Project title:	**Chrysanthemum: an investigation of factors influencing root establishment during the winter period under commercial conditions.**
Project Number:	PC 133
Project Leader:	Dr S C Clifford in liaison with Dr D P Wilson HRI Efford, Lymington, Hampshire, SO41 0LZ
Report:	Final Report (October 1998)
Key Workers:	**HRI Efford:**

	Dr S Clifford	Project Leader (author)
	Mrs S Foster	Scientific Officer
	Miss Sarah Williams	Assistant Scientific Officer
	Mr G Stancer	Nursery Staff
	Mr M Verran	Nursery Staff
	Mr C Vigor	Nursery Staff (Foreman)
	Miss S Wilson	Nursery Staff
	HRI Wellesbourne:	
	Dr D P Fuller	Technical Officer
	Mr R Edmondson	Biometrics

Location:	HRI Efford
Project Co-ordinator:	Mr JD Abbott, Southern Glasshouse Produce Ltd, Park Road, Lake Lane, Barnham, West Sussex PO22 0AQ
Date Commenced:	September 1996
Date Completed:	March 1998
Keywords:	Spray chrysanthemum, Propagation duration, Irrigation water temperature, winter quality.

CONTENTS

1. PRACTICAL SECTION FOR GROWERS

1.1. Background and introduction

Good plant establishment and take off of newly planted cuttings on the bed is an essential component in the production of a uniform, high quality crop of AYR spray chrysanthemums.

Several routine procedures, such as using rooting hormone and bench heating during propagation, ensure rapid development of roots, but factors that influence the early establishment of roots from the peat block into the soil following transplanting are less well understood. During winter, water temperature in external irrigation tanks can fall to freezing, and it is not known whether or not this has a negative impact on crop establishment or quality. Cold irrigation water on the soil beds may be particularly relevant to the transplanting stage when plants are moved from an environment benefiting from root zone warming to an unheated soil bed. Stage of root development within the peat block at transplanting can also vary widely according to labour pressures and the occurrence of delays in the programme, but the optimum root stage at planting has not yet been defined.

The subject of root establishment covers a wide range of issues, and trials in this project during the winters of 1996 and 1997 (PC 133) have concentrated on studying the effects of root and plant development at planting, and irrigation water temperature on subsequent plant establishment and winter quality.

Irrigation water temperature: Over the winter of 1996/97, influence of temperature of the water supply on root and and plant establishment and subsequent quality was studied. This trial used low level drip irrigation systems on beds that had been freshly steam-sterilised to ensure minimal disease pressure. In the 1997/98 trial, overhead irrigation was used until bud colour developed, since many growers used this type of system. In such systems, low temperature irrigation would be less likely to impact on temperature in the root zone, which is relatively well buffered, but could affect canopy temperature, which in turn could lead to reduced growth. In addition, since it is generally not possible to steam-sterilise between each planting in a commercial situation, the trial was planted onto beds on which three successive crops had been previously grown without sterilisation between each crop. In situations where plant vigour might be reduced by a factor such as low temperature irrigation water, pathogens could possibly infect root systems more readily.

Root development at planting: Another factor which could influence root establishment is the amount of root developed during propagation prior to planting out on the soil bed. The basis of these observations was to examine the impact of having to hold on to plants in the propagation stage as a result of delays elsewhere on the nursery. In the 1996/97 trial, this meant that while treatments were planted out at different times onto the final bed, they all started short days on the same date, thus plants given fewer days in propagation, but planted earlier onto the bed, received more long days on the beds than comparable plants given longer in propagation but planted later. The combined result of less competition on the bed and more long days would have been better establishment and quality in plants which had been given the shortest propagation phase. Consequently, during the 1997/98 trial, the interaction between time in propagation and plant establishment on the bed was examined in more detail by staggering the start point of propagation so that planting was on a common date. This tested the impact of stage of plant development at planting on subsequent establishment and development under otherwise uniform conditions of light, temperature and day-length.

All work looking at influences of root development at planting on establishment was done in sterilised beds to avoid and potential interactions with disease build up in unsterilised beds.

1.2 Summary of results

1.2.1 Summary of results 1996/97.

All work over this period was carried out on freshly sterilised beds.

Irrigation water temperature (applied via a low- level system):

The following four irrigation water temperature treatments were applied to crops planted on six occasions over the September to February period.

1. Irrigation supply stored in a tank outside the glasshouse (external tank)
2. Irrigation supply stored in a tank chilled to 4°C.
3. Irrigation supply stored in a tank heated by the glasshouse air temperature (to around 17°C).
4. Irrigation supply stored in a tank heated to 25°C.

These treatments had no significant effect on root establishment, plant development or final grade out. Although low temperature may have been expected to at least slow down root establishment and development, the cold water applied had relatively little effect on root zone temperatures. If irrigation was applied on a sunny day, it was impossible to detect any change in root zone temperature. When irrigation was applied on a dull day, a small drop in temperature (about 7.5 °C for the 4°C treatment) was detected at the surface of the soil beneath the peat block immediately after irrigation, but temperatures rapidly stabilised and the effects had disappeared within 2 hours. There was little evidence of irrigation water temperature affecting the temperature of the soil monitored at a depth of 10cm. Soil was better buffered against changes in temperature than peat blocks. This was true both for application of irrigation water at different temperatures, and from the effects of solar gain on bright days. From these observations, it might be expected that on less well-buffered growing systems (e.g. in shallow systems), low temperature irrigation might have a greater impact.

An observation trial was also set up to provide preliminary assessments of the impact of two other factors on root establishment during the winter. These were, stage of planting, and initial irrigation management.

Stage of planting: The aim of this work was to assess the impact of holding trays in propagation for extended periods on plant establishment and quality. Since there would be an increase in the amount of root growth developing out of the peat block prior to planting, with increased risk of root damage at planting. Rooted cuttings were therefore planted either 8 days (early), 12 days (standard) or 16 days (late) from sticking. Early planting improved plant development and final grade out in comparison with standard and late planting. However, since all treatments commenced short days at the same time, the results from the length of time blocks had been held in propagation were confounded by the increased growth resulting from the extra time each treatment had in LDs following planting out.

Irrigation observations: Three irrigation treatments were imposed on each planting stage treatment:

1) Dry initial irrigation (planting on to dry soil and not applying water for the first 48 hours)

2) Standard irrigation (planting on to a damp soil with a light water in after planting)

3) Wet irrigation (planting on to a wet soil with a heavy overhead irrigation after planting)

Although the irrigation treatments had less impact than the different planting stages, wet initial irrigation did appear to improve early plant development (recorded at the end of long days), but had no effect on final plant quality.

1.2.2. Summary of results 1997/98

Stage of plant development at planting : duration in propagation:

Three propagation treatments were applied, but in this trial, all were planted onto freshly sterilised beds on the same day. The three propagation treatments were:

1) 8 days
2) 12 days
3) 16 days

Extending duration in propagation resulted in plants with larger root systems that established more rapidly in sterilised soil beds than comparable plants given fewer days in propagation. Of the varieties tested, Reagan was far more vigorous in rooting out of the block after planting than Snowdon, and even when planted after only 8 days in propagation, plants established quickly and uniformly.

The main effect of extending the duration in propagation to 16 days, was for plants to reach a height of 30 cm more quickly than plants given only 8 or 12 days. This has important implications for reducing the number of long days on the bed before starting short days, and thereby to a reduction in crop duration (although these differences could not be quantified from available data in the current study).

The data showed no consistent trends in the effects of duration in propagation on wrap grade-out in grades 1 and 2 at final harvest, but there was a tendency for Snowdon to produce more waste stems per plot than Reagan.

Although larger root systems resulted in better establishment when planting onto sterilised beds, this benefit may be reduced in situations where plants are planted onto un-sterilised beds with disease present. Increased chances of root damage in larger root systems at planting may make these plants more susceptible to attack by root-rot pathogens. Further studies will investigate the interaction between root development at planting and susceptibility to subsequent infection.

Irrigation water temperature: Irrigation water was applied at one of three temperatures to beds which had had three consecutive crops without sterilisation in between each:

1) 4°C
2) Internal ambient (18 – 20°C)
3) External ambient (fluctuating between 3.2 and 12.8°C)

Irrigation, using water which was cooled to a constant 4°C, did reduce stem length and leaf number at the end of long days. This reduction in stem length was statistically significant (P = 5%), and may result in a delay in the start of SDs. From the current data, this time delay could not be quantified, but estimates indicate that the crop may take about 4-5 days longer to reach a height of 40 cm in the winter.

Irrigation using cold water had no observable negative impact on wrap quality or grade-out at harvest. Any small shortfall in stem length at this time was not significant as, at this stage, stems were all trimmed to a standard wrap length.

Although, the water temperature in the external tank briefly reached a minimum of 3.2°C in week 5, the external tank temperature was, on average warmer than that supplied from the 4°C treatment. From these observations, it is unlikely that growers in locations which do not normally experience prolonged cold periods, would experience any crop delays, reductions in yield, quality or uniformity due to the temperature of the irrigation supply. However, growers in colder regions, or those having smaller irrigation water holding tanks which are less well buffered against cold irrigation supplies, should be wary of the temperature that water is delivered onto the beds, as they are more liable to crop delays due to irrigation water temperature.

Measurements of canopy microclimate showed that vapour pressure deficit (VPD: the driving force for transpiration) was only depressed for about 1½ hours after overhead irrigation given early in the day. Care should be taken to avoid irrigating late as VPD remained depressed for much longer during the night, providing ideal conditions for pathogen attack. In the current trial, it was not possible to quantify the disease pressure, but this aspect will be investigated in future trials.

1.3. Action points for growers

Stage of development at planting:

- Under conditions where beds have been sterilised prior to planting, there is scope for reductions in crop duration by using plants which have been given longer in propagation (using the standard 84 blocks/tray winter format). This assumes comparison between plants given varying duration in propagation and planted on a common date.

- In cases where plants are planted at different times, those put onto the beds earlier may benefit from reduced competition and extended duration in long days on the bed.

- There is a point where increased competition between plants in propagation will impact negatively on subsequent plant performance. One important factor that determines the duration in propagation will be the size of block used. Recent work in Holland has shown that larger blocks ('star pots') mean that propagation can be extended significantly to reduce crop duration after planting.

- In less vigorous varieties such as Snowdon, extending duration in propagation has more marked benefits on early plant establishment. This may be important when considering the implications of problems such as *Pythium* attack as roots are establishing.

- There was no evidence that extending duration in propagation reduced either grade-out of 1st and 2nd quality stems or wrap weight.

- In cases where there is a residual disease load present in the cropping system (un-sterilised beds), further trials will quantify whether or not root damage at planting is a major factor in increasing plant susceptibility to root-rot pathogens early in establishment.

Irrigation temperature:

- From data collected during the two years of trials studying the effects of irrigation water temperature, there is no evidence to suggest that cold irrigation water applied either overhead, or via a low-level drip irrigation system, has a negative impact on root establishment.

- When applied overhead, cold water may reduce stem extension rate slightly, leading to a delay in the time at which the crop starts SDs. This will have economic implications in terms of extended crop duration, and growers in cold areas, or with small irrigation holding tanks need to be aware of their irrigation water temperature.

- Irrigation using cold water is best carried out early in the day if humidity build-up in the canopy during the night is to be avoided. If irrigated late in the day, the crop may be more susceptible to diseases such as rusts and *Botrytis* which thrive in humid environments.

1.4. Practical and anticipated financial benefits

- The main benefits of extended propagation are due to savings in time on the bed rather than increased quality or reduced wastage. It must be remembered that these observations were made using freshly steam-sterilised beds, so any potential reductions in benefits due to pathogens in the bed could not be quantified in the current trial.

- Savings in crop duration on the bed through extended propagation techniques will enable more efficient use of each planting block with a better return per unit glasshouse area per year.

- There is no evidence to suggest that plant quality is significantly reduced by overhead irrigation using water at 4°C.

