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CONTRACT REPORT

HDC PC41

Control of plant stature by manipulation of day and night temperatures (DIF) regimes 1992

Part II; Bedding Plants

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AUTHENTICATION

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

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CONTENTS

RELEVANCE TO GROWERS AND PRACTICAL APPLICATION

Application

Various difference in temperature regimes (DIF) were compared with the aim of achieving some growth control of bedding plants in order to reduce the use of plant growth regulators. This trial, in conjunction with that of 1991, suggests that the most effective DIF regime for the bedding species investigated would appear to be a temperature drop (DROP) treatment at sunrise.

Summary

In the past there has been a heavy dependency on chemicals to provide the desired growth control for bedding plant production in the UK. Recent legislation and concern over the use of pesticides may well result in a reduction in the number of plant growth regulators available to the bedding plant producer and hence alternative methods of growth control need to be sought. Breeding of new more compact cultivars will help but this work is very long term. An alternative approach is to manipulate the growing environment to achieve a more compact plant, without having detrimental effects on overall plant quality and development. Difference in temperature (DIF) regimes have shown promise in preliminary trials work in helping to reduce plant growth regulator use and to control extension growth of both pot and bedding plant species. The potential benefits to the grower of applying a DIF regime include a reduction in chemical input and hence reduced risk of soil/drainage water contamination, reduced exposure of staff to sprays and residues, lower labour requirement and possible improvements in plant quality.

This trial continued the programme of work started in 1991 when the Horticultural Development Council (HDC) commissioned HRI Littlehampton and HRI Efford to investigate the potential use of DIF as a growth control measure in pot and bedding plants. Four controlled environment cabinet experiments were also completed at HRI Littlehampton to determine the effects of DIF and DROP treatments on stem elongation in poinsettia, geranium and chrysanthemum (Reported as HDC PC41 Part I, Controlled Environment Cabinet Experiments).

Commercial production protocols, based on the results of these experiments, were set up in glasshouse trials at HRI Efford. The 1991 work on the bedding species *Impatiens walleriana*, *Pelargonium zonale*, *Petunia* hybrid and *Salvia splendens* showed a distinct response to regimes where the temperature was dropped in the early morning. However, a 6°C DROP from sunrise caused some chlorosis of *Salvia* and the 1992 trial, therefore, tested the response of the same species to a 4°C DROP.

Consequently, this trial both consolidated the results from the 1991 bedding DIF trial at HRI Efford and growth cabinet work from HRI Littlehampton and concentrated on DIF regimes around sunrise.

Treatments were as follows:

A. Zero DIF (16°C day/night temperature).
B. Negative DIF (-4°C for 2 hours at sunrise [DROP]).
C. Positive DIF (+4°C boost for 2 hours at end of night [JUMP]).
D. Higher end night followed by negative DIF (night temperature raised to 18 °C for 2 hours prior sunrise then dropped to 14°C [JUMP/DROP]).

Growth regulation

1.	Control, no growth regulation			
2.	Alar (daminozide) spray,	2500 ppm	-	Petunia, Impatiens
	Cycocel (chlormequat 46%) spray,	3 x 300 ppm	-	Pelargonium
		3000 ppm	-	Salvia

Growth differences recorded between regimes were small when compared to the 1991 trial but the results still indicated some growth control responses at the species level with treatment B and D, the negative DIF treatments (DROP and JUMP/DROP) performing best. This matches the results from the growth cabinet work from HRI Littlehampton. However, degree of response has varied between sowings both at the plug stage and on finished plants and further clarification of factors which can affect the species response needs to be done. Possible reasons for the small response to DIF treatment may be due to factors such as, timing, duration, stage of growth applied and the higher temperature used when compared to 1991.

As might be expected chemical growth regulant application produced smaller, more compact plants in all regimes with the DROP plants tending to be smallest for all four species. There was no influence of temperature treatment on 'garden performance' once bedded out.

All the plants produced, regardless of treatment, were of good quality, but the control with no plant growth regulator (treatment A) tended to produce more 'leggy' plants which when bedded out were more susceptible to wind damage.

