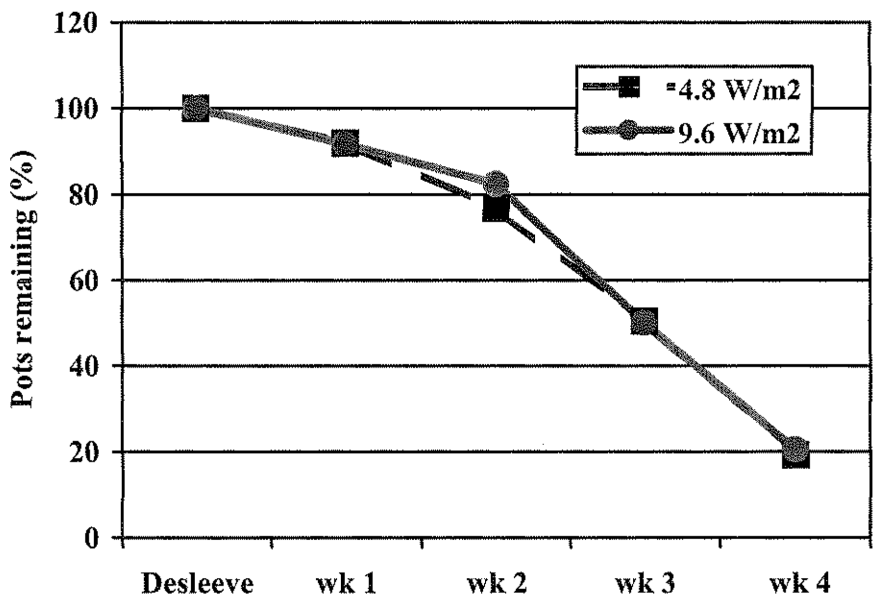
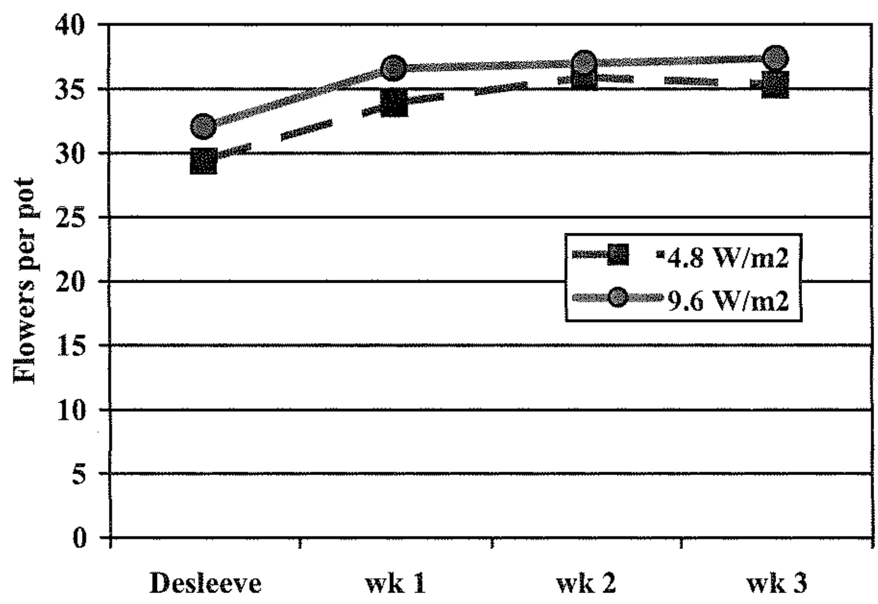



**Fig. 2.10 Numbers of flowers per pot (stage 4 or above) during the first 3 weeks of home life for Ivory Time. Results are averaged over stick week.**



*Distorted flowers per pot*

Table 2.6 shows average numbers of distorted flowers per pot after 2 weeks of home life, a reflection of uneven bud. Overall, levels were rather low in both lighting treatments, but were lowest when pots had been lit at 9.6 $W/m^2$. Since lighting conditions during home life were the same for both treatments, it is clear that lighting during production can have an influence on flower distortion, and that lighting at 9.6 $W/m^2$ can go some way to ameliorate the problem. Numbers of distorted flowers were highest in pots from the week 41 stick which finished in the poorest light, and in this case the respective numbers of distorted flowers per pot were 1.44 (4.8 $W/m^2$) and 0.51 (9.6 $W/m^2$). Levels of distortion were also affected by cultivar, with those most prone to the problem being Springfield (1.93 distorted flowers when lighting was at 4.8 $W/m^2$ - 4.00 in the week 41 stick), and Prize Time (1.13 distorted flowers). Neither had been identified at the outset as being marginal for winter quality.

**Table 2.6 Effects of lighting treatments on pot quality after 2 weeks of home life (averaged over cultivars and stick weeks).**

| | **Quality determinants** | | |
|---|---|---|---|
| **Lighting treatment** | **No. Distorted flowers per pot** | **Flower quality score (0-2 worst)** | **Foliage quality score (0-4 worst)** |
| **4.8 $W/m^2$** | 0.75 | 0.60 | 0.46 |
| **9.6 $W/m^2$** | 0.30 | 0.47 | 0.41 |
| **Significance of difference** | *** | ** | n.s. |

n.s. non-significant; ** significant at $P<0.01$; *** significant at $P<0.001$

*Flower and foliage quality scores*

Table 2.6 also shows average flower and foliage scores after 2 weeks of home life. This shows that prior lighting treatment can influence flower score during home life, since lighting at 9.6 $W/m^2$ significantly reduced flower deterioration. Flower deterioration scores were significantly higher in pots from the week 41 stick than in pots stuck later (0.67 against an average of 0.47) indicating that it is primarily light during the later stages of production that is important in determining flower deterioration.

There was no obvious effect of prior lighting treatment on foliage quality after 2 weeks of home life. However, there was a small, but significant, effect of stick week. This indicates that prior light conditions can affect this parameter (average scores of 1.38, 0.41 and 0.18 for weeks 41, 45 and 48 respectively).

### 2.3.7 Economic evaluation

Supplementary lighting has to be cost-effective for a grower using it to stay in business. Accordingly, a cost-benefit methodology has been established for pot chrysanthemum lighting and is fully described in PC 92e. The methodology outlined there is used here to give a more objective basis to comparisons between lighting at 4.8 $W/m^2$ and 9.6 $W/m^2$. It should be borne in mind, however, that actual costs of a given lighting treatment will inevitably vary from grower to grower since installation charges, the costs of borrowing money and electricity costs etc vary widely. For this reason, it is strongly recommended that growers considering installing new or replacement lighting should carry out their own cost-benefit analysis.

***Lighting costs per unit area***

Running costs, capital costs and total costs (pence/$m^2$/week) for the two irradiance regimes are presented in Table 2.7. As in PC 92e, running costs take account of the area lit by a single 400 W or 600 W SON/T lamp, the electrical energy used in 'burning' the lamp, and the cost of electrical energy. These figures are then adjusted on the assumption that 50% Climate Change Levy (CCL) is paid on electricity costs (0.215 pence/kWh), and are then reduced to reflect the contribution that the lamps make to glasshouse heating costs.

PC 92e uses estimates of glasshouse area lit by a single lamp obtained from Hortilux Schreder. These assume that, averaged over the glasshouse as a whole, a single 400 W lamp lights an area of 22.5 $m^2$ when the glasshouse is at an irradiance of 4.8 $W/m^2$, and an area of 11.2 $m^2$ when the glasshouse is at an irradiance of 9.6 $W/m^2$. The area increases to 18.2 $m^2$ for an irradiance of 9.6 $W/m^2$ when 600 W lamps are used instead of 400 W lamps (600 W lamps are not suited to lighting at the lower irradiance since they give non-uniform lighting when installed at conventional mounting heights). However, Chris Plackett of the Farm Energy Centre has suggested that these relationships overestimate the areas lit, and has provided data suggesting that more appropriate areas are 15.2 $m^2$ for an irradiance of 4.8 $W/m^2$, and 7.6 $m^2$ (400 W lamps) or 13.22 $m^2$ (600 W lamps) for an irradiance of 9.6 $W/m^2$. Both the Hortilux Schreder and the Plackett estimates are used in arriving at the running costs in Table 2.7.