- Cold irrigation water applied overhead resulted in a 9% reduction in plant height at the end of long days. When growing to a height of 40 cm in the depths of winter, this could represent a delay of several days to the start of the SD phase. It is possible that growers using extended propagation to increase the rate of early establishment may lose some or all of the benefit if they are also using very cold irrigation water.

2. SCIENCE SECTION (1997/98 season)

2.1. Introduction

Good plant establishment and take off of newly planted cuttings on the bed is an essential component in the production of a uniform, high quality crop of AYR spray chrysanthemums. HDC funded work at HRI Efford over the winter 1996/97 period examined this critical stage of production through assessment of the temperature of irrigation water. Temperatures at the surface of the soil (i.e. where roots initially become established) dropped rapidly when low temperature water was applied using drip irrigation systems under periods of the low light and low external temperatures. These temperature drops were short lived, and little impact was made on the more buffered soil at 10cm depth (i.e. where majority of the developed root system would be expected to be). Consequently, low temperature irrigation supply had little impact on either plant development or final grade out.

Irrigation water temperature: Certain questions still remained regarding irrigation temperatures. Firstly, during the 1996/97 trial, irrigation was predominantly supplied via low level drip lines. While this system is representative of some growers, there are many who use overhead irrigation for the majority of the production period, only switching to low level systems when buds develop colour. Low temperature irrigation using overhead spray lines may not impact on root zone temperature, which is relatively well buffered, but may affect canopy temperature, leading to reduced growth. Secondly, the work in 1996/97 was carried out on freshly steam sterilised beds where pressure from root disease would be expected to be minimal. In a commercial situation however, it is possible that beds planted in the winter have not been sterilised. In a situation where plant vigour is reduced by factors such as low temperature, pathogens might be expected to infect root systems more readily.

During 1997/98, it was therefore proposed to examine the effects of low temperature irrigation supplies, delivered overhead until bud colour, on crops planted during the winter period on soil beds which had previously been planted with three successive crops without sterilisation treatment in between.

Root development at planting: Another factor which could influence root establishment is the amount of root developed in propagation prior to planting out on the soil bed. Observations made during the winter 1996/97 trials indicated that an early planting stage (when little if any root material had grown out of the peat block) may improve initial plant establishment, but this was confounded by extra long days received by this treatment. However, a later planting stage might be more detrimental to plant development and final grade out. The basis of these observations was to examine the impact of having to hold on to plants in the propagation stage as a result of delays elsewhere on the nursery. This meant that while treatments were planted out at different times onto the final bed, they all started short days on the same date. Hence different treatments had different proportions of the total long day period at final spacing which would therefore potentially result in a difference in assimilate accumulation. In the 1997/98 trial, the converse was examined. The starting point of propagation was staggered, but planting was on a common date. This tested the impact of plant size and degree of rooting at planting on subsequent establishment and development under otherwise uniform conditions of light, temperature and day-length.

2.2. Objectives

The 1997/98 work was divided into two discrete trials to address each of the following objectives:

- To examine the influence of stage of root development at planting out on plant establishment and final quality. Sticking was staggered with plants put onto steam-sterilised beds and introduced into short days together.

- To examine the effects of overhead irrigation water temperature (until the development of bud colour) on plant growth and final stem quality during the winter period., with crops planted onto unsterilised soil beds (3 previous crop cycles).

2.3. Material and Methods

2.3.1. Glasshouse site

All material was propagated in E Block 9 & 10. Plants for Trial 1: stage of development at planting were grown on in R Block (appendix 1), and Trial 2: overhead irrigation water temperature was conducted in C Block (appendix 2).

For both trials:

- Sticking Dates: Weeks 43 & 48
- Planting Dates: Weeks 45 & 50

2.3.2. TRIAL 1: Stage of development at planting: duration in propagation

2.3.2.1. Chrysanthemum varieties

- Splendid Reagan and Snowdon

Variety descriptions:

- Splendid Reagan: Deep pink single; 8 ½ week response
- Snowdon: Large-flowered white decorative; 9 ½ week response

2.3.2.2. Treatments

Three stages of plant / root development were compared on two winter plantings (week 45 and week 50) by manipulating length of time in propagation as follows:

	Stage of root development	*Length of time in propagation*
1)	Early planting (little root visible)	8 days
2)	Standard planting (roots emerging from block)	12 days
3)	Late planting (advanced root development)	16 days

These treatments were achieved by sticking cuttings at four-day intervals and then planting them out on the same day.

2.3.2.3. Experimental Design

R Block: beds 22 - 24 for the week 45 planting (bed 24 as a guard); beds 13 - 15 for the week 50 planting (with bed 15 as a guard).

Each root stage treatment was replicated twice, with replicates blocked to take account of north-south effects within the beds (see plans in appendix 1).

2.3.3. TRIAL 2 : Overhead irrigation water temperature: effect on winter quality.

2.3.3.1. Chrysanthemum varieties used:

- Splendid Reagan

2.3.3.2. Irrigation water temperature treatments:

The impact of overhead irrigation water temperature applied to the crop (until bud colour) was assessed on replicate plots using the following treatments:

1) Irrigation using water stored under ambient external environmental conditions (to represent current commercial practise).

2) Irrigation using water stored inside the glasshouse and maintained at 17-19°C.

3) Irrigation using water chilled to a temperature of 4°C.

Irrigation water drawn from the appropriate treatment tanks was applied manually (using a rose) overhead with irrigation volume and frequency determined by solar radiation levels accumulated. From bud colour, irrigation was applied via low level drip irrigation until harvest.

2.3.3.3. Experimental Design

C Block: beds 22 - 25 for week 45 planting (beds 22 & 25 as guards); beds 26 - 29 for the week 50 planting (beds 26 & 29 as guards; see plans in appendix 1).

2.3.4 Cultural Techniques for both trials

- **Propagation:**

  Unrooted cuttings were sourced from Yoder Toddington from stock raised in Kenya and propagated on site in peat blocks (5 cm x 5 cm x 3 cm made from standard Levington blocking compost with Etridiazole incorporated as Aaterra). Cuttings were rooted on heated benches to maintain 18°C in the peat blocks, with atmospheric control achieved by heating set points of 18 / 19°C day / night and venting at 23 °C. Long day conditions were maintained by cyclic lighting using incandescent bulbs from 20:30 to 03:30. Clear –polythene sheeting was removed after 6 days propagation

Outer guard beds were planted with an appropriate Reagan colour mix under standard commercial conditions.

Trial 1: Development at planting: Cuttings given 8, 12 or 16 long days in propagation prior to planting on a common date.

Trial 2: Irrigation water temperature: Cuttings given 12 long days in propagation.

Polythene sheets removed after 6 long days from all trays.

- **Planting:**

  All plantings at 55 / m^2 of bed (85% growing area).

Trial 1: Development at planting:

Sticking was staggered, with planting on the same day for all treatments in each planting week. Soil beds were **STEAM-STERILISED**. Beds were sterilised to ensure that the treatment effects were not affected by other factors such as root rot pathogens which would have added more variability to the trial and which could not be quantified in any way.

Trial 2: Irrigation water temperature:

Soil beds were **UNSTEAMED**. Unsteamed beds were used to enable examination of the possibility that cold irrigation water could increase plants' susceptibility to P&D attack, in particular fungal pathogens which require a high humidity micro-environment.

- **Schedule:**

  A common schedule for all beds was maintained as follows.

  Long days until plant height was 30 cm for the commercial standard treatments (12 days in propagation), with a 10 day interruption given with timing calculated according to cumulative light integral for Snowdon. Due to the blocking structure of the trial, a common interruption was applied across both varieties and all treatments.

- **Environment/Nutrition:**

  18°C day 19°C night with venting at 23°C.

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

Standard ADAS Winter feed 150 N : 200 K_2O (166 K) was applied with each irrigation according to light levels.

- **Pest and Disease Control:**
  Routine spray programme for preventative WFT control plus spot treatments as required through daily crop monitoring (see crop diary in appendix 3).

- **Plant Growth Regulation:**
  Daminozide (as B-Nine) to be applied according to the following schedule:

Variety	2 weeks before SDs	Start SDs	14 days after start SDs	10 days later
Snowdon	-	0.75 g/l	0.75 g/l	0.75 g/l
Reagan	0.75 g/l	0.75 g/l	1.00 g/l	0.75 g/l

2.3.5. Experimental Records

The following records were common to BOTH trials unless otherwise indicated:

Root establishment after planting: was assessed non-destructively via a qualitative assessment three times a week. This involved exerting a gentle pull at the top of a random selection of 10 plants per plot to assess extent of root penetration into the soil. Resistance to this pull was scored as follows:

Score 0= no resistance and no evidence from the base of the block of initials beginning to penetrate the soil.

Score 1= little/no resistance but evidence of root initials beginning to grow out of the peat block into the soil.

Score 2= good resistance with firm establishment of roots in the soil.

These records were supplemented by a destructive root sample taken at the end of the long day period (as shown on the plot diagram (appendix 4). Ten plants were carefully dug out of the plot to ensure all root material was included in the sample. The roots were cut at the point where they emerged from the base of the original peat block and assessed as follows:

1) Assigned a score to indicate extent of rooting (from 0-5 where 0 = no rooting and 5 = extensive root system apparent). A photographic record of the score system was taken (Plate 1).

2) Plants were carefully dug up and roots emerging from the peat block were removed, cleaned and blotted dry before recording fresh weight (week 45) and dry weights (week 50). It was decided after carrying out fresh weight determinations in week 45 that the technique was so prone to experimental error that root dry weights would provide much better data.

Plant development (above ground): was assessed on a destructive sample of 24 plants (2 complete rows) on two occasions, (i) at the end of long days and (ii) at harvest (layout of plot in appendix 4):

On each of these occasions, the sample of plants was assessed by recording the following:

1) Stem length from top of peat block to apex (cm)
2) Fresh weight of material above peat block (g)
3) Leaf number (leaflets arising from the same node were counted as one and nodes where leaves had been lost through damage/decay were also counted).
4) Bulk dry weight of all stems in sample (g)

Additional records at maturity included:

1) Number of harvests on each plot, date of each harvest and number of stems per harvest.
2) Grade out of harvested stems from each plot recording number and weight of wraps produced in marketing grades 1, 2 and 3 as defined below, with a record of bulk fresh weight and number of waster (i.e. below grade 3 stems.

Grade 1 = At least five open flowers with at three buds with potential to open post-harvest.

Grade 2 = At least three open flowers with an additional three buds with potential to open post-harvest.

Grade 3 = At least two open flowers and a further two buds with potential to open post-harvest.

4) Mineral element analysis of foliage using expanded leaves from guard plants. Sample size = 50 leaves per plot.

2.3.6. Environmental Records

For both trials, environmental data was collected for the following parameters:

i) Day / night air temperature (°C)
ii) Day / night relative humidity (RH)
iii) Solar radiation levels (MJ/d)

In addition to the above, the following measurements were taken in Trial 2: Irrigation temperature (C block)

i) Water temperature of each of the irrigation supplies; logged hourly averages.
ii) Leaf temperatures in the most recently expanded leaf, and in mid- and lower canopy positions*.
iii) Humidity and temperature within the canopy*.

* Sensors were cited in the southernmost 4°C and 17°C irrigation temperature treatment plots (see equipment in Plate 2).

2.3.7. Statistical Analysis

The data were analysed using Analysis of Variance. Main effects were examined for the treatments within each planting and averaged across plantings. Interactions between treatment effects and planting date were also compared.

Statistical terms used include:

L.S.D.	Least squares difference of the means
P = 0.05 or 5%	The probability of this result occurring purely by chance is equal to 1 in 20.