Action Points

- Over the two years' work, a DROP of 6°C for 2 hours from sunrise appears better than 4°C in terms of providing growth control but the extent of response varies between species.

- DIF DROP treatments from sunrise become more difficult to achieve as the season progresses due to higher outside night temperatures.

- DIF treatments can commence once the cotyledons have fully expanded without any detrimental effects on *Pelargonium*, *Impatiens* and *Petunia* but some chlorosis may occur with *Salvia*.

- DIF regimes are still to be tested on other species of bedding plant so the extent of growth control and the effect on plant quality is yet to be determined, but a follow up trial in 1993 will test a further four species.

- DIF response may be affected by plug size and this will be evaluated in later studies.

EXPERIMENTAL SECTION

INTRODUCTION

DIF (difference in temperature) regimes are at present being examined to establish their potential for growth (height) control on a range of both bedding and pot plant species throughout Europe. Earlier investigations examined temperature regimes where the whole of the daytime period was maintained below that of the night. Due to the practical problems of achieving this duration of temperature control for much of the year in the UK, manipulation of temperature around sunrise has been investigated.

MAFF-funded work

In 1990/91 MAFF funded work at HRI Efford evaluated the potential benefit of a 2 hour drop in temperature before and after sunrise. This work indicated that a measure of height restriction was possible when bedding subjects were exposed to a negative DIF of 6°C for 2 hours at sunrise. This short period temperature change is now commonly referred to as DROP. Variations of possible temperature manipulations around sunrise to control growth are currently being examined; these include raising the temperature towards the end of the night period and dropping back to the "normal" day temperature at sunrise (JUMP). Another variation is to give a modest temperature boost at the end of the night period followed by a drop to below "normal" day temperature at sunrise before returning to "normal" day temperature (JUMP/DROP). Despite the DROP treatment giving best results, some chlorosis was evident on the *Salvia* and therefore this study tested a smaller DROP of 4°C for 2 hours from sunrise.

Controlled environment studies - HRI Littlehampton

Work was commissioned through the Horticultural Development Council (HDC) to investigate the ability of DIF regimes to control plant stature of pot and bedding species in a joint project at HRI Littlehampton and HRI Efford. Four controlled environment cabinet experiments were completed at HRI Littlehampton to determine the effects of DIF and DROP treatments on stem elongation in poinsettia, geranium and chrysanthemum.

In the case of poinsettia, both negative DIF and DROP treatments reduced stem length. The most effective time to give a DROP treatment was during the first half of the day, with response being determined by both the magnitude and duration of the temperature reduction. Both negative DIF and DROP advanced flowering, this effect being particularly marked when the temperature of the remaining period was raised to maintain a standard 24 hour average temperature (temperature compensation). Negative DIF had a larger effect than DROP in reducing leaf chlorophyll content; both treatments reduced average leaf area and plant dry weight.

Geranium was relatively insensitive to negative DIF and DROP treatments, but petiole length was reduced. Stem length was unaffected. There were no observable effects on flowering.

Stem length in chrysanthemum was reduced by negative DIF and DROP treatments in a similar manner to poinsettia. However, these treatments did not advance flowering; flowering was delayed if treatment resulted in the average 24 hour temperature being lowered. Low temperatures during the second half of the day had a particularly noticeable effect in delaying flowering. As with poinsettia, negative DIF and DROP treatments reduced leaf chlorophyll content, average leaf size and plant dry weight.

Glasshouse trials - HRI Efford

Commercial production protocols based on the results of the controlled environment cabinet experiments were set up in the glasshouses at HRI Efford.

The 1991 work at HRI Efford on the bedding species *Impatiens walleriana*, *Pelargonium zonale*, *Petunia* hybrid and *Salvia splendens*, showed a distinct response to regimes where the temperature was dropped in the early morning. However, there was not sufficient detail in the results to confirm how the species would perform using different sowing dates and plug sizes. Also, a 6°C DROP from sunrise was used and some chlorosis of *Salvia* occurred. The 1992 trial, therefore, tested the response of the same species to a 4°C DROP.