Estimates of electrical energy used per lamp are taken directly from PC 92e for a daily lighting duration of 12h 15m. These are 38.84 kWh/week for 400 W lamps and 55.31 kWh/week for 600 W lamps. It is assumed that all lighting will be during the 'standard' tariff period and a generalized figure for electricity of 5.50 pence/kWh has been used for calculation purposes. In adjusting running costs it is assumed that heat from the lamps substitutes for glasshouse heating based on gas oil priced at 20 pence per litre and with a calorific value of 10.93 kWh per litre, fueling a boiler with an efficiency of 70%. The calculation procedure (see PC 92e) takes account of the glasshouse area lit per lamp and, as a consequence, is very sensitive to the assumptions made. Again, both the Hortilux Schreder and Plackett estimates are used. The methodology in PC 92e assumes that all of the heat generated by the lamps substitutes for glasshouse heating and this is also assumed in Table 2.7 for calculations based on Hortilux Schreder lamp data. However, Chris Plackett has suggested that 25% of the heat from the lamps is probably lost since the lamps are sited high up in the roof of the glasshouse.

Accordingly the calculations in Table 2.7 based on Plackett lamp data assume that only 75% of the heat from the lamps substitutes for glasshouse heating costs.

It is clear from Table 2.7 that estimates of electrical running costs can vary greatly depending on the assumptions made. The Plackett assumptions, for example, increase the estimates given by using the methodology in PC 92e by about 67% when 400 W lamps are used and by about 54% when 600 W lamps are used. As might be expected, the running costs for an irradiance of 9.6 W/m$^2$ are double those for an irradiance of 4.8 W/m$^2$ when the same wattage lamps are used, but costs are reduced by between 10 and 17% when 600 W lamps rather than 400 W lamps are used to achieve the higher irradiance. This saving is only available, however, if sufficient headroom above the crop (minimum 3m) is available to mount the higher wattage lamps.

Capital costs on a unit area basis are calculated as in PC 92e. It is assumed that the lamps are purchased at £150 each (installed) and that this cost is amortized over 5 years at 9% annual interest to give an annual cost per lamp of £37.44. Dividing this figure by glasshouse area per lamp and converting to pence/m$^2$/week gives capital costs on an annual basis. The figures in Table 2.7 have, however, been doubled so that capital costs are wholly assigned to the weeks of the year when lighting is used (assumed to be 26 weeks).

Total costs of lighting in Table 2.7 are derived by simply adding running and capital costs. All lighting costs are thus assigned to the 26 weeks when lighting is assumed to be in use. It is a simple matter to convert these costs to an annual basis if this is required. The total costs for an irradiance of 9.6 W/m$^2$ are double those for an irradiance of 4.8 W/m$^2$ when the same wattage lamps are used, but costs are reduced by between 24 and 29% when 600 W rather than 400 W lamps are used to achieve the higher irradiance.

**Table 2.7 Estimated lighting costs per unit area assuming either Hortilux Schreder (HS) or Plackett (P) estimates of area lit per lamp. Costs assume 50% CCL and are reduced to reflect expected savings in heating costs.**

| **Irradiance** | **4.8 W/m$^2$** | | **9.6 W/m$^2$** | | | |
|---|---|---|---|---|---|---|
| **Lamp wattage** | **400** | | **400** | | **600** | |
| **Authority** | **HS** | **P** | **HS** | **P** | **HS** | **P** |
| **Area lit per lamp (m$^2$)** | 22.5 | 15.2 | 11.2 | 7.6 | 18.2 | 13.2 |
| **Running costs (pence/m$^2$/week)*** | 6.58 | 10.96 | 13.21 | 22.03 | 11.82 | 18.19 |
| **Capital costs (pence/m$^2$/week)*** | 6.40 | 9.48 | 12.86 | 19.04 | 7.92 | 10.90 |
| **Total costs (pence/m$^2$/week)*** | 12.98 | 20.44 | 26.07 | 41.07 | 19.74 | 29.09 |

* All costs are assigned to the 26 weeks of the year when lighting is assumed to be in use.

*Lighting costs per pot*

Costs per unit area are converted to costs per pot in Table 2.8. The methodology for this is given in PC92e. It is assumed that the glasshouse area under the lamps is fully occupied by pots, and that the pots at 4.8 W/m$^2$ take 8.86 weeks of SD to reach the marketing stage whilst pots at 9.6 W/m$^2$ take 8.48 weeks. The calculation takes account of the spacing used (standard) and that lighting is used for 26 weeks per year. It should be noted that costs per pot are per lit pot, and that no attempt has been made to average costs over all pots produced during the year. As with costs per unit area, doubling the irradiance doubles the lighting costs per lit pot, but lighting with 600 W lamps reduces costs per lit pot by between 24 and 29%.

**Table 2.8 Estimated lighting costs per pot assuming either Hortilux Schreder (HS) or Plackett (P) estimates of area lit per lamp. Costs assume 50% CCL and are reduced to reflect expected savings in heating costs.**

| **Irradiance** | **4.8 W/m$^2$** | | **9.6 W/m$^2$** | | | |
|---|---|---|---|---|---|---|
| **Lamp wattage** | **400** | | **400** | | **600** | |
| **Authority** | **HS** | **P** | **HS** | **P** | **HS** | **P** |
| **Running costs (pence/m$^2$/pot)** | 3.83 | 6.38 | 7.35 | 12.21 | 6.55 | 10.08 |
| **Capital costs (pence/m$^2$/pot)** | 3.71 | 4.74 | 7.11 | 9.52 | 4.39 | 5.45 |
| **Total costs* (pence/m$^2$/pot)** | 7.54 | 11.12 | 14.46 | 21.73 | 10.94 | 15.53 |

* costs of lighting for 26 weeks apportioned to lit pots only.

*Cost-benefit analysis*

The costs of lighting of the two regimes calculated above take no account of differences in numbers of pots produced over the year as a whole as a consequence of differences in crop throughput. This has to be taken into account when overall benefits of the two lighting regimes are assessed. Similarly, benefits need to take account of possible differences in pot quality which can increase average annual returns. The following is an attempt to balance the costs and benefits of lighting as reflected in the grower's final production 'margin'. The methodology (and unitary costs) follow those in PC 92e exactly.

The calculations have been made on the assumption that pot mums are produced on an area of 5,000 m$^2$ with 85% space utilization. Approximately 283 m$^2$ of the cropped area will need to be given over to propagation (51 pots/m$^2$), with time in propagation varying between 2 and 3 weeks per crop over the year. It is assumed that this area is unlit. An area of double this size (567 m$^2$) will house pots at half spacing (27 pots/m$^2$), and pots will remain there for just 2 weeks, regardless of time of year or whether lit or not. The remaining area, 3,400 m$^2$, will house pots at final spacing (13.5 pots/m$^2$). Calculations of increased throughput when lighting is used are based solely on faster production, and increased numbers of pots coming off this final production area in the course of a year.

Rates of production during the lighting season are based on estimates of average numbers of days crops would be likely to spend at final spacing. These are shown in Table 2.9. Cropping durations for stick weeks 43-4 in Table 2.9 are average SD found for stick weeks 45 and 48 in this present study (data in Table 2.3 minus 14 days at half-spacing). However, data for stick weeks 5-9 and 36-42 are not based on that for week 41 in the present study. This is because the week 41 pots were probably harvested at a more mature stage than those stuck in weeks 45 and 48. Instead, it has simply been assumed that crops stuck in weeks 5-9 and 36-42 will reach harvest 2 days faster than those stuck in weeks 43-4. The figure for week 10-35, 40 days, is simply based on grower experience of summer growing (as per PC 92e). These figures enable calculations to be made of the annual increase in numbers of pots produced when lighting is raised from 4.8 to 9.6 W/m$^2$ (during 26 weeks of the year). This increase amounts to 2.83%. The calculation assumes standard spacing (27 pots/m$^2$ at half-spacing and 13.5 pots/m$^2$ at final spacing).

**Table 2.9 Assumptions made for numbers of SD to harvest at final spacing**

| | Lighting regime | |
|---|---|---|
| | **4.8 W/m$^2$** | **9.6 W/m$^2$** |
| **Stick weeks 10-34** | 40.0 | 40.0 |
| **Stick weeks 5-9 and 36-42** | 44.3 | 41.6 |
| **Stick weeks 43-4** | 46.3 | 43.6 |

This increase has been factored into a cost-benefit analysis using the costs given in PC 92e (see Table 2.10). These costs exclude transport, maintenance, office overheads, depreciation, interest charges (except in relation to capital costs of lighting installations) and management. Costs of lighting take account of heat savings from the use of lamps and assume payment of CCL at the 50% rate.

Two further, crucial assumptions made are that:

a) wastage will be reduced from 1.0% to 0.5% when irradiance is raised to 9.6 W/m$^2$, and
b) returns per marketed pot will remain unchanged at £1.10p, and that this price will be constant though the year.