3. RESULTS AND DISCUSSION

3.1. Stage of development at planting

3.1.1 Growing conditions and regime

	Plant date	LDs	SDs	Interruption	SDs	1st cut	Clear
Week 45	05/11/97	28	19	10	45	16/2	23/2
Week 50	10/12/97	30	17	10	41	18/3	23/3

Environmental data for the external light, temperature and compartment temperatures and humidity can be seen in Appendix 5.1 – 5.2.

External light levels fell from 5 $MJ/m^2/d$ in week 45 to a minimum of 1.8 $MJ/m^2/d$ in week 51, and increased to 9.5 $MJ/m^2/d$ by week 12. The crop planted in week 45 established in decreasing light, whilst the week 50 planting established in low light and matured as irradiance increased.

Compartment temperature remained stable throughout the trial (Appendix 4.2), with one small drop in week 51. This was due to a day when the system had to be switched off for boiler modifications.

3.1.2. Root score data: rate of root establishment

Non-destructive sampling during establishment on the bed: At the time of planting, there was significantly more root visible on the block surface in the 16 day propagation treatment than in the 12 or 8 day treatments (Plate 1). Of the two varieties in the trial, Reagan was by far the most vigorous rooting (Plate 1). The extra root material emerging from the block could have been more prone to damage as the blocks were slid out of the tray onto the bed, and increased susceptibility to attack by root-rot pathogens such as *Pythium*. The beds for the trial had been steam-sterilised prior to planting to ensure that only the influence of the degree of root development on plant establishment was monitored (rather than data confounded by the effects of the background soil pathogen load). This tested the potential for more developed root systems on larger plants at the time of planting performing better than comparatively small plants (with correspondingly little root development). From the current data, there is no evidence to suggest that increased root damage which may be incurred on larger root systems at planting had any negative impacts on plant establishment in a sterilised bed (root damage was not quantified). Further work is required to investigate how the stage of root development at planting may impact on a plant's susceptibility to *Pythium* attack in a challenged environment.

Data from the non-destructive "random tug method" for assessing plant establishment are presented in Figures 1 and 2. Reagan showed rapid root establishment following all propagation treatments (figs. 1b & 2b). In the week 45 planting, there were no significant differences between the rates of root establishment in Reagan given 8, 12 or 16 LDs in propagation (Figure 1b). In week 50, the 8 day propagation treatment lagged at the start, but rapidly caught up with the 12 and 16 day treatments, so that by 12 days after planting, all treatments were rooting equally well.

Snowdon, however, had a far less vigorous rooting habit than Reagan, and in both plantings, there was a marked lag between rooting in plants given 8 days in propagation, compared to 12 or 16 days (figs. 1a & 2a).

3.1.3 Mean root score at the end of long days

Destructive root sample at the end of LDs: Data in (Table 1) show that, although there were trends in the effects of extended duration in propagation increasing root score at the end of long days, the treatment differences were not statistically significant within each variety. This trend was stronger in Snowdon than in Reagan.

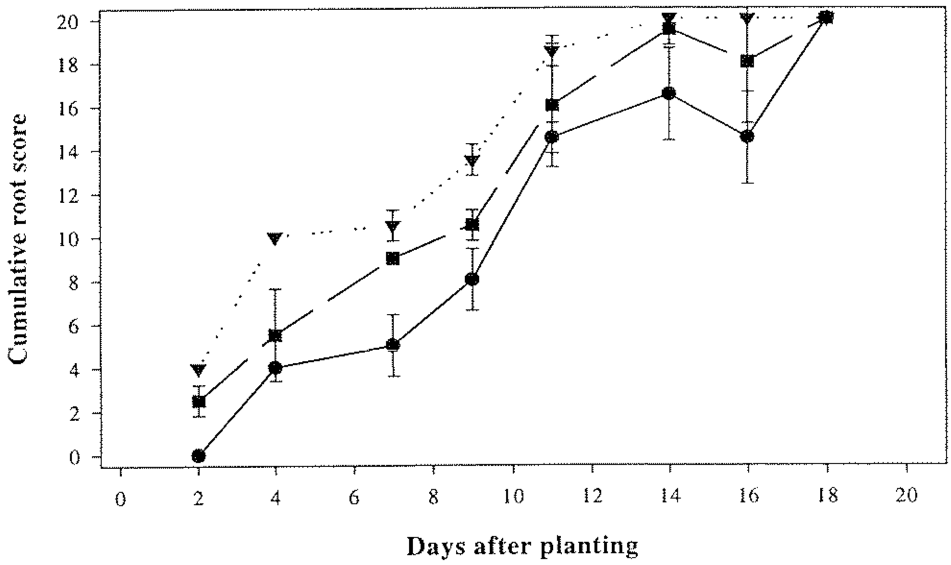
The increased root scores in the longer propagation treatments were not reflected in increased root weights (Table 2). This suggests that duration in propagation may impact on root morphology such that plants given shorter periods in propagation may relatively few thick roots on the bad compared to plants given 12 or 16 days. This may explain why the visual scores of the destructive samples were lower in plants given 8 days in propagation where fewer thicker (but heavier) roots would have less visual impact than those with many fine (lighter) root hairs. Further studies are required before this question can be answered.

Table 1: Effect of duration in propagation on root establishment score at the end of long days (mean root score (0 – 5; 5 = best) from 10 plants / plot).

	Splendid Reagan		Snowdon	
Time in prop. (days)	**Week 45**	**Week 50**	**Week 45**	**Week 50**
8	2.90	2.75	1.90	2.20
12	2.83	3.05	2.40	2.35
16	3.15	3.35	2.65	2.80
5% LSD (10 d.f.)	0.783	comparing between plantings		
	0.723	comparing within plantings		

Figure 1: **Effect of duration in propagation on early root establishment in Snowdon (a) and Splendid Reagan (b) from a week 45 planting.**

a) Rate of root development in Snowdon: Week 45 planting



b) Rate of root development in Reagan: Week 45 planting

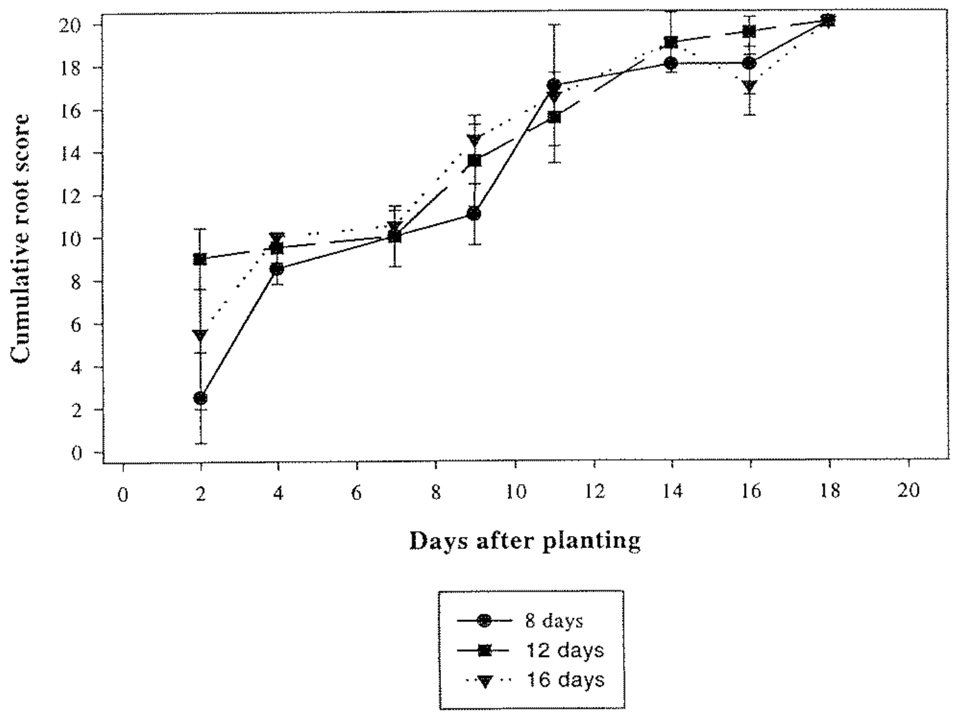
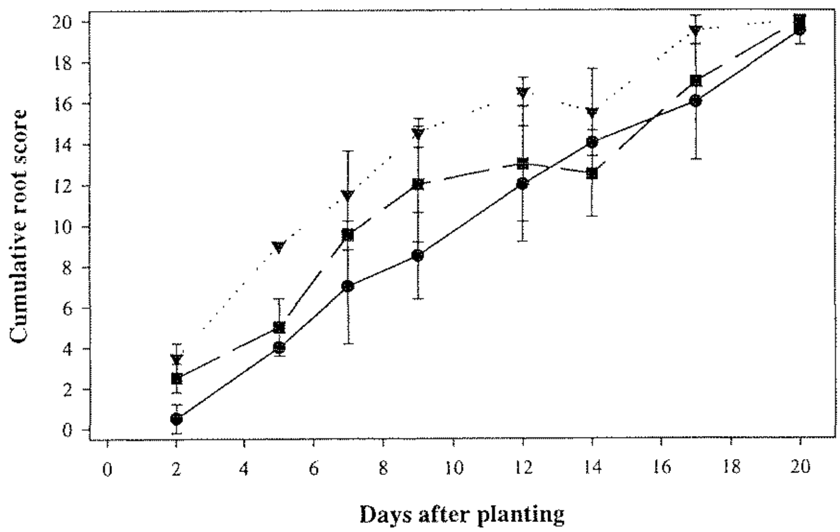
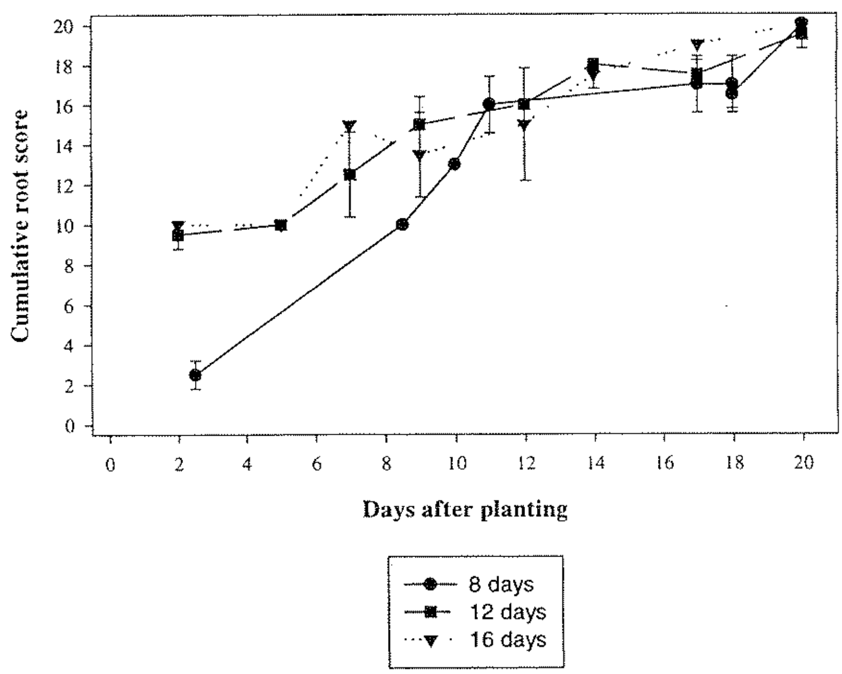


Figure 2: Effect of duration in propagation on early root establishment in Snowdon (a) and Splendid Reagan (b) from a week 50 planting.

a) Rate of root development in Snowdon: Week 50 planting



b) Rate of root development in Reagan: Week 50 planting



3.1.4 Destructive sample at the end of long days

Increasing the number of days given in propagation produced significant increases in stem length, weight and leaf number (Table 2).