In order to assess the extent of the commercial benefits of growth control achieved by different DIF treatments, a comparison using plant growth regulators was used for all regimes.

OBJECTIVES

To investigate the use of DIF, using early morning temperature drops as a means of control of growth on a range of bedding plant species grown in modules.

To evaluate the effect of the above treatments on subsequent shelf-life of plants.

MATERIALS AND METHODS

Site

Seeds were sown into plug trays in the H south propagation facility at HRI Efford. Once the first true leaves were expanded the seedlings were grown-on on sand floors in four compartments of the multifactorial glasshouse 'K' block, equipped with computerised environmental control, each compartment having a separate DIF treatment. Performance under glass and in the garden was assessed, with planting out on an area of newly rotovated and established ground which had previously been down to grass. The soil type was of the Waterstock Series - a slightly stony sandy silt loam.

Start Material

Seeds for the trial were bought from Colegrave Seeds Limited.

Species

Impatiens walleriana	cv.	F1 Accent Salmon
Pelargonium zonale	cv.	F1 Century Cardinal
Petunia hybr.	cv.	F1 Frenzy Rose Star
Salvia splendens	cv.	Vanguard

Treatments

Sowing dates

Two sowings for each species: 15 January 1992 and 10 February 1992.

Temperature regimes

A. Zero DIF (16°C day/night temperature).
B. Negative DIF (-4°C for 2 hours at sunrise). (DROP).
C. Positive DIF (+4°C boost for 2 hours at end of night). (JUMP).
D. Higher end night followed by negative DIF (night temperature raised to 18 °C for 2 hours prior to sunrise then dropped to 14°C). (JUMP/DROP).

Growth regulation

1.	Control, no growth regulation			
2.	Alar (daminozide) spray,	2500ppm	-	*Petunia, Impatiens*
	Cycocel (chlormequat 46%) spray,	3 x 300 ppm	-	*Pelargonium*
		3000 ppm	-	*Salvia*

Design

Each species was treated as an individual experiment. The design was a randomised block layout with four replicates and the two growth regulant treatments fully randomised within each block.

4	main plots (temperature regimes)
x	
2	sub plots (growth regulant treatments)
x	
4	replicates
32	sub plots per sowing
x	
2	sowing dates per species
64	sub plots per species
x	
4	species
256	sub plots in total

Plot size: 15 plants

The trial layout is given in Appendix 1, page 17

Cultural details

The seeds were hand sown into plug cells containing Fisons Professional Levington F1 growing media drenched with propamocarb hydrochloride as Filex at 2.5 ml/l for disease control. Plug tray sizes used were P140 for *Pelargonium* and P252 for *Impatiens*, *Petunia* and *Salvia*. The *Impatiens* and *Salvia* were lightly covered with 3 mm of vermiculite and the *Pelargonium* seeds were covered with 5 mm as per the seed suppliers recommendations. The module trays were then placed on heated benches covered with polythene with the *Salvia*, *Impatiens* and *Petunia* germinated at a bench temperature of 23°C and the *Pelargonium* at 20°C. After emergence the temperature was dropped to 18°C. Once the first true leaves had fully expanded, module trays were moved to their multifactorial compartment in 'K' block and the temperature treatments commenced.

Plant growth regulator treatments appropriate for each species were applied during the module stage (see Table 1, Page 9). The timing of application was done as per the label recommendations as follows:

Pelargonium	-	Cycocel: 3 x 300 ppm at weekly intervals commencing 30-40 days after sowing.
Salvia	-	Cycocel: 3000 ppm once plants had 4 true leaves.
Impatiens	-	Alar: 2500 ppm when plants had two pairs of true leaves.
Petunia	-	Alar: 2500 ppm when plants had 'covered the box'.