**Table 2.10 Cost-benefit analysis based on annual production from 5,000 m²**

| | Irradiance (lamp wattage) | | |
|---|---|---|---|
| | 4.8 W/m² (400 W lamps) | 9.6 W/m² (400 W lamps) | 9.6 W/m² (600 W lamps) |
| **Heating costs (£)** | 37,400 | 37,400 | 37,400 |
| **Cuttings (£)** | 50,864 | 52,306 | 52,306 |
| **Pots (£)** | 13,682 | 14,070 | 14,070 |
| **Compost (£)** | 14,240 | 14,644 | 14,644 |
| **Water (£)** | 1,875 | 1,875 | 1,875 |
| **Fertilisers (£)** | 1,250 | 1,250 | 1,250 |
| **PGRs (£)** | 3,125 | 3,125 | 3,125 |
| **P&D control (£)** | 3,125 | 3,125 | 3,125 |
| **Night-break (£)** | 1,563 | 1,563 | 1,563 |
| **Pot sleeves (£)** | 19,000 | 19,539 | 19,539 |
| **Boxes (£)** | 26,380 | 27,128 | 27,128 |
| **Labour (£)** | 67,705 | 67,705 | 67,705 |
| **Lighting (£)** | 15,749 [24,800]* | 31,631 [49,832]* | 23,952 [35,296]* |
| | | | |
| **Total costs (£)** | 255,958 [265009]* | 275,361 [293,562]* | 267,682 [279,026]* |
| **Total pots produced** | 393,380 | 404,532 | 404,532 |
| **Total pots marketed** | 389,446 | 402,509 | 402,509 |
| **Cost per marketed pot (£)** | 0.657 [0.680]* | 0.684 [0.729]* | 0.665 [0.693]* |
| **Av. return per pot (£)** | 1.10 | 1.10 | 1.10 |
| **Total annual return (£)** | 428,391 | 442,760 | 442,760 |
| **Return minus costs (£)** | 172,433 [163,382]* | 167,399 [149,198]* | 175,078 [163,734]* |
| **% increased margin** | -- -- | -2.9 [-8.7]* | +1.5 [+0.2]* |

* these figures assume Plackett area per lamp.

The cost-benefit analysis shown in Table 2.10 indicates that supplementary lighting constitutes about 6.2% of total production costs when used at an irradiance of 4.8 W/m² for 12h 15m per day and assuming that the Hortilux Schreder estimates of lit area per lamp are correct. This is slightly more than that calculated in PC 92e (5.6%) since this latter took no account of CCL, was based on 11h of light per day and assumed a marginally different effect of this irradiance on harvest duration. The figure of 6.2% increases to 9.4% when the Plackett modifications are included. Percentage costs of lighting when the irradiance is increased to 9.6 W/m² are 11.5% (Hortilux Schreder assumptions) and 17.0% (Plackett assumptions), but these reduce to 8.9% and 12.6% respectively when 600 W lamps are used rather than 400 W lamps.

On the assumptions of slightly faster flowering and a reduction of waste from 1% to 0.5%, lighting at 9.6 $W/m^2$ is as cost effective as lighting at 4.8 $W/m^2$ so long as 600 W lamps are used. This is the case whether the Hortilux Schreder or Plackett figures are correct. It must be borne in mind, however, that sufficient headroom needs to be available in order to benefit from the greater efficiency of 600 W lamps.

Raising the irradiance from 4.8 to 9.6 $W/m^2$ appears not to be cost effective if 400 W lamps have to be used. In this case an additional increase in revenue of 1 to 3 pence per pot would be needed to cover increased production costs. On a more positive note, however, lighting at the higher irradiance should give the grower a greater assurance of meeting market quality requirements, especially for buds and flowers per pot in low light years, will enable the grower to produce a wide range of flower types to meet continuously changing market needs, and will ensure the continued appeal of the UK pot chrysanthemum in the face of competing alternatives produced either in the UK or overseas.

## 2.4 SUMMARY

### *Production time*

- Pots grown with supplementary lighting at an irradiance of 9.6 $W/m^2$ for 12h 15m per day reached the marketing stage 2.2 to 3.0 days ahead of pots grown with supplementary lighting at 4.8 $W/m^2$. Stick date had little obvious influence on this. Previous work has shown that crops lit at 4.8 $W/m^2$ reach the marketing stage 4-5 days ahead of unlit crops, so it seems that doubling the level of lighting from 4.8 to 9.6 $W/m^2$ gives about a 50% additional saving in production time. All cultivars were advanced by the higher irradiance treatment.

### *Plant height and spread*

- The use of supplementary lighting made it difficult to meet the minimum height specification of 16-23 cm above the pot rim, particularly for pots stuck in week 45 which received the lowest solar radiation levels. However, the problem was no greater when supplementary lighting was applied at 9.6 $W/m^2$ than at 4.8 $W/m^2$. No problems were found in reaching the minimum specification for pot spread, 25 cm.

### *Flower development*

- Doubling the irradiance of supplementary lighting from 4.8 $W/m^2$ to 9.6 $W/m^2$ increased the total number of buds and flowers per pot (averaged over cultivars and stick weeks) by 18.4%. The percentage increase in flowers per pot was smaller, averaging 12.6%. Not all cultivars benefitted equally, and the largest increases in number of flowers per pot where shown by Mirimar (+4.8 flowers, +14.7%), Tattoo Time (+6.1 flowers, +36.7%) and Prize

Time (+4.6 flowers, +22.9%). There was also a smaller but useful increase in flowers per pot in Ivory Time (+1.5 flowers, +11.1%). Assuming flowers per pot is a useful yardstick of quality, then increasing the irradiance of supplementary lighting gave enhanced quality in Mirimar, Tattoo Time and Prize Time, a marginal improvement in Ivory Time, but no obvious improvement in Trenton and Springfield. In these latter two cultivars, increasing the irradiance primarily increased the numbers of large buds. There appeared to be no obvious relationship between total flower count and increase in flowers due to increased irradiance.

- Previous studies have shown that flower and bud numbers tend to be greater in pots stuck in week 48 than in pots stuck in either week 41 or 45, since the week 48 pots receive the highest light integrals during the final three weeks of SD. Week 48 pots certainly had more buds and flowers than week 45 pots in this trial, but had no more buds and flowers than week 41 pots. This was probably because week 41 pots were harvested at a more mature stage than week 45 or week 48 pots.

***Plant dry weight***

- Dry weight reflects photosynthetic growth made by the plant and, in general, the higher the dry weight, the higher the quality. Lighting at 9.6 $W/m^2$ increased dry weight per pot over that given by lighting at 4.8 $W/m^2$ by about 21% on average, but by up to 34.6% for pots stuck in week 45 when natural solar radiation was lowest.

***Home life***

- Only about 20% of pots were judged still to be of reasonable quality after 4 weeks of home life, and this was not affected by prior supplementary lighting treatment.

- Pots grown at the higher light level had a greater number of open flowers at the start of home life than pots grown at the lower light level, and this difference was maintained through home life. In general, pots showed a modest increase in the number of flowers per pot during home life, reflecting some continued bud opening. However, the increase in the number of open flowers was not affected by prior lighting treatment.

- Numbers of distorted flowers per pot (which reflect uneven bud opening) were low after 2 weeks of home life, but were lowest when pots had been lit at 9.6 $W/m^2$. Since lighting conditions during home life were the same for both treatments, it is clear that lighting during production had had an influence on flower distortion, and that lighting at 9.6 $W/m^2$ can go some way to ameliorate the problem.

- Prior lighting at 9.6 $W/m^2$ also significantly reduced flower deterioration during home life. Flower deterioration scores were significantly higher in pots from the week 41 stick than from pots stuck later, indicating that it is primarily light during the later stages of production that is important. There was no obvious effect of prior lighting treatment on foliage quality after 2 weeks of home life.

***Economic evaluation***

- It was calculated that lighting at 4.8 $W/m^2$ increased the cost per lit pot by between 7.54 and 11.12 pence depending on assumptions made regarding glasshouse area lit per lamp. This cost was doubled when lighting was increased to 9.6 $W/m^2$ using the same wattage lamps (400 W SON/T). The increased cost of the higher irradiance was, however, reduced by 24-29% when 600 W lamps were used (assuming sufficient available headroom to mount 600 W lamps).

- A cost-benefit analysis was done taking into account the slightly faster cropping (and greater throughput) given by lighting at 9.6 $W/m^2$ as against 4.8 $W/m^2$. It was further assumed that wastage is reduced from 1.0% to 0.5% when the irradiance is increased from 4.8 $W/m^2$ to 9.6 $W/m^2$ but that return per marketed pot will remain unchanged at £1.10. This showed that lighting at 9.6 $W/m^2$ is likely to be as cost effective as lighting at 4.8 $W/m^2$ so long as 600 W lamps are used to achieve the increased irradiance. Raising the irradiance using 400 W lamps will require an extra 1-3 pence per pot to be achieved to cover the additional costs.