Stem length and weight: In both varieties, stem lengths were significantly longer (P = 0.05) in plants given 12 or 16 days in propagation than in the 8 day treatment (Table 2). When averaged across plantings, stems for Reagan in the 16 day treatment were 9.4% and 27% longer than in the 12 and 8 day treatments respectively. In Snowdon, the increases in stem length due to extended propagation were more dramatic than in Reagan, with the 16 day treatment stimulating 13.2% and 45% longer stems than in the 12 and 8 day treatments respectively. Stem weight increased in line with length. For Reagan, plants given 16 days in propagation were 10% and 33.8% heavier than in the 12 and 8 day treatments respectively. For Snowdon, the increases were 16% and 60%. The observed differences in stem length and weight correlate with the effects of duration in propagation on differences in root establishment between varieties.

Leaf number: Leaf number increased in line with stem length and weight. Reagan showed the largest increases in leaf number in plants given 16 days compared to 8 or 12 days (24.4% and 7.3% respectively), with increases of 17.5% and 4% for Snowdon. This might be expected in a vigorous rooting variety where growth would not easily be limited by rooting, but being more dependent on the number of long days received and temperature. In Snowdon, slower development was probably governed to a greater extent by poorer root establishment in plants given a shorter time in propagation.

Bulk dry weight: The increases in dry weight due to 16 days in propagation were 14.8% compared to the 12 day and 38.1% higher than for the 8 day treatment in Reagan, with increases of 18.7% and 64% for Snowdon. Again, these data indicate that Snowdon required longer in propagation than Reagan to ensure optimal root establishment on the bed, with the 8 day treatment compromised due to lower root development / vigour in this treatment.

Implications for a reduction in the long day phase on the bed for plants given extended propagation: The destructive samples at the end of long days measured stem length from the top of the peat block, with weights and leaf numbers recorded for the whole stem length. A common long day schedule was applied to all treatments after planting, with the duration determined by the time required for the 12 day propagation treatment to reach 30 cm (average for the varieties). This means that if the number of long days after planting could be tailored independently for each treatment, plants given longer in propagation would require fewer long days after planting since they were taller at planting. Although the current data could not be used to quantify time-savings on the bed due to extended propagation, this may have important economic implications for year-round production. Future trials in 1998/99 will accurately quantify these savings.

In all cases, the effects were more marked in the week 45 planting than in week 50. The light levels were higher during propagation and establishment phases in the week 45 planting.

Table 2: Effect of duration in propagation on measured crop variables at the end of long days (SR = Splendid Reagan; SN = Snowdon).

Time in prop. (days)	Stem length (cm)		Stem weight (g)		Leaf number		Bulk dry weight (g)		Root fresh weight (g)	
	SR	SN	SR	SN	SR	SN	SR	SN	SR	SN
8	27.66	23.35	8.72	7.46	15.50	14.43	16.73	15.61	0.36	0.37
12	32.24	29.85	10.62	10.29	17.97	16.31	20.12	21.58	0.35	0.25
16	35.26	33.80	11.67	11.94	19.28	16.95	23.10	25.62	0.36	0.28
5 % LSD (10 d.f.)	2.24		1.54		0.53		3.09		0.148 (5 d.f.)	

3.1.5 Harvest data.

Stem length, leaf number and weight: The trends observed at the end of long days persisted until harvest, although the magnitude of the effects was less marked by this stage. Increasing the duration in propagation resulted in significant increases in stem length (up to 13%), and leaf number (up to 12%; Table 3), with the largest effects observed in Snowdon (Table 4). However, this did not follow through with increased stem weight or bulk dry weight at harvest. This may be due, in part, to variability in the data within plots, and perhaps also due to effects on stem thickness (not measured), with thinner stems in plants given extended propagation and competing more actively for light.

Table 3: Effect of duration in propagation on stem length, weight and leaf number (average across varieties and stick dates)

Time in prop. (days)	Stem length (cm)	Stem weight (g)	Leaf number
8	73.37	54.00	29.37
12	77.73	58.80	31.41
16	80.53	57.10	32.45
5 % LSD (10 d.f.)	4.04	7.80	0.94

Table 4: Effect of duration in propagation on stem length, stem weight, leaf number and dry weight for each variety (data averaged across stick dates; SR = Splendid Reagan; SN = Snowdon).

Time in prop. (days)	Stem length (cm)		Stem weight (g)		Leaf number		Bulk dry weight (g)	
	SR	SN	SR	SN	SR	SN	SR	SN
8	76.11	70.63	57.00	51.00	29.48	29.26	162.8	140.8
12	77.35	78.11	54.10	63.50	31.04	31.78	150.2	161.3
16	81.04	80.03	59.50	54.70	32.17	32.73	160.2	158.1
5 % LSD (10 d.f.)	5.72		10.98		1.32		24.21	

3.1.6 Wrap grade-out data: Effect of duration in propagation.

Grade-out: Mean numbers (and %) stems in each grade are presented averaged across varieties and stick dates to show the effect of duration in propagation (Table 5), with data averaged across plantings to show the effect of time in propagation on stem grade-out for each variety (Table 6). The data show that there was no significant effect of duration in propagation on numbers of grade 1, 2 or 3 stems, although there was a tendency for reduced numbers of waste stems in the 12 day treatment. This may reflect the fact that the growing regime was run according to the requirements of the 12 day treatment, with the 8 and 16 day treatments producing more waste stems as a result, particularly for Snowdon (Table 6).

Table 5: Effect of duration in propagation on stem numbers in each grade
(data averaged across varieties and stick dates)

Time in prop. (days)	Number (%) Stems in each grade			
	Grade 1	Grade 2	Grade 3	Waste
8	75.4 (59.2)	39.2 (30.8)	6.63 (5.21)	6.13 (4.81)
12	81.9 (64.9)	36.4 (28.8)	4.50 (3.56)	3.50 (2.77)
16	80.8 (63.1)	36.0 (28.1)	5.50 (4.29)	5.75 (4.49)
5% LSD (10 d.f.)	7.33	9.60	3.08	1.97

Table 6: Effect of duration in propagation on numbers of stems in each grade for each variety
(data averaged across stick dates; SR = Splendid Reagan; SN = Snowdon).

Time in prop. (days)	Number (%) Stems in each grade							
	Grade 1		Grade 2		Grade 3		Waste	
	SR	SN	SR	SN	SR	SN	SR	SN
8	74.0 (58.1)	76.8 (60.4)	43.2 (33.9)	35.2 (27.7)	6.75 (5.30)	6.50 (5.11)	3.50 (2.75)	8.75 (6.88)
12	85.0 (66.3)	78.8 (63.4)	35.0 (27.3)	37.7 (30.3)	4.75 (3.70)	4.25 (3.42)	3.50 (2.73)	3.50 (2.82)
16	81.5 (63.2)	80.0 (63.0)	39.2 (30.4)	32.7 (25.8)	4.25 (3.30)	6.75 (5.32)	4.00 (3.10)	7.50 (5.91)
5 % LSD (10 d.f.)	10.36		13.57		4.36		2.78	

Wrap weights: When averaged across plantings and varieties, there appeared to be small, but significant effects of duration in propagation on mean wrap weight. Grade 1 and 2 wraps from the 8 day propagation treatment were consistently heavier than in the 12 or 16 day treatments (Table 7). When analysed in more detail (Table 8), this appeared to be largely due to increased weights in the 8 day treatment for Reagan, rather than Snowdon, and was particularly marked for the week 45 planting. The trends were not consistent in the week 50 planting. This may be a function of the higher light levels during propagation and early establishment in the week 45 planting resulting in the more vigorous Reagan variety developing more dry matter early in production. Alternatively, the B-nine may have been more effective on the less vigorous plants, resulting in more effective control of pedicel extension, and facilitating heavier thicker stem development.

Table 7: Effect of duration in propagation on mean wrap weight at harvest
(data averaged across stick dates)

Time in prop. (days)	Mean wrap weight Grade 1 (g)	Mean wrap weight Grade 2 (g)	Total weight of Waste stems / plot (g)
8	296.6	194.8	137.9
12	290.2	186.7	81.5
16	286.0	187.0	147.0
5% LSD (10 d.f.)	10.07	5.11	56.73

Table 8: Effect of duration in propagation on mean wrap weight at harvest
(mean for each variety within each planting; SR = Splendid Reagan; SN = Snowdon).

Time in prop. (days)	Mean wrap weight (g) in each grade											
	Grade 1				Grade 2				Total Waste			
	SR		SN		SR		SN		SR		SN	
	45	50	45	50	45	50	45	50	45	50	45	50
8	273.9	294.7	283.2	334.4	184.9	205.9	172.0	216.4	121.0	48.5	247.0	134.9
12	242.5	307.5	271.7	339.2	152.5	215.9	166.3	212.0	87.0	70.0	68.0	100.9
16	255.0	299.5	263.8	325.9	154.3	211.9	168.3	213.7	103.0	126.0	232.0	126.9
5 % LSD (d.f)	33.58 (5)* 20.16 (10)$				7.77 (11)* 10.22 (10)$				137.1 (7)* 113.4 (7)$			

* Comparing means between plantings
$ Comparing means within planting

3.1.7 General observations: duration in propagation and stage of plant development at planting.

- Extended time in propagation resulted in plants with larger root systems that established more rapidly in sterilised soil beds than comparable plants given fewer days in propagation. Of the varieties tested, Reagan was far more vigorous in rooting out of the block after planting compared with Snowdon, and even when planted after only 8 days in propagation, plants established quickly and uniformly.

- The main effect of extending the duration in propagation to 16 days, was for plants to reach a height of 30 cm more quickly than plants given only 8 or 12 days. This has important implications for reducing the number of long days on the bed before starting short days, and thereby to reductions in crop duration (although this could not be quantified in the current study).

- The data showed no consistent trends in the effects of duration in propagation on wrap grade-out in grades 1 and 2 at final harvest, but there was a tendency for Snowdon to produce more waste stems per plot than Reagan.

- Although larger root systems resulted in better establishment when planting onto sterilised beds, this benefit may be reduced in situations where crops are planted onto unsterilised beds with the possibility of a build-up of disease. Increased chances of root damage in larger root systems at planting may make these plants more susceptible to attack by root-rot pathogens, especially when humidity is high and growth rate is slow. Further studies will investigate the interaction between root development at planting and susceptibility to subsequent infection.

3.2 Trial 2: Irrigation water temperature trial

3.2.1 Growing conditions and regime

	Plant date	LDs	SDs	Interruption	SDs	1st cut	Clear
Week 45	3/11/97	29	21	10	40	11/2	16/2
Week 50	8/12/97	26	17	10	42	16/3	18/3

The average irrigation tank temperatures were :

Treatment	Mean temp (°C)	Max temp (°C)	Min temp (°C)
4°C	4.07	10.65	2. 02
Internal ambient	18.07	21.06	16.57
External ambient	8.04	12.77	3.18

The external tank was consistently cooler than the internal tank, but warmer than the 4°C tank. It was not sufficiently cold outside during the season to depress the external tank temperature to below a minimum of 3°C, with and average of 8°C.

The internal ambient tank temperature was consistently just above the heating set point. The only time it dipped was in week 51 when the compartment was connected to the new heating system and ambient compartment temperature dropped leading to a depression in the tank temperature.