Records were taken at transplanting stage when seedling roots had fully explored the module, forming an easy to remove 'plug'. Plants were potted-on into 90 mm round terracotta pots using Fisons Professional Levington M2 growing media. Again a drench of propamocarb hydrochloride as Filex at 2.5 ml/l was applied. No further fungicides were applied and a standard biological control programme was followed for pest control using *Aphidius colmanii* for aphid control, *Amblyseius cucumeris* for thrips, *Steinernema feltae* for fungus gnats and *Encarsia formosa* for glasshouse whitefly (*Trialeuroides vaporirium*).

Liquid feeding commenced once the cotyledons had fully expanded and occurred at every watering. The initial feed supplied 150 ppm N and 150 ppm K_2O. Once the seedlings were established this was altered to give 150 ppm N, 110 ppm P_2O_5 and 150 ppm K_2O.

Plants were grown-on in the glasshouse until the sale stage (maturity) i.e. when 50% of plants in a plot had at least one flower showing in colour. At this point final assessments were made. Plant material was then planted out in the bedding out site on 9 June and maintained throughout the summer with observations being made on garden performance.

Table 1: Crop Diary

Species	Sowing date	Germination date	DIF trts commenced	PGR application	Transplant date ≈	Sale date +
Sowing 1						
Impatiens	15 Jan	23 Jan	10 Feb	20 Feb	2 Mar	13 Apr
Pelargonium	15 Jan	18 Jan	31 Jan	11 Feb	28 Feb	10 May
				19 Feb		
				26 Feb		
Petunia	15 Jan	20 Jan	10 Feb	26 Feb	18 Mar	28 Apr
Salvia	15 Jan	21 Jan	5 Feb	20 Feb	27 Feb	14 Apr
Sowing 2						
Impatiens	10 Feb	17 Feb	28 Feb	20 Mar	1 Apr	30 Apr
Pelargonium	10 Feb	13 Feb	25 Feb	16 Mar	2 Apr	28 May
				23 Mar		
				30 Mar		
Petunia	10 Feb	16 Feb	28 Feb	20 Mar	2 Apr	8 May
Salvia	10 Feb	17 Feb	25 Feb	17 Mar	24 Mar	5 May

≈ **Transplant date = first recording date**

\+ **Sale date = second recording date**

Assessments

Crop Diary

Throughout the course of the trial, notes were made on plant development including foliage colour and time to 50% flowering.

At Transplanting

At the point of transplanting, plant height (mm) for all plots was measured together with certain selected assessments on certain species. These included:

Leaf number of *Impatiens* and *Petunia*
Leaf size (mm) of *Impatiens*
Internode lengths (mm) of *Salvia*

At Maturity

Plant height (mm)
Internode length (mm) of *Impatiens*
Number of branches of *Petunia*
Leaf diameter (mm) of *Pelargonium*

Shelf-life

Six plants of each plot of *Impatiens* were bedded out and subsequent garden performance expressed as a plant quality score (5= best 1= worst) recorded over a two month period.

Statistical Analysis

Statistical analysis was limited as the facilities did not allow for the replication of temperature treatments. However, for both transplanting and maturity assessments comparisons were made between individual pairs of treatments within species using the t-test to see if the differences were significant at the 5% level.

RESULTS

Impatiens

Transplanting stage

Values for mean plant height are given in Tables 2a and 3a, Appendix II page 18 and 19. Some growth control was achieved with the DROP and JUMP/DROP treatments with the early sowing but the effects were less than in 1991 where a 6°C DROP regime was used. Little growth control was achieved by the application of Alar in the first sowing but this might be due to the plants being smaller at the transplanting stage than the later sowing, masking the effects of growth regulators.

There were no apparent treatment effects on leaf number and size from either sowings.

Maturity stage

By maturity, measurements of plant height (Tables 2b and 3b, Appendix II, page 18 and 19) showed that plants from the DROP and JUMP/DROP treatments were still shorter with a marked reduction in internode length. Plant growth regulator use superimposed on top of the temperature treatments tended to have little further effect on growth.

Garden performance

After planting out, fortnightly visual observations showed little difference in plant growth between the various treatments. There was no difference in flowering performance.