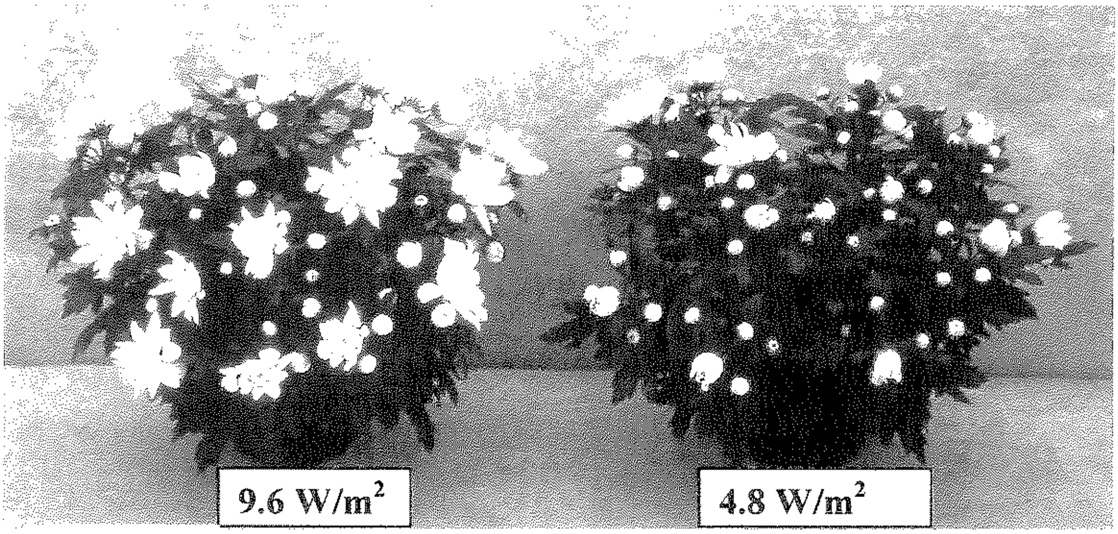
- On a more positive note, lighting at the higher irradiance should give the grower a greater assurance of meeting market quality requirements, especially for buds and flowers per pot in low light years, will enable the grower to produce a wide range of flower types to meet continuously changing market needs, and will ensure the continued appeal of the UK pot chrysanthemum in the face of competing alternatives produced either in the UK or overseas.

# APPENDICES

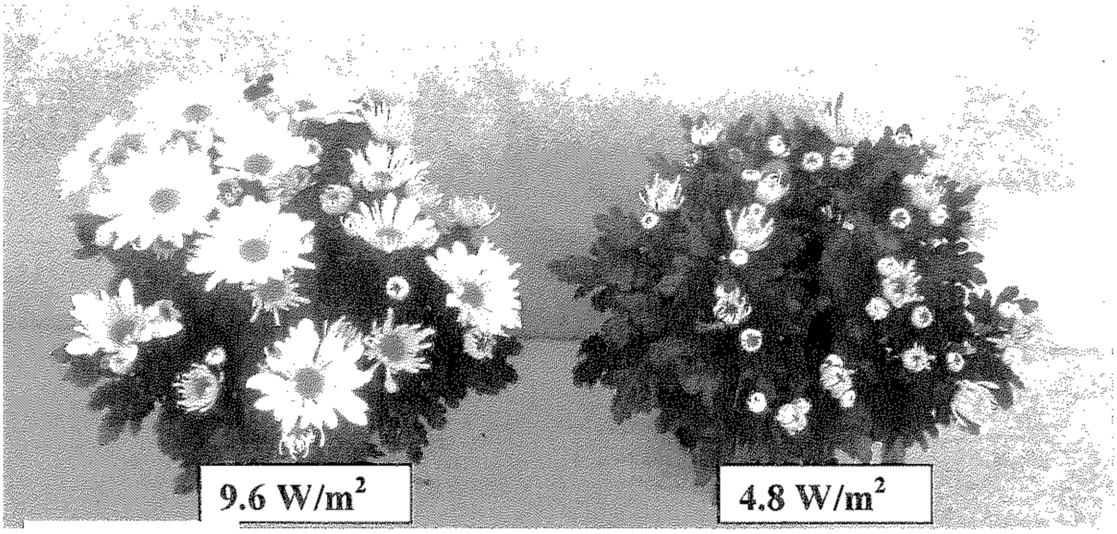
**APPENDIX 1 Photographic Record**

**Plate 1. General view of one compartment used for the lighting trials at Efford**

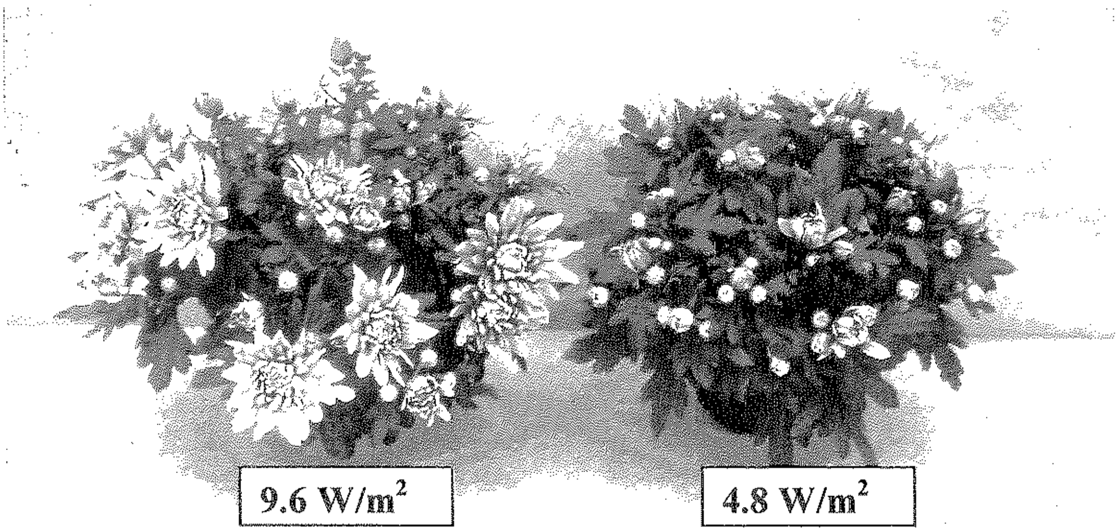
**Plate 2. Representative pots (stick week 45) photographed towards the end of production.**