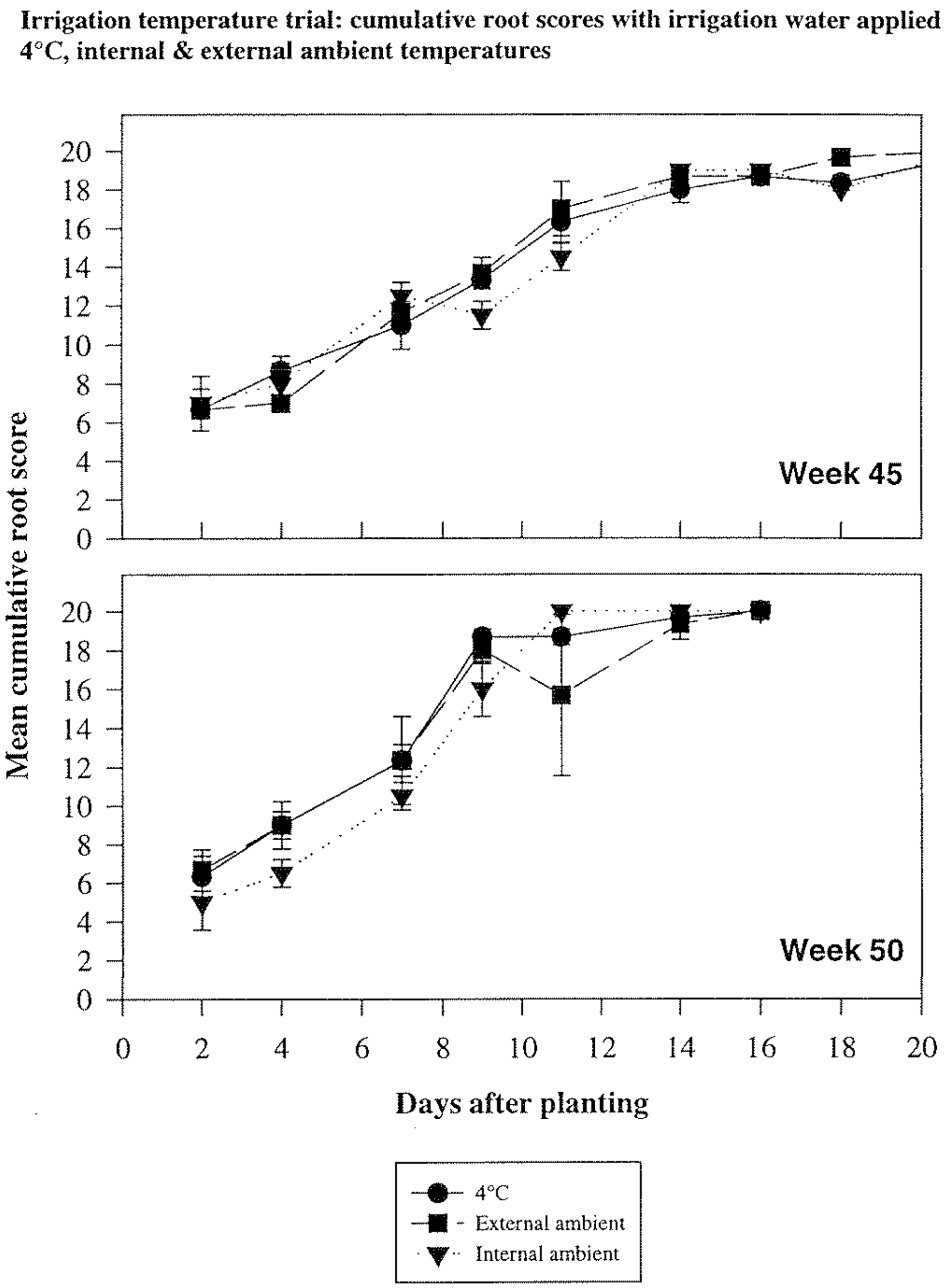
Although the temperature in the 4°C tank briefly reached a maximum of 10.65°C when the cooler stopped operating, the tanks were checked daily and this was quickly spotted and corrected. This maximum value did not occur on an irrigation day and so did not compromise the treatments.

External light levels fell from 5 $MJ/m^2/d$ in week 45 to a minimum of 1.8 $MJ/m^2/d$ in week 51, and increased to 9.5 $MJ/m^2/d$ by week 12.

3.2.2 Effect of overhead irrigation water temperature on early root establishment

Rooting was assessed at 2 - 3 day intervals after planting using the non-destructive "random tug method" which involved sampling plants at random, pulling gently, and scoring them according to degree of rooting into the bed (0 = none; 1 = starting to root into the bed; 2 = rooted in firmly). The cumulative score at each sample time was calculated such that a score of 0 represents no plants in the sample rooting into the bed, and 20 = all plants sampled rooting firmly. Figure 3 shows that there was no significant effect of irrigation water temperature on the rate of rooting into the beds in either the week 40 or week 50 plantings. Since the soil is better buffered against temperature fluctuations when overhead irrigation is used, perhaps it is not surprising that no significant effects of irrigation water temperature were observed on rooting in a vigorous variety like Reagan. It must be noted however, that in less vigorous rooting varieties, irrigation water temperature may have some measurable impact on early establishment, and this requires further investigation.

Figure 3: Effect of overhead irrigation water temperature on early root establishment in Splendid Reagan from a week 45 and week 50 planting



3.2.3 Effect of overhead irrigation water temperature on plant development at the end of long days.

Trends in the data were consistent across both planting dates and so mean data are presented in tables 9 and 10.

Table 9 presents data for destructive root samples taken at the end of the long day period. In both plantings, there was no significant effect of irrigation water temperature on the mean root score.

Table 9: Effect of irrigation water temperature on mean root score (0 – 5; 5 = best) at the end of long days (figures are mean of 10 plants per plot)

	PLANTING WEEK	
Tank temperature	**45**	**50**
Ext Ambient	2.20	3.05
4°C	2.01	2.94
Internal Ambient	2.06	3.13
5% LSD[1] (8 d.f.)	0.83	
5% LSD[2] (8 d.f.)	0.93	

LSD[1]: when comparing 4°C with internal ambient

LSD[2]: when comparing external ambient with 4°C / internal ambient treatments

Stem length: Data for the destructive harvest of plants at the end of long days are presented in Table 10. Cold irrigation water had a small, but significant (P = 0.05) effect on stem length, with plants irrigated with water at 4°C 9% shorter than plants irrigated with water at internal ambient temperature, and 7.7% shorter than plants irrigated with water at external ambient temperatures. This may be the result of a DROP-type response of the crop to short periods of lower temperatures in the canopy, resulting in slight reductions in stem elongation. If one assumes that plants were 14 cm at planting, and they took 28 days to reach 30 cm, this represents a growth rate of approximately 0.6 cm / day. The 9% reduction in height at the end of long days seen in the 4°C treatment is 2.7 cm. At the calculated growth rate, this reduction would result in a 4.5 day delay to the start of SDs in crops irrigated with water at 4°C.

As was highlighted earlier, the external tank was always warmer than the 4°C tank (with one exception), and so there was no significant reduction in stem length when irrigating with water from the either internal ambient or outside tanks. The external tank used in the current trial had a 1500 litre capacity, and was small compared to tanks on commercial holdings.

To study whether or not temperature fluctuated more in small than in larger tanks, work was conducted at commercial nurseries along the south coast during 1996/97 (year 1 of the project). The data clearly showed that the larger tanks on commercial holdings were better buffered against freezing air temperatures than the 1500 litre Efford tank. During the period 03/01/97 to 10/01/97, whilst the Efford tank temperature fluctuated between 0 and 1.5°C, temperatures in the larger commercial tanks never fell below 2°C. Growers who are in locations where water kept in external tanks is liable to prolonged cooling to below 4°C may observe slight reductions in stem length, and this will be enhanced if the irrigation holding tank is small.

Stem weight and leaf number: Correlated with the reduction in stem length was a decrease in stem weight (total stem above the block) and a small reduction in mean leaf number of 2.5% in the 4°C irrigation treatment compared to the other irrigation temperature treatments (Table 10). This suggests that the reduction in stem length was not accompanied by any change in stem thickness, but that the slight depression in canopy temperature, which would occur immediately after irrigation, has slowed development marginally.

Table 10: Effect of overhead irrigation water temperature on measured variables at the at the end of long days (data averaged across planting dates).

Irrigation temperature	Stem length (cm)	Mean stem fresh weight (g)	Leaf number	Bulk dry weight of 24 stems (g)
Ext Ambient	28.56	8.25	16.70	19.98
4°C	26.36	7.63	16.29	20.19
Internal Ambient	29.06	8.53	16.71	20.49
5% LSD[1] (8 d.f.)	1.59	0.51	0.39	1.31
5% LSD[2] (8 d.f.)	1.44	0.46	0.43	1.18

LSD[1]: when comparing 4°C with internal ambient

LSD[2]: when comparing external ambient with 4°C / internal ambient treatments

Bulk dry weight: Despite small (but significant) reductions in stem length, stem fresh weight and leaf number, there was no significant effect of irrigation water temperature on bulk dry weight. This indicates that stem extension in the warmer irrigation treatments is driven mainly by cell expansion (fewer cells and more water per unit stem length), rather than by enhanced assimilation, cell division or dry matter production. If this is the case, stems from the coldest irrigation treatment may be stronger than stems from the warmer irrigation treatments. The potential increase in stem strength due to cold irrigation water was not assessed in the current trial.

3.2.4 Effect of overhead irrigation water temperature on plant development at harvest.

At final harvest, there was no significant effect of irrigation temperature treatment on stem weight, leaf number, root dry weight or bulk plant dry weight (Table 11).

However, the reduction in stem length due to cold irrigation water that had been observed at the end of long days was still present at harvest, with stems in this treatment 5% shorter than the internal or external ambient irrigation temperature treatments ($P = 0.05$). Cool irrigation water had no affect on response time, with all plots were harvested together. It must be remembered that the initial reduction in growth rate due to cold irrigation water would increase the long day phase resulting in a crop delay under commercial conditions.

Table 11: Effect of irrigation water temperature (applied overhead) on measured variables at harvest (data averaged across planting dates).

Irrigation temperature	Stem length (cm)	Mean stem fresh weight (g)	Leaf number	Root dry weight (g)	Bulk dry weight of 24 stems (g)
Ext Ambient	76.23	56.11	30.82	0.088	151.7
4°C	72.73	53.10	29.43	0.087	161.8
Internal Ambient	76.77	52.86	30.53	0.079	156.0
5% LSD[1] (8 d.f.)	2.62	4.75	1.68	0.018	19.3
5% LSD[2] (8 d.f.)	2.89	5.25	1.85	0.019	21.3

LSD[1]: when comparing 4°C with internal ambient

LSD[2]: when comparing external ambient with 4°C / internal ambient treatments

Grade-out and wrap weights: Data for numbers of stems in each grade (Table 12) and wrap weights and wastage (Table 13) indicate that there was no significant effect of overhead irrigation water temperature on stem quality, grade-out or wastage at harvest.

Table 12: Effect of irrigation water temperature (applied overhead) on number of stems in each grade at harvest.

Irrigation temperature	Grade 1	Grade 2	Grade 3	Waste
Ext Ambient	106.3	22.5	2.50	4.50
4°C	106.3	26.5	1.14	5.97
Internal Ambient	113.8	19.0	1.36	4.20
5% LSD[1] (8 d.f.)	12.89	7.06	3.02	3.41
5% LSD[2] (8 d.f.)	14.20	7.79	3.33	3.76

LSD[1]: when comparing 4°C with internal ambient

LSD[2]: when comparing external ambient with 4°C / internal ambient treatments

Table 13: Effect of irrigation water temperature (applied overhead) on mean wrap weight in each grade at harvest.

	Mean wrap weight		Total weight
Irrigation temperature	Grade 1 (g)	Grade 2 (g)	Waste (g)
Ext Ambient	260.3	166.1	102.0
4°C	259.9	167.4	113.1
Internal Ambient	253.1	165.6	74.6
5% LSD[1] (8 d.f.)	12.48	14.04	58.67 (7 d.f.)
5% LSD[2] (8 d.f.)	11.30	12.73	54.32 (7 d.f.)

LSD[1]: when comparing 4°C with internal ambient

LSD[2]: when comparing external ambient with 4°C / internal ambient treatments

3.2.5 General observations: effects of irrigation water temperature

- From these results, irrigation using water which was cooled to a constant 4°C did reduce stem length and leaf number at the end of long days. This reduction in stem length was statistically significant (P = 5%), and may result in a delay in the start of SDs. From the current data, this time delay could not be quantified, but estimates indicate that the crop may take about 4-5 days longer to reach a height of 40 cm in the winter.