Pelargonium

Transplanting stage

For *Pelargonium*, results for mean plant height are given in Tables 4a and 5a, Appendix II, pages 20 and 21. Dropping the compartment temperature at sunrise for 2 hours gave slightly shorter plants. Little growth control was exhibited by the other DIF treatments while the application of Cycocel gave some growth control in all regimes.

Maturity stage

The early effect of some growth control for the DROP treatment was no longer evident by the time the plants flowered. This could partly be explained by the fact that DROP is harder to achieve as you progress into the warmer nights experienced during the late spring period (Tables 4b and 5b, pages 20 and 21).

Effects of Cycocel application were still obvious at flowering with height and leaf diameter reduced.

Garden performance

There were no visible differences between treatments with regard to flowering period.

Petunia

Transplanting stage

Little growth control was achieved by any of the DIF treatments for both sowings. This is not consistent with the 1991 trial which saw a reduction in plant height at the transplanting stage when using a 6°C drop treatment at sunrise; this difference may be explained by the DIF effects being masked by the plugs being smaller in 1992 at the transplanting stage and the temperature drop not being so great. Plant growth regulant use gave shorter plants in all DIF regimes.

Leaf numbers were similar for all treatments (Tables 6a and 7a, Appendix II, pages 22 and 23).

Maturity stage

The effect of DROP and JUMP/DROP treatments were greater than at the transplanting stage for the second sowing with a more compact plant being produced which was shorter and had more branches (Table 6b and 7b, Appendix II, pages 22 and 23).

Both DIF and plant growth regulator use had a influence on development. Side shooting also tended to be greater where plant growth regulators had been used.

Garden performance

Plants from all treatments performed equally well during the bedding out stage with the slightly more compact plants suffering from less wind damage.

Salvia

Transplanting stage

The first sowing of *Salvia* demonstrated a similar response to the other species with regard to temperature and plant growth regulator treatments. A small reduction in plant height and internode length was seen in both sowings by the application of plant growth regulator and in the first sowing by the DROP and JUMP/DROP treatments (Tables 8a and 9a, Appendix II, pages 24 and 25).

The better response to DIF treatments by the first sowing may partially be explained by 'DROP' treatments being harder to practically achieve as you advance into spring.

Maturity stage

Values for plant height (Tables 8b and 9b, Appendix II, page 24 and 25) followed a similar pattern to transplanting results, from the first sowing, being responsive to DROP and JUMP/DROP.

Garden performance

All treatments gave good garden performance with the shorter plants from DROP and JUMP/DROP tending to be more stable in windy conditions.

DISCUSSION

Generally, all four species responded slightly to the use of DIF temperature regimes where an early morning drop for two hours restricted extension growth, giving rise to a more compact plant at both the transplanting and maturity stages. The effects were more pronounced where plant growth regulators were also applied.

The results and observations in relation to growth control made on this trial were not so pronounced as in the 1991 trial where a larger 6°C temperature DROP for 2 hours from sunrise was used. The smaller response produced by the DROP this year varied with species and in some cases with sowing dates. On comparison with the 1991 project it would appear that DIF responses may well be reduced by the smaller plug sizes used in this study. Furthermore, any delay in transplanting a smaller plug may cause it to 'draw' and further mask the treatment effects. DIF treatment did not affect leaf number.

Subsequent garden performance was unaffected by the prior temperature treatments. There was some indication that the more compact plant was better suited to wind exposed sites which would suggest if adequate growth control can be achieved by DIF then a better value for money product would be made available for the consumer.

From the results obtained from the last two years trials it would appear that the use of DIF to restrict extension growth, may offer the potential for reducing or even eliminating the use of plant growth regulators during bedding plant production. The regime involving a two hour drop in temperature starting at sunrise has the most potential but it appears from this year that a drop of greater than 4°C may be required and this needs examining further in the final year of the work.