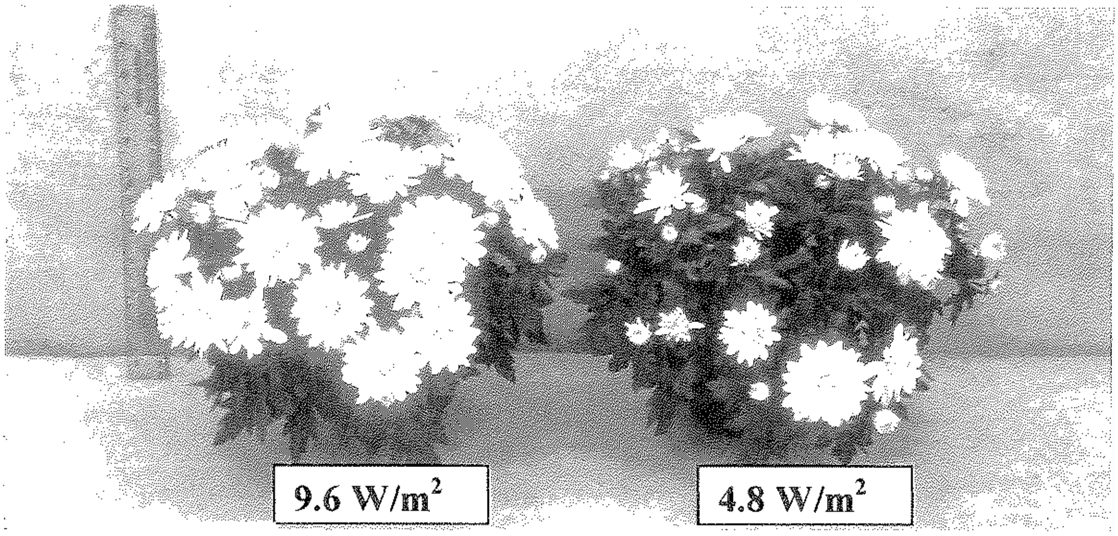

**a) Trenton**



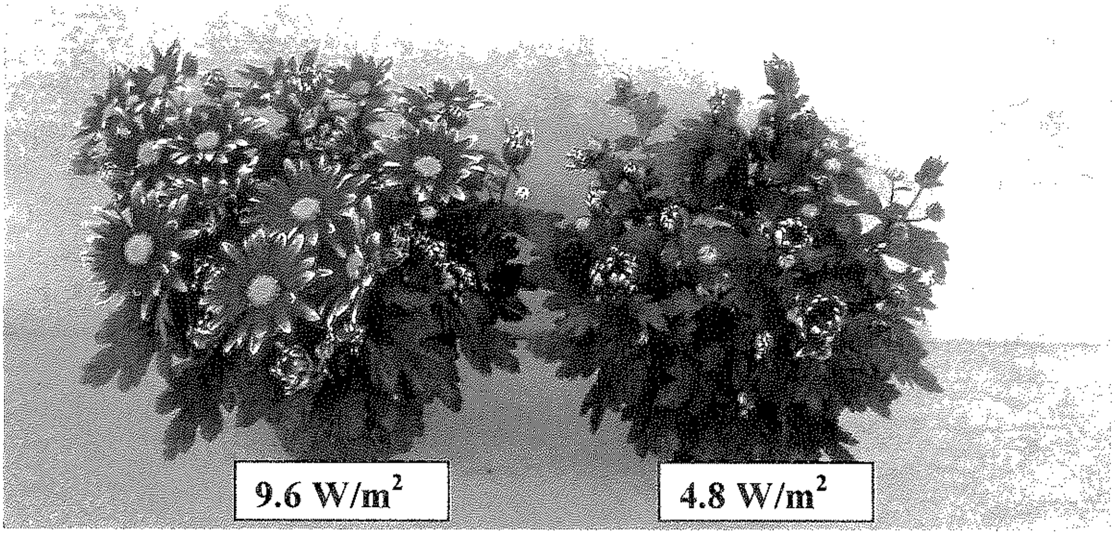

**b) Mirimar**



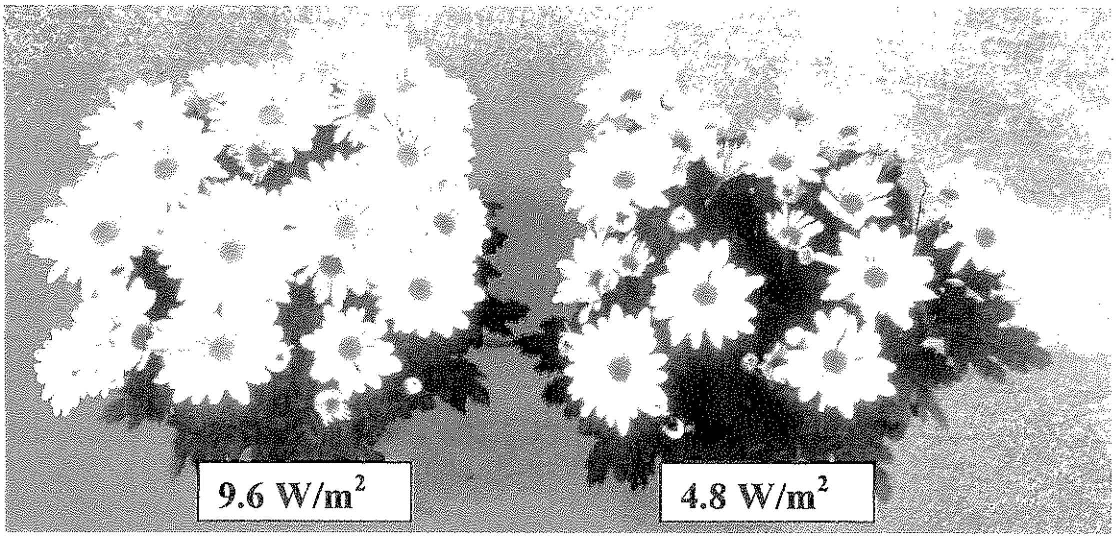

**c) Springfield**




d) Ivory Time




e) Tattoo Time




f) Prize Time

**APPENDIX : 2** **Trial Plan** Layout of trial in F Block compartments 2-5. Codes for cultivars are as given below.

GLP 3074

| Compartment 2 | | | 3 | | | 4 | | | 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| GUARD | GUARD | GUARD | GUARD | GUARD | GUARD | GUARD | GUARD | GUARD | GUARD | GUARD | GUARD |
| 6 54 | 2 6 | 6 30 | 1 36 | 6 12 | 3 60 | 2 42 | 3 66 | 6 18 | 6 72 | 4 48 | 2 24 |
| 3 53 | 1 5 | 3 29 | 6 35 | 3 11 | 1 59 | 5 41 | 2 65 | 3 17 | 3 71 | 3 47 | 5 23 |
| 5 52 | 4 4 | 1 28 | 4 34 | 5 10 | 5 58 | 1 40 | 4 64 | 1 16 | 5 70 | 1 46 | 3 22 |
| 2 51 | 3 3 | 2 27 | 5 33 | 4 9 | 2 57 | 6 39 | 5 63 | 4 15 | 2 69 | 2 45 | 6 21 |
| 4 50 | 6 2 | 5 26 | 2 32 | 1 8 | 4 56 | 3 38 | 1 62 | 2 14 | 6 68 | 5 44 | 4 20 |
| 1 49 | 5 1 | 4 25 | 3 31 | 2 7 | 6 55 | 4 37 | 6 61 | 5 13 | 1 67 | 6 43 | 1 19 |
| 48 | 41 | 45 | 45 | 41 | 48 | 45 | 48 | 41 | 48 | 45 | 41 |
| 4.8 W/m² (A) | | | 9.6 W/m² (B) | | | 4.8 W/m² (A) | | | 9.6 W/m² (B) | | |

| **Code** | **Cultivar** |
|---|---|
| 1 | Trenton |
| 2 | Mirimar |
| 3 | Springfield |
| 4 | Ivory Time |
| 5 | Tatoo Time |
| 6 | Prize Time |

## APPENDIX 3: Treatment means at marketing stage

a) **Number of short days (SD) to marketing**

| | Trenton | | Mirimar | | Springfield | |
|---|---|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 61.0 | 58.6 | 66.8 | 65.3 | 66.3 | 60.1 |
| 45 | 57.5 | 54.6 | 63.9 | 61.4 | 58.2 | 53.9 |
| 48 | 57.2 | 54.6 | 64.3 | 61.7 | 62.7 | 60.3 |

| | Ivory Time | | Tattoo Time | | Prize Time | |
|---|---|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 60.9 | 59.9 | 72.8 | 67.2 | 66.2 | 65.3 |
| 45 | 53.8 | 51.4 | 64.5 | 60.3 | 59.3 | 57.5 |
| 48 | 55.6 | 53.8 | 68.5 | 65.0 | 58.0 | 57.2 |

b) **Plant height above the pot rim (cm)**

| | Trenton | | Mirimar | | Springfield | |
|---|---|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 22.0 | 20.0 | 18.8 | 17.8 | 17.2 | 18.0 |
| 45 | 18.1 | 19.0 | 13.9 | 14.8 | 13.7 | 14.1 |
| 48 | 16.8 | 17.2 | 15.8 | 15.9 | 19.5 | 16.1 |

| | Ivory Time | | Tattoo Time | | Prize Time | |
|---|---|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 18.2 | 19.3 | 21.2 | 20.4 | 21.5 | 21.0 |
| 45 | 13.7 | 14.8 | 16.5 | 15.8 | 16.9 | 18.3 |
| 48 | 14.7 | 15.1 | 19.2 | 18.1 | 18.2 | 17.7 |

c) **Plant spread (diameter) (cm)**

| | Trenton | | Mirimar | | Springfield | |
|---|---|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 37.5 | 35.6 | 33.6 | 33.9 | 33.7 | 34.2 |
| 45 | 37.4 | 36.6 | 34.6 | 35.8 | 33.2 | 32.5 |
| 48 | 38.5 | 37.1 | 37.5 | 37.6 | 37.8 | 35.9 |

| | Ivory Time | | Tattoo Time | | Prize Time | |
|---|---|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 34.6 | 34.2 | 32.7 | 32.0 | 33.8 | 33.0 |
| 45 | 31.6 | 31.6 | 33.0 | 33.0 | 32.7 | 33.0 |
| 48 | 33.9 | 33.7 | 33.6 | 34.4 | 33.8 | 32.4 |