- All treatments started SDs together, and so any effects on crop duration due to height differences at the end of LDs were lost at final harvest. Had it been possible to impose the appropriate start of SDs for each treatment independently, we would have expected to see delays in the cold-water irrigation treatment.

- Irrigation using cold water had no observable negative impact on wrap quality or grade-out at harvest.

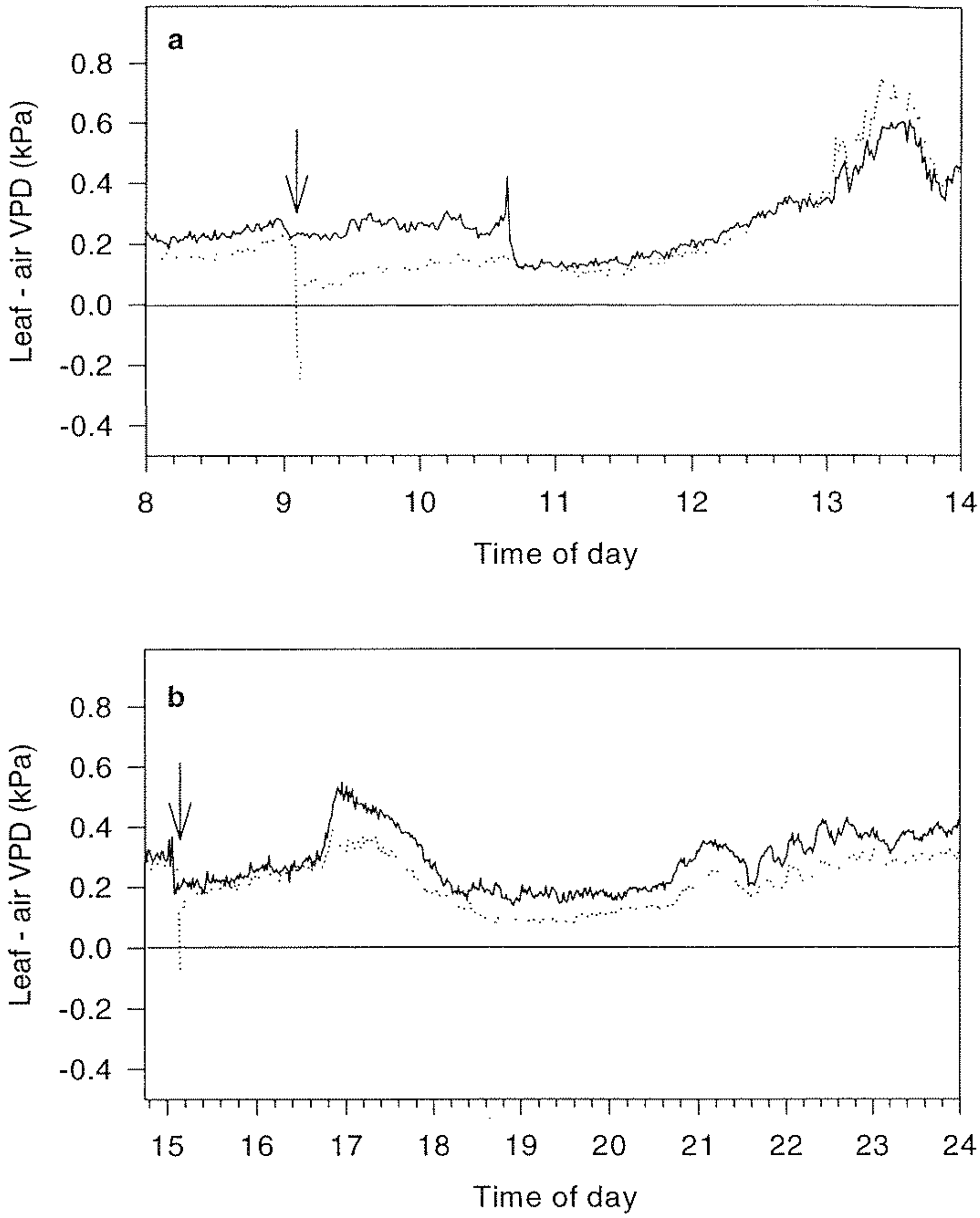
- Natural ambient temperatures at Efford meant that irrigation water from the external tank was always warmer than that supplied from the 4°C treatment. From these observations, it is unlikely that growers in locations which do not normally experience prolonged cold periods, would experience any reductions in yield, quality or uniformity due to the temperature of water held in outdoor tanks. However, growers in cold areas and with small tanks should not be complacent as their irrigation water will be less well buffered against cooling.

3.2.6 Effect of overhead irrigation water temperature on canopy microclimate.

In the 1996/97 trial, when irrigated via a low-level drip irrigation system, cold water, applied directly to the soil surface caused transient reductions in soil and block temperature which rapidly recovered after irrigation. When irrigation is applied overhead, the small water droplets quickly warm up as they pass through the canopy, and as a result, the soil was relatively well buffered against temperature fluctuations (not measured in the current trial). However, the canopy microclimate was affected for a period of time after the irrigation event. Leaf temperature was depressed, with corresponding impacts on relative humidity within the canopy and in humidity deficit (or vapour pressure deficit; VPD) between the leaf and the air within the canopy. It is the VPD that provides the driving force for transpiration from areas of high humidity (internal leaf spaces in sub-stomatal cavity), to areas of lower humidity, such as the air surrounding the leaf or the air above the canopy. Creating an active growing environment relies on the grower's ability to ensure that the atmosphere in the growing environment is not 'stagnant' in terms of gradients in atmospheric water pressure. By controlling heating and air circulation to enhance the VPD from the leaf to the air, the plants will continue to transpire freely and in doing so will remain relatively active in terms of their gas exchange (and in particular assimilation). It is when the environment stagnates, and humidity is very high around the leaves, that problems of poor productivity and susceptibility to a range of pests and diseases arise.

Figure 4 shows the effect of irrigation water temperature on leaf-to-air VPD calculated as the mean of three probes per plot. When irrigated using chilled water from a 4°C source early in the day there was a rapid but transient depression in VPD, with recovery to control levels within 1 ½ hours (fig. 4a). In cases where irrigation was delayed until the late afternoon (fig. 4b), and particularly in overcast conditions, the depression in leaf temperature and VPD extended into the night period, during which the differences could be very persistent. In these cases, where moisture remains in the canopy for long periods, there is increased risk from pathogen attack. In severe cases, certain varieties have been known to suffer from cell rupture or calcium deficiency problems due to high cell turgor and lack of transpiration (respectively).

Figure 4: Effect of irrigation water temperature on Leaf - air vapour pressure deficit : a) morning irrigation, b) late pm irrigation



VPD 4°C irrigation treatment : ....

VPD internal ambient treatment : __________

Arrow indicates time of irrigation

4 Conclusions

4.1 Trial 1: Duration in propagation and stage of development at planting :

- Extending duration in propagation resulted in plants with larger root systems that established more rapidly in sterilised soil beds than comparable plants given fewer days in propagation. Of the varieties tested, Reagan was far more vigorous in rooting out of the block after planting than Snowdon, and even when planted after only 8 days in propagation, plants established quickly and uniformly.

- The main effect of extending the duration in propagation to 16 days, was for plants to reach a height of 30 cm more quickly than plants given only 8 or 12 days. This has important implications for reducing the number of long days on the bed before starting short days, and a consequent reduction in crop duration (although this could not be quantified in the current study).

- The data showed no consistent trends in the effects of duration in propagation on wrap grade-out in grades 1 and 2 at final harvest.

- Although larger root systems resulted in better establishment when planting onto sterilised beds, this benefit may be reduced in situations where plants are planted onto un-sterilised beds with potential for disease to be present. Increased chances of damage to larger root systems due to handling at planting may make these plants more susceptible to attack by root-rot pathogens. Further studies in 1998/99 will investigate the interaction between root development at planting and susceptibility to subsequent infection.

4.2 Trial 2: Irrigation water temperature:

- Irrigation using water which was cooled to a constant 4°C significantly reduced stem length and leaf number at the end of long days. Since SDs could not be applied independently to each treatment, any effects of cold irrigation water on crop duration after planting were lost a harvest. Under commercial conditions, the reduction in growth rate due to cold irrigation water early in establishment on the bed would result in a delay in the start of SDs. From the current data, this delay could not be quantified, but estimates indicate that, when the crop is irrigated with a constant 4°C water supply, it may take about 4 - 5 days longer to reach a height of 40 cm in the winter than a crop irrigated with warmer water.

- Irrigation using cold water had no observable negative impact on wrap quality or grade-out at harvest.

- Natural ambient temperatures resulted in irrigation water from the external tank always being warmer than that supplied for the 4°C treatment. From these observations, it is unlikely that growers in locations which do not normally experience prolonged cold periods, would observe any reductions in yield, quality or uniformity due to the temperature of water held in outdoor tanks. However, growers in cold areas and with small tanks should not be complacent, as their irrigation water will be less buffered against cooling.

- Measurements of canopy microclimate showed that vapour pressure deficit (VPD: the driving force for transpiration) was only depressed for about 1 ½ hours after overhead irrigation given early in the day. Care should be taken to avoid irrigating late as VPD remained depressed for much longer during the night providing ideal conditions for pathogen attack, or other physiological disorders associated with poor transpiration.

ACKNOWLEDGEMENTS

The author would like to acknowledge Mr Dave Abbott and the Chrysanthemum Committee for their help, guidance and input throughout the current trials. I would also like to thank Yoder Toddington for their flexibility in dealing with the demands of supplying high quality uniform material for research trials.

Appendix 1: Treatment layout for stage of root establishment at planting trial : PC 133 (R Block east)

Guard					Guard
	SR 8	SN 8	SR 8	SN 8	
	SR 12	SN 12	SR 12	SN 12	
	SR 16	SN 16	SR 16	SN 16	
	SN 16	SR 16	SN 16	SR 16	
	SN 12	SR 12	SN 12	SR 12	
	SN 8	SR 8	SN 8	SR 8	
BED NO: 13	14	15	22	23	24