The ability to maintain the early morning cool treatments becomes more difficult as the season progresses and the 1991 trial indicated that the effectiveness of DIF was more pronounced during early growth (i.e. module stage) whilst this year the response was less when using smaller plugs. Therefore, further investigation into DIF responses when growing bedding plants in different plug sizes would appear to be necessary.

Most commercial bedding plant production units grow a range of similar temperature tolerant species in a single glasshouse. The trials work to date has indicated that some species are more responsive than others and it is clear that for any DIF treatment to be adopted by the industry the regime will need investigating on a broader range of subjects as some more vigorous bedding species may require the combined use of a DIF regime in conjunction with a chemical plant growth regulators to effectively control growth.

The trials programme has also highlighted possible future directions for further study. To date, only the early morning period has been studied. Whilst in most trials this has been shown to be the point in which sensitivity to DIF is at its greatest, it may well be that some bedding species may be more responsive to DIF at other time periods. Hence, the timing of DIF application may need to be investigated further.

DIF has proved more effective during the early stage of growth than on more mature plants. As with other subjects, such as *Poinsettias* and *Chrysanthemums*, the responsiveness to DIF treatment may alter with the stage of plant development. Indeed, DIF treatments in this trial were used on smaller plugs than in 1991 and a greater response may have occurred if plants had been exposed longer to temperature treatment by being grown in larger sized modules; it is proposed that the effects of plug sizes will be investigated in the future.

CONCLUSIONS

- DROP (dropping the temperature for two hours starting at sunrise by 6°C) and JUMP/DROP (night temperature raised to 18°C for 2 hours prior to sunrise then dropped to 14°C for 2 hours) were the most effective temperature treatments for growth control.

- Degree and duration of DROP: A 4°C decrease in temperature (1990/91 -6°C) was employed in this trial which was maintained over a relatively short time period (2 hours). It may well be that some bedding species require a more intense DROP in temperature or a DROP lasting for a greater duration to produce a distinct height reduction.

- DIF had little effect on leaf number.

- All treatments produced saleable plants, although untreated control plants tended to be more 'leggy'.

- DIF treatments during production had no apparent effect on subsequent 'shelf-life' of plants bedded out.

- Some more vigorous bedding species may require the combined use of a DIF regime in conjunction with a chemical plant growth regulator to effectively control growth.

- Manipulation of the temperature regime was more difficult to achieve as the season progressed.

Future Programme 1992/93

The final trial in the series on bedding plants will assess the use of DIF at different stages of growth on a wider range of species using various plug sizes. As the results from previous years work have shown the benefit of using DROP at sunrise, a 6°C DROP for 2 hours from sunrise will be used.

APPENDIX I

TRIAL LAYOUT

Geranium

S1

1	4	2	3
3	1	4	2
4	2	3	1

S2

2	3	1	4
1	2	4	3
3	4	2	1

Impatiens

S2

2	4	3	1
3	1	4	2
4	2	1	3

S1

4	1	2	3
2	3	1	4
1	4	3	2

Antirrhinum

S1

2	1	4	3
1	2	3	4
4	3	2	1

S2

3	1	2	4
4	2	1	3
2	3	4	1

Petunia

S1

2	3	4	1
3	1	2	4
4	2	1	3

S2

3	1	2	4
4	2	1	3
1	3	4	2

Pansy

S2

1	4	3	2
2	1	4	3
4	3	2	1

S1

2	4	3	1
1	2	4	3
3	1	2	4

Lobelia

S1

4	2	3	1
1	3	4	2
2	4	1	3

S2

4	1	3	2
2	3	1	4
1	4	2	3

Salvia

S2

4	3	2	1
2	1	4	3
1	2	3	4

S1

2	4	1	3
3	2	4	1
1	3	2	4

Marigold

S2

1	2	4	3
2	1	3	4
3	4	2	1

S1

4	2	3	1
1	4	2	3
3	1	4	2

S1 - First sowing
S2 - Second sowing

APPENDIX II

SUMMARY OF RESULTS AT TRANSPLANT STAGE AND MATURITY

Table 2: *IMPATIENS* WALLERIANA 'F1 ACCENT SALMON'