d) **Total number of buds and flowers per pot**

| | Trenton | | Mirimar | | Springfield | |
|---|---|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 86.6 | 115.7 | 56.6 | 64.9 | 60.9 | 80.9 |
| 45 | 78.6 | 86.2 | 55.1 | 68.0 | 51.7 | 63.7 |
| 48 | 84.0 | 98.9 | 59.8 | 66.4 | 56.4 | 72.0 |

| | Ivory Time | | Tattoo Time | | Prize Time | |
|---|---|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 49.3 | 55.3 | 62.3 | 67.9 | 52.1 | 61.6 |
| 45 | 44.7 | 50.6 | 61.8 | 73.4 | 49.2 | 62.0 |
| 48 | 53.9 | 61.3 | 66.4 | 70.9 | 48.4 | 58.5 |

e) **Number of small buds (flower stage <1) per pot**

| | Trenton | | Mirimar | | Springfield | |
|---|---|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 4.3 | 8.8 | 3.8 | 3.5 | 7.5 | 3.8 |
| 45 | 1.1 | 2.7 | 3.0 | 7.8 | 0.4 | 0.8 |
| 48 | 0.6 | 3.4 | 1.6 | 0.6 | 6.5 | 5.9 |

| | Ivory Time | | Tattoo Time | | Prize Time | |
|---|---|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 1.4 | 2.9 | 4.5 | 5.2 | 2.1 | 2.8 |
| 45 | 0.6 | 6.6 | 1.6 | 2.1 | 0.2 | 1.2 |
| 48 | 0.3 | 0.77 | 9.0 | 3.0 | 0.1 | 0.8 |

f) **Number of large buds (flower stage 1-3) per pot**

| | Trenton | | Mirimar | | Springfield | |
|---|---|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 63.5 | 75.5 | 11.1 | 5.1 | 26.0 | 55.2 |
| 45 | 55.7 | 68.3 | 21.9 | 25.8 | 37.6 | 51.9 |
| 48 | 61.2 | 80.3 | 24.9 | 35.9 | 38.1 | 52.5 |

| | Ivory Time | | Tattoo Time | | Prize Time | |
|---|---|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 33.0 | 36.7 | 28.6 | 26.7 | 23.2 | 22.0 |
| 45 | 31.0 | 28.2 | 45.7 | 52.7 | 31.4 | 38.2 |
| 48 | 38.0 | 45.5 | 45.8 | 48.1 | 29.9 | 39.0 |

g) **Number of flowers (flower stage 4-8) per pot**

| | Trenton | | Mirimar | | Springfield | |
|---|---|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 14.4 | 30.4 | 39.8 | 54.4 | 22.9 | 17.2 |
| 45 | 19.7 | 14.3 | 28.7 | 32.7 | 13.3 | 10.3 |
| 48 | 20.9 | 14.4 | 31.3 | 29.1 | 11.2 | 13.1 |

| | Ivory Time | | Tattoo Time | | Prize Time | |
|---|---|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 13.1 | 15.0 | 26.4 | 32.0 | 25.1 | 34.6 |
| 45 | 12.5 | 15.3 | 13.8 | 18.0 | 17.0 | 21.8 |
| 48 | 14.6 | 14.4 | 11.1 | 19.0 | 17.9 | 18.2 |

h) **Dry weight per pot (g)**

| | Trenton | | Mirimar | | Springfield | |
|---|---|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 15.45 | 16.95 | 15.16 | 16.41 | 11.68 | 16.71 |
| 45 | 10.39 | 14.52 | 11.51 | 15.49 | 9.16 | 12.94 |
| 48 | 11.47 | 14.14 | 15.76 | 16.02 | 15.50 | 16.22 |

| | Ivory Time | | Tattoo Time | | Prize Time | |
|---|---|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 13.27 | 15.34 | 13.10 | 15.97 | 14.56 | 17.23 |
| 45 | 9.02 | 12.80 | 12.84 | 14.29 | 11.47 | 16.60 |
| 48 | 11.32 | 14.67 | 13.90 | 16.38 | 13.36 | 14.64 |

**APPENDIX 4: Home-life data**

**a) Number of flowers (stage 4+) per pot at weekly intervals during home life. Figure in brackets is no. of pots of sufficient quality to be scored (max. 6)**

**Trenton**

| | De-sleeve | | 1 week | | 2 weeks | |
|---|---|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 37.0 (6) | 52.5 (6) | 37.3 (4) | 53.0 (2) | 35.0 (4) | 44.5 (2) |
| 45 | 43.3 (6) | 44.5 (6) | 45.0 (6) | 47.7 (6) | 46.6 (2) | 47.3 (6) |
| 48 | 47.8 (6) | 42.8 (6) | 45.0 (5) | 45.7 (6) | 46.3 (3) | 43.7 (6) |

| | 3 weeks | | 4 weeks | |
|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | -- (0) | -- (0) | -- (0) | -- (0) |
| 45 | 49.0 (1) | 52.3 (3) | -- (0) | -- (0) |
| 48 | -- (0) | 40.0 (1) | -- (0) | -- (0) |

**Mirimar**

| | De-sleeve | | 1 week | | 2 weeks | |
|---|---|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 33.0 (2) | 51.8 (6) | 28.0 (2) | 47.3 (6) | 26.5 (2) | 46.3 (3) |
| 45 | 37.7 (6) | 33.3 (6) | 37.7 (6) | 36.0 (6) | 35.2 (6) | 34.8 (5) |
| 48 | 43.7 (6) | 45.3 (6) | 45.3 (6) | 43.5 (6) | 44.2 (5) | 41.7 (6) |

| | 3 weeks | | 4 weeks | |
|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 21.0 (1) | -- (0) | -- (0) | -- (0) |
| 45 | 35.0 (4) | 29.0 (3) | -- (0) | -- (0) |
| 48 | 44.0 (3) | 41.5 (2) | -- (0) | -- (0) |

**Springfield**

| | De-sleeve | | 1 week | | 2 weeks | |
|---|---|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 24.0 (6) | 27.0 (6) | 23.4 (5) | 29.0 (5) | 23.0 (4) | 27.5 (4) |
| 45 | 18.8 (4) | 21.5 (6) | 19.3 (3) | 20.2 (6) | 16.0 (1) | 20.8 (5) |
| 48 | 21.3 (6) | 22.0 (6) | 22.2 (6) | 22.7 (6) | 21.8 (4) | 23.4 (5) |

| | 3 weeks | | 4 weeks | |
|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | -- (0) | -- (0) | -- (0) | -- (0) |
| 45 | -- (0) | -- (0) | -- (0) | -- (0) |
| 48 | 21.5 (2) | 23.7 (3) | -- (0) | -- (0) |

**Appendix 4a continued - Number of flowers (stage 4+) per pot at weekly intervals**

**Ivory Time**

| | De-sleeve | | 1 week | | 2 weeks | |
|---|---|---|---|---|---|---|
| **Stick Week** | 4.8 $W/m^2$ | 9.6 $W/m^2$ | 4.8 $W/m^2$ | 9.6 $W/m^2$ | 4.8 $W/m^2$ | 9.6 $W/m^2$ |
| 41 | 27.7 (6) | 35.3 (6) | 35.0 (5) | 41.0 (5) | 35.6 (5) | 41.6 (5) |
| 45 | 29.3 (6) | 28.3 (6) | 31.8 (6) | 32.8 (6) | 33.2 (6) | 33.2 (6) |
| 48 | 31.7 (6) | 32.0 (6) | 35.2 (6) | 36.0 (6) | 36.7 (6) | 35.8 (6) |

| | 3 weeks | | 4 weeks | |
|---|---|---|---|---|
| **Stick Week** | 4.8 $W/m^2$ | 9.6 $W/m^2$ | 4.8 $W/m^2$ | 9.6 $W/m^2$ |
| 41 | 35.2 (5) | 41.2 (5) | 34.5 (4) | 42.8 (4) |
| 45 | 34.0 (6) | 34.5 (6) | 32.8 (6) | 34.0 (6) |
| 48 | 37.2 (6) | 36.0 (6) | 39.7 (3) | 42.0 (2) |