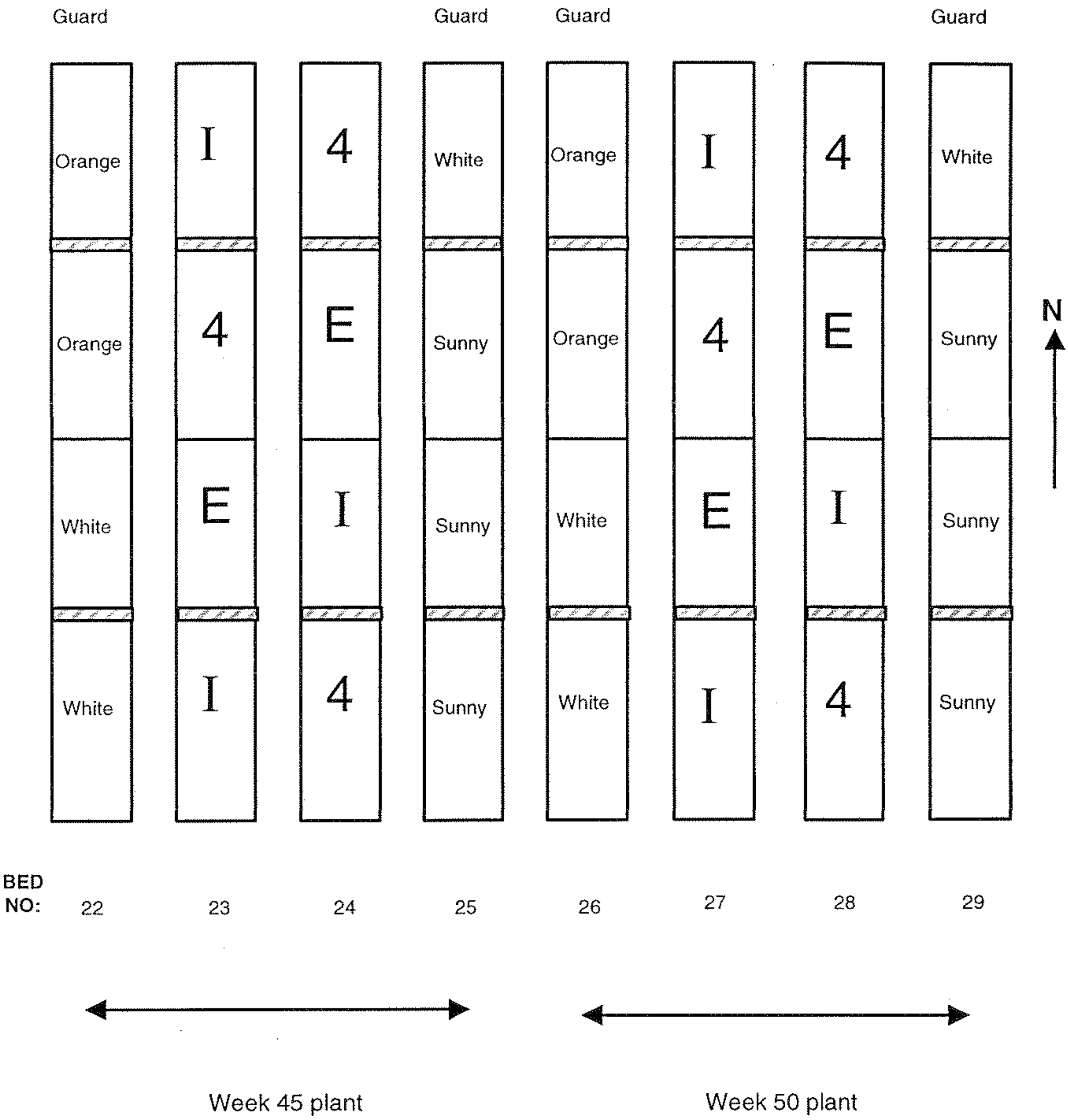
N

Week 50 planting (beds 13–15) | Week 45 planting (beds 22–24)

Key to codes:

SR	= Splendid Reagan
SN	= Snowdon
8, 12, 16	= Number of LD's in prop

Appendix 2: Treatment layout for irrigation water temperature trial: PC 133 (C Block)



Key to codes:

4 = 4°C irrigation temperature
I = Internal ambient tank
E = External ambient temperature

[hatched bar] 5 rows lost due to pipework

Appendix 3.1: Crop diary/activity record for Trial 1: stage of development at planting: week 45 planting.

DATE	Day	ACTIVITY
20.10.1997	LDs	**Stick 16 LD**
23.10.1997	3	Mycotal (1 g/l) & Vertalec (2 g/l)
24.10.1997	4	**Stick 12 LD**
28.10.1997	8	**Stick 8 LD**
04.11.1997	15	Rovral 1 .5 g/l
05.11.1997	16	**Plant**
09.11.1997	**ON BED** 4	Malathion 1.8 ml/l
16.11.1997	11	Thiodan 2 g/l
18.11.1997	13	B-Nine 0.75 g/l SR only
23.11.1997	18	Malathion 1.8 ml/l
30.11.1997	25	Dichlorvos 1 ml/l
03.12.1997	28	**Start SDs**
07.12.1997	32	Malathion 1.8 ml/l
14.12.1997	39	Thiodan 2 ml/l
21.12.1997	46	Malathion 1.8 ml/l
22.12.1997	47	**Start Of Interruption**
23.12.1997	48	Snowdon 0.75g/l; S Reagan 1 g/l B-Nine
24.12.1997	49	Pirimor 0.5 g/l
28.12.1997	53	Dichlorvos 1 ml/l
01.01.1998	57	**End Of Interruption**
04.01.1998	60	Thiodan 2 ml/l
05.01.1998	61	B-Nine 0.75 g/l Snowdon & Reagan
11.01.1998	67	Malathion 1.8 ml/l
18.01.1998	74	Thiodan 2 ml/l
25.01.1998	81	Dichlorvos 1 ml/l
26.01.1998	82	Disbud
29.01.1998	85	Pirimor 0.5 g/l
01.02.1998	88	Malathion 1.8 ml/l
03.02.1998	90	Bud Colour Snowdon
06.02.1998	93	Bud Colour Reagan

Appendix 3.2: **Crop diary/activity record for Trial 1: stage of development at planting: week 50 planting.**

DATE	Day	ACTIVITY
24.11.1997	LDs	**Stuck 16 LD**
28.11.1997	4	**Stuck 12LD + Guards**
01.12.1997	16	Rovral 0.5g/l
02.12.1997	8	**Stuck 8LD (East end)**
05.12.1997	11	Removed sheeting 12LD
10.12.1997	16	**Plant**
14.12.1997	**ON BED**	Thiodan 2 ml/l
	4	
21.12.1997	11	Malathion 1.8 ml/l
24.12.1997	14	B-Nine 0.75 SR only
28.12.1997	18	Malathion 1.8 ml/l
04.01.1998	25	Thiodan 2 ml/l
09.01.1998	30	**Start Of SDs**
09.01.1998	30	B-Nine 0.75 g/l Snowdon & Reagan
11.01.1998	32	Malathion 1.8 ml/l
18.01.1998	39	Thiodan 2 ml/l
23.01.1998	44	B-Nine Reagan 0.75 g/l Snowdon 1g/l
25.01.1998	46	Dichlorvos 1 ml/l
26.01.1998	47	**Start Of Interruption**
01.02.1998	53	Malathion
02.02.1998	54	B-Nine Reagan & Snowdon
04.02.1998	56	**End Of Interruption**
08.02.1998	60	Thiodan 2 ml/l
15.02.1998	67	Dichloruos 1 ml/l
22.02.1998	74	Malathion 1.8 ml/l
24.02.1998	76	Pirimor 0.5 g/l
01.03.1998	81	Thiodan 2 ml/l
01.03.1998	81	Bud Colour Snowdon
05.03.1998	85	Bud Colour Reagan
08.03.1998	88	Dichlorvos 1 ml/l

Appendix 3.3: Crop diary/activity record for Trial 2: irrigation water temperature trial: week 45 planting.

DATE	Day	ACTIVITY
22.10.1997	**LDs**	**Stuck**
23.10.1997	1	Mycotal (1 g/l) + Vertalec (2 g/l)
29.10.1997	7	Removed Sheeting
02.11.1997	11	Roural 0.5 g/l
03.11.1997	12	**Planted**
09.11.1997	**ON BED** 6	Malathion 1.8 ml/l
17.11.1997	14	Thiodan 2 mg/l
24.11.1997	21	Malathion 1.8 ml/l
31.11.1997	28	Dichlorvos 1 ml/l
01.12.1997	**29**	**Start SDs**
01.12.1997	29	B Nine 0.75 g/l
02.12.1997	30	Malathion 1.8 ml/l
14.12.1997	42	Thiodan 2 ml/l
15.12.1997	43	B Nine 0.75 g/l
21.12.1997	49	Malathion 1.8 ml/l
22.12.1997	50	**Start Of Interruption**
24.12.1997	52	Pirimor 0.5 g/l
28.12.1997	56	Dichlorvos 1ml/l
29.12.1997	57	B Nine 0.75 g/l
01.01.1998	60	**End Of Interruption**
04.01.1998	63	Thiodan 2 mls/l
11.01.1998	70	Malathion 1.8 mls/l
18.01.1998	77	Thiodan 2 mls/l
22.01.1998	81	Disbudded
25.01.1998	84	Dichlorvos 1ml/l
29.01.1998	88	Pirimor 0.5 g/l
01.02.1998	91	Malathion 1.8 ml/l
02.02.1998	92	Bud Colour – Changed to low-level irrigation

Appendix 3.4: Crop diary/activity record for Trial 2: irrigation water temperature trial: week 50 planting.

DATE	Day	ACTIVITY
26.11.1997	LDs	**Stuck**
03.12.1997	7	Removed sheeting
07.12.1997	11	Rovral 0.5 g/l
08.12.1997	12	Planted / Lights on
14.12.1997	**ON BED** 6	Thiodan 2 ml/l
21.12.1997	13	Malathion 1.8 ml/l
28.12.1997	20	Malathion 1.8 ml/l
04.01.1998	24	Thiodan 2 ml/l
06.01.1998	26	**Start of Short Days**
06.01.1998	26	B-Nine 0.75 g/l
20.01.1998	40	B-Nine 0.75g/l
23.01.1998	43	**Start of Interruption**
25.01.1998	45	Dichlorvos 1mls/l
30.01.1998	50	B-Nine 0.75g/l
01.02.1998	52	Malathion 1.8mls/l
02.02.1998	53	**End of Interruption**
08.02.1998	59	Thiodan 2 ml/l
15.01.1998	66	Dichlorvos 1 ml/l
22.01.1998	73	Malathion 1.8 ml/l
24.02.1998	75	Pirimor 0.5 g/l
01.03.1998	80	Thiodan 2 ml/l
02.03.1998	81	Bud Colour
04.03.1998	83	Changed to low level irrigation

Appendix 4: Plot layouts in C and R Blocks

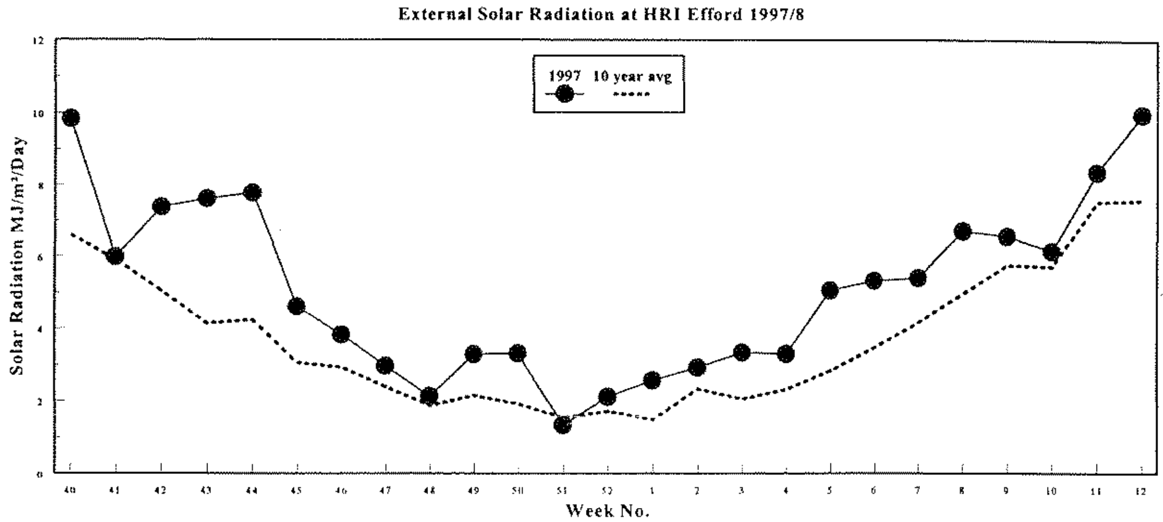
NB: In R Block, each plot has extra rows for the grade-out sample
because no plot rows are lost to pipe-work as in C