Sowing 1

a. Transplanting

Treatment	PGR	Height (mm)	% Growth Control	Leaf Number	Leaf Size
ZERO DIF	+	41	-	9	33
	-	44	-	8	36
DROP	+	39	5	8	34
	-	35	20	8	31
JUMP	+	43	0	9	36
	-	46	0	9	37
JUMP/DROP	+	41	0	8	34
	-	37	16	8	32

b. Maturity

Treatment	PGR	Height (mm)	% Growth Control	Internode Length (mm)	Internode Length % Reduction
ZERO DIF	+	140	-	18	-
	-	127	-	18	-
DROP	+	122	13	15	17
	-	119	6	12	33
JUMP	+	138	0	17	6
	-	126	0	19	0
JUMP/DROP	+	119	15	13	28
	-	116	9	11	39

NB: % growth control expressed in terms of plant height reduction compared with standard (zero DIF) regime.

APPENDIX II

Table 3: ***IMPATIENS* WALLERIANA 'F1 ACCENT SALMON'**

Sowing 2

a. Transplanting

Treatment	PGR	Height (mm)	% Growth Control	Leaf Number	Leaf Size
ZERO DIF	+	39	-	10	29
	-	53	-	11	36
DROP	+	37	5	9	31
	-	53	0	11	36
JUMP	+	52	0	13	36
	-	67	0	12	41
JUMP/DROP	+	52	0	12	40
	-	56	0	12	39

b. Maturity

Treatment	PGR	Height (mm)	% Growth Control	Internode Length (mm)	% Reduction
ZERO DIF	+	99	-	15	-
	-	104	-	20	-
DROP	+	80	19	14	7
	-	91	13	19	5
JUMP	+	114	0	18	0
	-	117	0	22	0
JUMP/DROP	+	99	0	17	0
	-	100	4	19	5

NB: % growth control expressed in terms of plant height reduction compared with standard (zero DIF) regime.

APPENDIX II

Table 4: ***PELARGONIUM*** **ZONALE 'F1 CENTURY CARDINAL'**

Sowing 1

a. Transplanting

Treatment	PGR	Height (mm)	% Growth Control
ZERO DIF	+	52	-
	-	81	-
DROP	+	48	8
	-	72	11
JUMP	+	53	0
	-	81	0
JUMP/DROP	+	52	0
	-	77	5

b. Maturity

Treatment	PGR	Height (mm)	% Growth Control	Leaf Diameter (mm)	Leaf Diameter % Reduction
ZERO DIF	+	220	-	110	-
	-	301	-	147	-
DROP	+	195	11	109	0
	-	292	3	142	3
JUMP	+	200	9	110	0
	-	280	7	141	4
JUMP/DROP	+	204	7	109	0
	-	291	3	140	5

NB: % growth control expressed in terms of plant height reduction compared with standard (zero DIF) regime.

APPENDIX II

Table 5: *PELARGONIUM* ZONALE 'F1 CENTURY CARDINAL'

Sowing 2

a. Transplanting

Treatment	PGR	Height (mm)	% Growth Control
ZERO DIF	+	78	-
	-	104	-
DROP	+	71	9
	-	97	7
JUMP	+	77	1
	-	114	0
JUMP/DROP	+	78	0
	-	104	0

b. Maturity

Treatment	PGR	Height (mm)	% Growth Control	Leaf Diameter (mm)	Leaf Diameter % Reduction
ZERO DIF	+	173	-	96	-
	-	185	-	148	-
DROP	+	163	6	96	0
	-	219	0	140	5
JUMP	+	158	9	92	4
	-	233	0	137	7
JUMP/DROP	+	147	15	96	0
	-	206	0	138	7

NB: % growth control expressed in terms of plant height reduction compared with standard (zero DIF) regime.