**Tattoo Time**

| | De-sleeve | | 1 week | | 2 weeks | |
|---|---|---|---|---|---|---|
| **Stick Week** | 4.8 $W/m^2$ | 9.6 $W/m^2$ | 4.8 $W/m^2$ | 9.6 $W/m^2$ | 4.8 $W/m^2$ | 9.6 $W/m^2$ |
| 41 | 31.0 (3) | 33.0 (6) | 35.7 (3) | 32.0 (5) | 34.3 (3) | 30.8 (5) |
| 45 | 32.7 (6) | 32.3 (6) | 33.7 (6) | 34.0 (6) | 33.3 (6) | 33.5 (6) |
| 48 | 24.7 (6) | 35.8 (6) | 30.5 (6) | 41.7 (6) | 31.7 (6) | 41.8 (6) |

| | 3 weeks | | 4 weeks | |
|---|---|---|---|---|
| **Stick Week** | 4.8 $W/m^2$ | 9.6 $W/m^2$ | 4.8 $W/m^2$ | 9.6 $W/m^2$ |
| 41 | 34.3 (3) | 29.8 (5) | -- (0) | 32.0 (3) |
| 45 | 32.8 (6) | 32.7 (6) | -- (0) | 34.0 (3) |
| 48 | 30.6 (5) | 42.0 (5) | 29.0 (1) | -- (0) |

**Prize Time**

| | De-sleeve | | 1 week | | 2 weeks | |
|---|---|---|---|---|---|---|
| **Stick Week** | 4.8 $W/m^2$ | 9.6 $W/m^2$ | 4.8 $W/m^2$ | 9.6 $W/m^2$ | 4.8 $W/m^2$ | 9.6 $W/m^2$ |
| 41 | 31.7 (6) | 39.3 (6) | 32.6 (5) | 41.8 (5) | 29.3 (3) | 42.5 (4) |
| 45 | 26.8 (6) | 37.5 (6) | 28.4 (5) | 38.8 (6) | 27.4 (5) | 39.2 (6) |
| 48 | 26.8 (6) | 33.5 (6) | 25.3 (6) | 34.6 (5) | 26.8 (5) | 38.0 (3) |

| | 3 weeks | | 4 weeks | |
|---|---|---|---|---|
| **Stick Week** | 4.8 $W/m^2$ | 9.6 $W/m^2$ | 4.8 $W/m^2$ | 9.6 $W/m^2$ |
| 41 | 29.7 (3) | 35.5 (2) | 30.5 (2) | 25.0 (1) |
| 45 | 29.0 (3) | 38.2 (6) | 29.3 (3) | 37.3 (3) |
| 48 | 29.0 (2) | 42.0 (1) | -- (0) | -- (0) |

b) **Number of distorted buds per pot at weekly intervals during home life.**

**Trenton**

| | De-sleeve | | 1 week | | 2 weeks | |
|---|---|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 1.00 | 1.00 | 1.25 | 1.00 | 1.25 | 1.00 |
| 45 | 0.17 | 0.00 | 0.17 | 0.00 | 0.00 | 0.00 |
| 48 | 0.00 | 0.30 | 0.00 | 0.00 | 0.00 | 0.00 |

| | 3 weeks | | 4 weeks | |
|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | -- | -- | -- | -- |
| 45 | 0.00 | 0.00 | -- | -- |
| 48 | -- | 0.00 | -- | -- |

**Mirimar**

| | De-sleeve | | 1 week | | 2 weeks | |
|---|---|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 0.00 | 0.17 | 1.25 | 0.00 | 0.00 | 0.33 |
| 45 | 0.17 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 48 | 0.00 | 0.00 | 0.00 | 0.00 | 0.20 | 0.00 |

| | 3 weeks | | 4 weeks | |
|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 0.00 | -- | -- | -- |
| 45 | 0.00 | 0.00 | -- | -- |
| 48 | 0.00 | 1.50 | -- | -- |

**Springfield**

| | De-sleeve | | 1 week | | 2 weeks | |
|---|---|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 2.33 | 1.83 | 3.80 | 2.00 | 4.00 | 0.25 |
| 45 | 1.25 | 0.83 | 1.67 | 1.00 | 1.00 | 0.40 |
| 48 | 0.30 | 0.00 | 0.70 | 0.00 | 0.80 | 0.00 |

| | 3 weeks | | 4 weeks | |
|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | -- | -- | -- | -- |
| 45 | -- | -- | -- | -- |
| 48 | 1.00 | 0.00 | -- | -- |

**Appendix 4b continued - Number of distorted buds per pot at weekly intervals**

**Ivory Time**

| | De-sleeve | | 1 week | | 2 weeks | |
|---|---|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 1.00 | 0.50 | 1.20 | 0.60 | 1.40 | 0.40 |
| 45 | 0.17 | 0.00 | 0.17 | 0.33 | 0.00 | 0.17 |
| 48 | 0.00 | 0.00 | 0.00 | 0.40 | 0.00 | 0.20 |

| | 3 weeks | | 4 weeks | |
|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 0.80 | 0.60 | 0.75 | 0.50 |
| 45 | 0.00 | 0.17 | 0.00 | 0.00 |
| 48 | 0.00 | 0.00 | 0.00 | 0.00 |

**Tattoo Time**

| | De-sleeve | | 1 week | | 2 weeks | |
|---|---|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 0.00 | 0.00 | 0.00 | 0.20 | 1.00 | 0.80 |
| 45 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 48 | 0.00 | 0.00 | 0.00 | 0.00 | 0.50 | 0.20 |

| | 3 weeks | | 4 weeks | |
|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 1.33 | 0.40 | -- | 0.00 |
| 45 | 0.00 | 0.00 | -- | 0.00 |
| 48 | 0.20 | 0.00 | 0.00 | -- |

**Prize Time**

| | De-sleeve | | 1 week | | 2 weeks | |
|---|---|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 0.17 | 0.50 | 1.60 | 0.80 | 1.00 | 0.25 |
| 45 | 0.00 | 0.00 | 0.00 | 0.17 | 0.40 | 0.33 |
| 48 | 1.00 | 0.20 | 1.70 | 0.60 | 2.00 | 1.00 |

| | 3 weeks | | 4 weeks | |
|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 0.33 | 0.00 | 0.50 | 0.00 |
| 45 | 0.33 | 0.00 | 0.33 | 0.00 |
| 48 | 0.50 | 1.00 | -- | -- |

c) **Average flower score at weekly intervals during home life (0 = no deterioration, 1 = degeneration visible in centre of flower, 2 = flower wilting or necrotic)**

**Trenton**

| | De-sleeve | | 1 week | | 2 weeks | |
|---|---|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 45 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.33 |
| 48 | 0.00 | 0.00 | 0.00 | 0.00 | 0.30 | 0.00 |

| | 3 weeks | | 4 weeks | |
|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | -- | -- | -- | -- |
| 45 | 1.00 | 1.00 | -- | -- |
| 48 | -- | 2.00 | -- | -- |

**Mirimar**

| | De-sleeve | | 1 week | | 2 weeks | |
|---|---|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 0.00 | 0.00 | 0.50 | 0.00 | 1.50 | 2.00 |
| 45 | 0.00 | 0.00 | 0.00 | 0.00 | 0.83 | 0.80 |
| 48 | 0.00 | 0.00 | 0.00 | 0.00 | 0.80 | 1.00 |

| | 3 weeks | | 4 weeks | |
|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 1.00 | -- | -- | -- |
| 45 | 1.00 | 1.00 | -- | -- |
| 48 | 1.70 | 2.00 | -- | -- |

**Springfield**

| | De-sleeve | | 1 week | | 2 weeks | |
|---|---|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 0.00 | 0.00 | 0.00 | 0.00 | 0.50 | 0.50 |
| 45 | 0.00 | 0.00 | 0.00 | 0.00 | 2.00 | 0.00 |
| 48 | 0.00 | 0.00 | 0.00 | 0.00 | 0.80 | 0.00 |

| | 3 weeks | | 4 weeks | |
|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | -- | -- | -- | -- |
| 45 | -- | -- | -- | -- |
| 48 | 1.50 | 2.00 | -- | -- |

## Appendix 4c continued – Average flower score at weekly intervals

### Ivory Time

| | De-sleeve | | 1 week | | 2 weeks | |
|---|---|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.20 |
| 45 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 48 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

| | 3 weeks | | 4 weeks | |
|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 0.00 | 0.60 | 1.00 | 1.00 |
| 45 | 0.00 | 0.00 | 1.00 | 0.17 |
| 48 | 0.50 | 0.40 | 1.30 | 1.00 |

### Tattoo Time

| | De-sleeve | | 1 week | | 2 weeks | |
|---|---|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 1.00 |
| 45 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 48 | 0.00 | 0.00 | 0.00 | 0.00 | 0.50 | 0.70 |

| | 3 weeks | | 4 weeks | |
|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 1.00 | 1.00 | -- | 2.00 |
| 45 | 1.00 | 1.00 | -- | 1.67 |
| 48 | 1.40 | 1.40 | 2.00 | -- |