	1	2	3	4	5	6	7	8	9	10	11	12	
1	X	X	X	X	X	X	X	X	X	X	X	X	Guards
2	X	X	X	X	X	X	X	X	X	X	X	X	
3	X		X		X		X		X		X		Destructive root samples End LDs
4	X	X	■	X	■	■	X	X	■	X	X	X	
5	X	X	X	■	X	X	X	■	X	■	X	X	
6	X		■		X		■		■		X		
7	X	X	X	X	X	X	X	X	X	X	X	X	Sample 1 End LDs
8	X	X	X	X	X	X	X	X	X	X	X	X	
9	X		X		X		X		X		X		Guards
10	X	X	X	X	X	X	X	X	X	X	X	X	
11	X	X	X	X	X	X	X	X	X	X	X	X	
12	X		X		X		X		X		X		
13	X	X	X	X	X	X	X	X	X	X	X	X	Sample 2 Maturity
14	X	X	X	X	X	X	X	X	X	X	X	X	
15	X		X		X		X		X		X		Grade - out sample
16	X	X	X	X	X	X	X	X	X	X	X	X	
17	X	X	X	X	X	X	X	X	X	X	X	X	
18	X		X		X		X		X		X		
19	X	X	X	X	X	X	X	X	X	X	X	X	
20	X	X	X	X	X	X	X	X	X	X	X	X	
21	X		X		X		X		X		X		
22	X	X	X	X	X	X	X	X	X	X	X	X	
23	X	X	X	X	X	X	X	X	X	X	X	X	
24	X		X		X		X		X		X		
25	X	X	X	X	X	X	X	X	X	X	X	X	
26	X	X	X	X	X	X	X	X	X	X	X	X	
27	X		X		X		X		X		X		
28	X	X	X	X	X	X	X	X	X	X	X	X	
29	X	X	X	X	X	X	X	X	X	X	X	X	Guards
30	X		X		X		X		X		X		

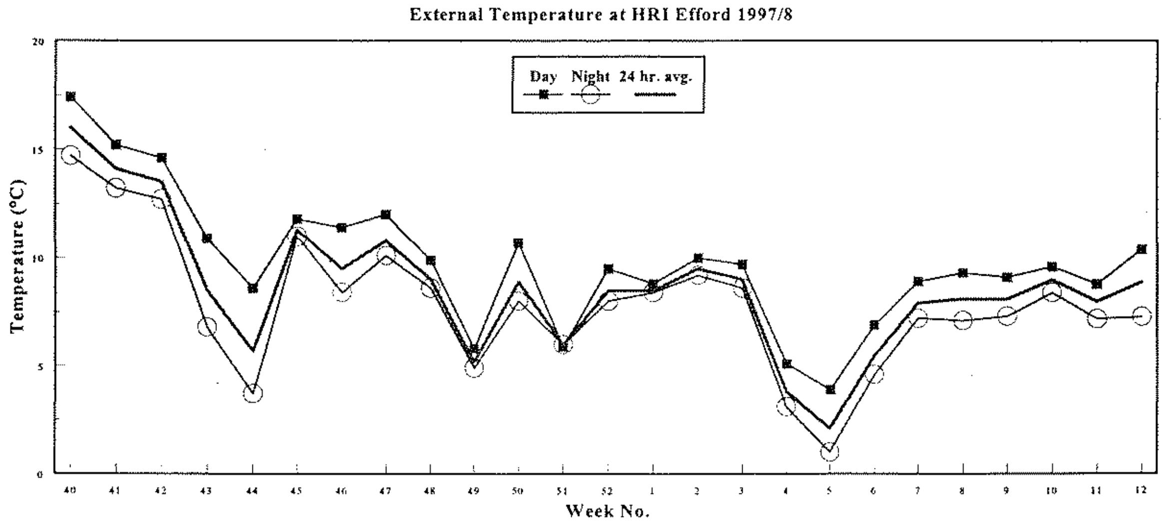
■ = Destructive root samples at end of LDs

Appendix 5.1: External light (a) and temperatures (b) at HRI Efford from week 40 1997 to week 12 1998.

a

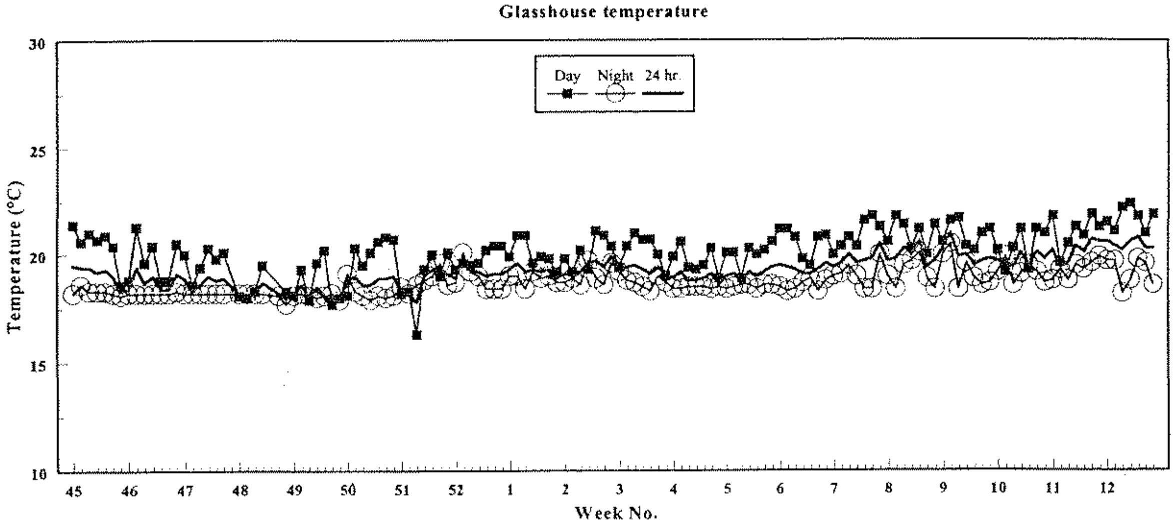


b

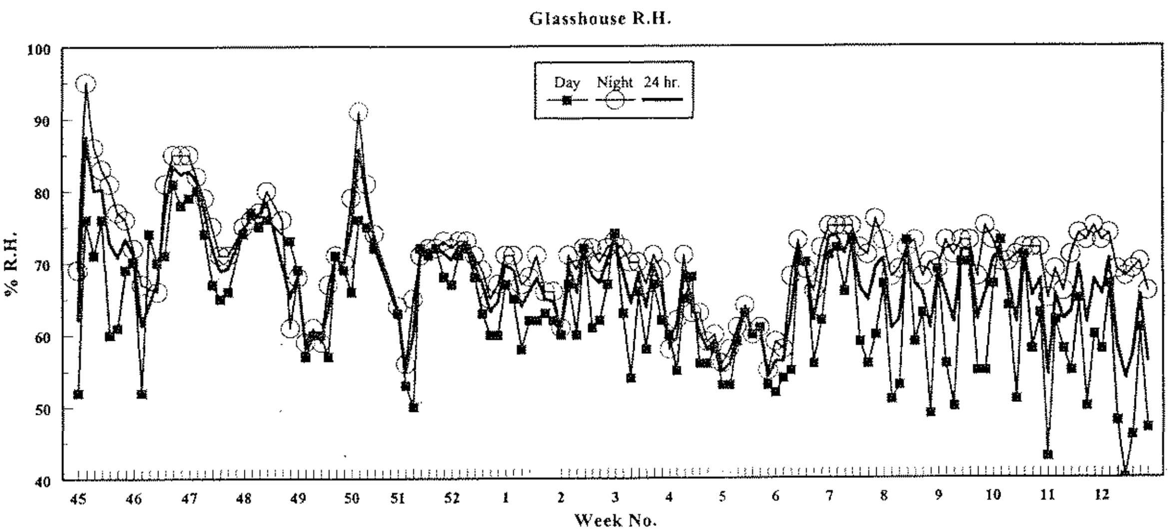


Appendix 5.2: Compartment day, night and 24 hour average temperature (a) and relative humidity (b) : R block : Stage of development at planting trial

a

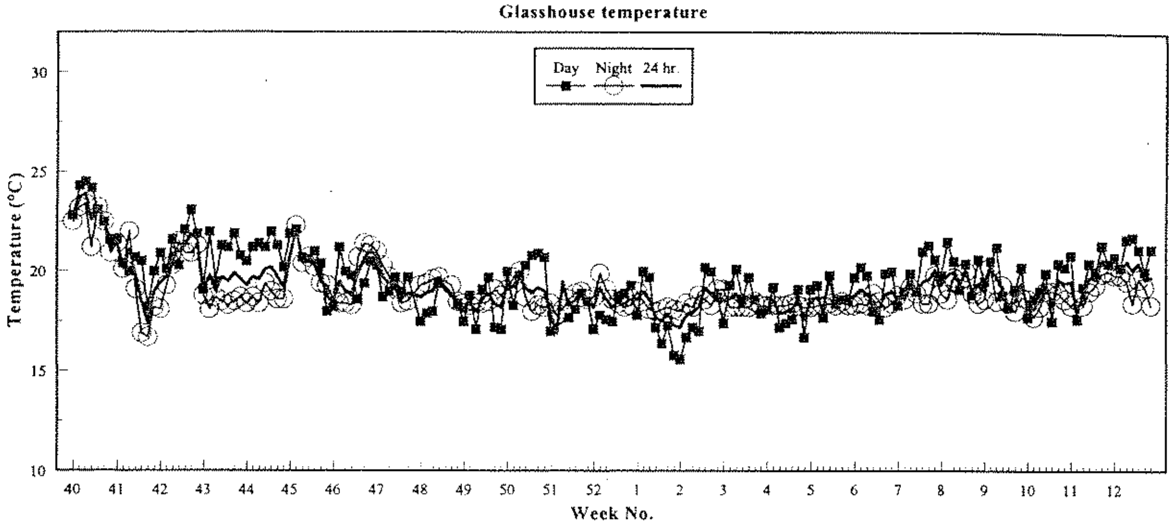


b



Appendix 5.3: Compartment day, night and 24 hour average temperature (a) and relative humidity (b) : C block : Irrigation temperature trial

a



b

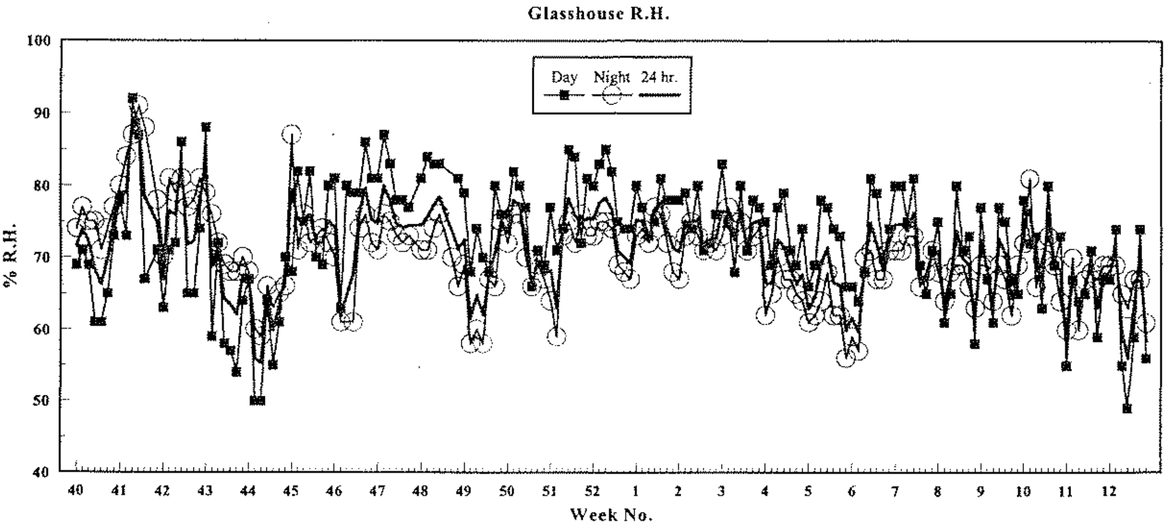


Plate 1: Effects of duration in propagation on root development at planting in Reagan and Snowdon (© 1998 HDC)

Reagan

Snowdon

8 days | **12 days (Standard)** | **16 days**

Plate 2 : Humidity probe (a) and leaf thermistor (b) for measuring canopy microclimate