### Prize Time

| | De-sleeve | | 1 week | | 2 weeks | |
|---|---|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 0.00 | 0.00 | 0.00 | 0.00 | 0.33 | 1.00 |
| 45 | 0.00 | 0.00 | 0.00 | 0.00 | 0.20 | 0.00 |
| 48 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 1.00 |

| | 3 weeks | | 4 weeks | |
|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 1.00 | 1.00 | 1.33 | 2.00 |
| 45 | 1.00 | 1.00 | 1.33 | 2.00 |
| 48 | 2.00 | 2.00 | -- | -- |

**d) Average foliage score at weekly intervals during home life (0 = leaves all green, 1 = yellow tinged, 2 = half green, half yellow; 4 = mostly yellow/brown)**

**Trenton**

| | De-sleeve | | 1 week | | 2 weeks | |
|---|---|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 0.11 | 0.22 | 0.25 | 0.83 | 0.50 | 0.83 |
| 45 | 0.11 | 0.17 | 0.33 | 0.28 | 0.33 | 0.44 |
| 48 | 0.00 | 0.00 | 0.07 | 0.00 | 0.00 | 0.00 |

| | 3 weeks | | 4 weeks | |
|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | -- | -- | -- | -- |
| 45 | 1.00 | 0.33 | -- | -- |
| 48 | -- | 0.33 | -- | -- |

**Mirimar**

| | De-sleeve | | 1 week | | 2 weeks | |
|---|---|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 0.67 | 0.78 | 0.83 | 1.22 | 0.83 | 1.22 |
| 45 | 0.50 | 0.50 | 0.50 | 0.50 | 0.67 | 0.67 |
| 48 | 0.07 | 0.00 | 0.22 | 0.00 | 0.20 | 0.33 |

| | 3 weeks | | 4 weeks | |
|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 1.00 | -- | -- | -- |
| 45 | 0.75 | 0.50 | -- | -- |
| 48 | 0.33 | 0.33 | -- | -- |

**Springfield**

| | De-sleeve | | 1 week | | 2 weeks | |
|---|---|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 0.78 | 0.22 | 1.33 | 1.13 | 1.33 | 1.08 |
| 45 | 0.58 | 0.39 | 1.00 | 0.61 | 1.33 | 0.73 |
| 48 | 0.67 | 0.17 | 0.67 | 0.33 | 0.33 | 0.33 |

| | 3 weeks | | 4 weeks | |
|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | -- | -- | -- | -- |
| 45 | -- | -- | -- | -- |
| 48 | 0.83 | 0.33 | -- | -- |

**Appendix 4d continued – Average foliage score at weekly intervals**

**Ivory Time**

| | De-sleeve | | 1 week | | 2 weeks | |
|---|---|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 0.06 | 0.17 | 0.13 | 0.20 | 0.33 | 0.27 |
| 45 | 0.06 | 0.00 | 0.06 | 0.06 | 0.22 | 0.11 |
| 48 | 0.06 | 0.00 | 0.22 | 0.07 | 0.22 | 0.13 |

| | 3 weeks | | 4 weeks | |
|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 0.47 | 0.60 | 0.33 | 0.50 |
| 45 | 0.33 | 0.28 | 0.44 | 0.33 |
| 48 | 0.33 | 0.27 | 1.00 | 0.33 |

**Tattoo Time**

| | De-sleeve | | 1 week | | 2 weeks | |
|---|---|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 0.00 | 0.06 | 0.00 | 0.13 | 0.33 | 0.33 |
| 45 | 0.11 | 0.00 | 0.11 | 0.00 | 0.22 | 0.06 |
| 48 | 0.00 | 0.00 | 0.06 | 0.06 | 0.17 | 0.17 |

| | 3 weeks | | 4 weeks | |
|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 0.44 | 0.40 | -- | 0.33 |
| 45 | 0.28 | 0.17 | -- | 0.22 |
| 48 | 0.20 | 0.33 | 0.33 | -- |

**Prize Time**

| | De-sleeve | | 1 week | | 2 weeks | |
|---|---|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 0.50 | 0.44 | 0.53 | 0.53 | 0.89 | 0.75 |
| 45 | 0.00 | 0.00 | 0.07 | 0.00 | 0.13 | 0.00 |
| 48 | 0.11 | 0.00 | 0.17 | 0.13 | 0.27 | 0.00 |

| | 3 weeks | | 4 weeks | |
|---|---|---|---|---|
| **Stick Week** | 4.8 W/m$^2$ | 9.6 W/m$^2$ | 4.8 W/m$^2$ | 9.6 W/m$^2$ |
| 41 | 1.33 | 1.17 | 1.33 | 1.33 |
| 45 | 0.22 | 0.11 | 0.33 | 0.33 |
| 48 | 0.33 | 0.33 | -- | -- |

## APPENDIX 5: Crop Diary

### Crop 1 (Week 41)

| | |
|---|---|
| 13.10.99 | Cuttings stuck; polythene covers on |
| 13.10.99 | Mycotal 1 g/l; Vertalec 2 g/l |
| 15.10.99 | B-Nine 1.5 g/l |
| 22.10.99 | Polythene covers off |
| 28.10.99 | Rovral 0.5 g/l |
| 29.10.99 | Moved pots into SD with supplementary lighting |
| 3.11.99 | Pinched Trenton |
| 8.11.99 | Pinched Ivory Time, Springfield, Mirimar |
| 9.11.99 | Pinched Prize Time, Tattoo Time |
| 14.11.99 | Dichlorvos 1 ml/l; Beehappy 1 ml/l |
| 15.11.99 | Final spaced all plants |
| 15.11.99 | B-Nine 3 g/l Trenton |
| 19.11.99 | B-Nine 3 g/l Springfield, Mirimar |
| 21.11.99 | Dichlorvos 1 ml/l; Beehappy 1 ml/l |
| 22.11.99 | B-Nine 2 g/l Prize Time, Tattoo Time, Ivory Time. |
| 28.11.99 | Malathion 1.8 ml/l; Beehappy 1 ml/l |
| 29.11.99 | B-Nine 3 g/l Trenton |
| 1.12.99 | B-Nine 2 g/l Prize Time, Tattoo Time |
| 3.12.99 | B-Nine 3 g/l Mirimar |
| 5.12.99 | Dichlorvos 1 ml/l; Beehappy 1 ml/l |
| 12.12.99 | Dichlorvos 1 ml/l; Beehappy 1 ml/l |

### Crop 2 (Week 45)

| | |
|---|---|
| 10.11.99 | Cuttings stuck; polythene covers on |
| 11.11.99 | Mycotal 1 g/l; Vertalec 2 g/l |
| 12.11.99 | B-Nine 1.5 g/l |
| 19.11.99 | Polythene covers off |
| 26.11.99 | Moved pots into SD with supplementary lighting |
| 26.11.99 | Started feeding pots |
| 28.11.99 | Malathion 1.8 ml/l; Beehappy 1 ml/l |
| 30.11.99 | Pinched Trenton |
| 3.12.99 | Pinched Mirimar, Springfield, Ivory Time |
| 5.12.99 | Dichlorvos 1 ml/l; Beehappy 1 ml/l |
| 6.12.99 | Pinched Prize Time, Tattoo Time |
| 12.12.99 | Dichlorvos 1 ml/l; Beehappy 1 ml/l |
| 13.12.99 | Final spaced all plants |
| 13.12.99 | B-Nine 3 g/l Trenton |
| 16.12.99 | B-Nine 3 g/l Mirimar, Springfield |
| 16.12.99 | B-Nine 2 g/l Ivory time, Prize Time |
| 18.12.99 | Dichlorvos 1 ml/l; Beehappy 1 ml/l |
| 21.12.99 | B-Nine 2 g/l Tattoo Time |
| 26.12.99 | B-Nine Prize Time 2 g/l |
| 29.12.99 | B-Nine 3 g/l Trenton, Mirimar; B-Nine 2 g/l Tattoo Time |

**Crop 3 (Week 48)**

| | |
|---|---|
| 1.12.99 | Cuttings stuck; polythene covers on |
| 2.12.99 | Mycotal 1 g/l; Vertalec 2 g/l |
| 3.12.99 | B-Nine 1.5 g/l |
| 10.12.99 | Polythene covers off |
| 16.12.99 | Rovral 0.5 g/l |
| 17.12.99 | Moved pots into SD |
| 22.12.99 | Pinched Trenton |
| 27.12.99 | Pinched Mirimar, Ivory Time, Prize Time |
| 02.01.00 | Pinched Springfield (very uneven variety) |
| 03.01.00 | Pinched Tattoo Time |
| 04.01.00 | Final spaced all plants |
| 06.01.00 | B-Nine 3 g/l Trenton |
| 10.01.00 | B-Nine 3 g/l Mirimar |
| 10.01.00 | B-Nine 2 g/l Ivory Time, Prize Time |