APPENDIX II

Table 6: ***PETUNIA*** **'F1 FRENZY ROSE STAR'**

Sowing 1

a. Transplanting

Treatment	PGR	Height (mm)	% Growth Control	Leaf Number
ZERO DIF	+	35	-	11
	-	42	-	12
DROP	+	33	6	11
	-	44	0	12
JUMP	+	32	9	11
	-	44	0	12
JUMP/DROP	+	30	14	11
	-	32	22	11

b. Maturity

Treatment	PGR	Height (mm)	% Growth Control	Leaf Number
ZERO DIF	+	363	-	9.7
	-	356	-	10.5
DROP	+	297	22	9.9
	-	326	9	9.5
JUMP	+	305	19	9.3
	-	304	17	8.3
JUMP/DROP	+	287	26	11.5
	-	275	29	13.4

NB: % growth control expressed in terms of plant height reduction compared with standard (zero DIF) regime.

APPENDIX II

Table 7: *PETUNIA* 'F1 FRENZY ROSE STAR'

Sowing 2

a. Transplanting

Treatment	PGR	Height (mm)	% Growth Control	Leaf Number
ZERO DIF	+	33	-	10
	-	35	-	9
DROP	+	36	0	9
	-	41	0	10
JUMP	+	40	0	11
	-	50	0	12
JUMP/DROP	+	37	0	10
	-	43	0	10

b. Maturity

Treatment	PGR	Height (mm)	% Growth Control	Number of Branches
ZERO DIF	+	252	-	7.4
	-	261	-	6.7
DROP	+	209	17	10.4
	-	224	14	9.4
JUMP	+	221	12	7.3
	-	237	9	7.6
JUMP/DROP	+	239	5	9.3
	-	235	10	8.0

NB: % growth control expressed in terms of plant height reduction compared with standard (zero DIF) regime.

APPENDIX II

Table 8: ***SALVIA* SPLENDENS 'VANGUARD'**

Sowing 1

a. Transplanting

Treatment	PGR	Height (mm)	% Growth Control	Internode Length (mm)	% Reduction
ZERO DIF	+	66	-	29	-
	-	74	-	34	-
DROP	+	63	5	29	0
	-	69	7	32	0
JUMP	+	66	0	30	0
	-	78	0	36	0
JUMP/DROP	+	59	11	26	10
	-	70	5	31	9

b. Maturity

Treatment	PGR	Height (mm)	% growth control
ZERO DIF	+	217	-
	-	233	-
DROP	+	188	13
	-	218	6
JUMP	+	221	0
	-	234	0
JUMP/DROP	+	192	12
	-	195	16

NB: % growth control expressed in terms of plant height reduction compared with standard (zero DIF) regime.

APPENDIX II

Table 9: ***SALVIA*** **SPLENDENS 'VANGUARD'**

Sowing 2

a. Transplanting

Treatment	PGR	Height (mm)	% Growth Control	Internode length (mm)	% Reduction
ZERO DIF	+	56	-	27	-
	-	77	-	37	-
DROP	+	59	0	27	0
	-	78	0	39	0
JUMP	+	63	0	30	0
	-	86	0	41	0
JUMP/DROP	+	60	0	26	10
	-	75	3	31	9

b. Maturity

Treatment	PGR	Height (mm)	% Growth Control
ZERO DIF	+	205	-
	-	215	-
DROP	+	198	3
	-	212	1
JUMP	+	208	0
	-	222	0
JUMP/DROP	+	223	0
	-	229	0

NB: % growth control expressed in terms of plant height reduction compared with standard (zero DIF) regime.

APPENDIX III

Contract with HRI and ADAS (hereinafter called the "Contractors") and the Horticultural Development Council (hereinafter called the "Council") for a research/development project.

PROPOSAL

1. TITLE OF PROJECT CONTRACT NO: PC41

Pot and Bedding Plants: Control of plant stature by manipulation of day and night temperatures (DIF regimes).

2. BACKGROUND AND COMMERCIAL OBJECTIVE

Public concern over environmental issues is inevitably leading to a reassessment of commonly accepted horticultural practices. The present heavy reliance on the use of plant growth regulators to control plant stature may be found unacceptable in the future and may be restricted by legislation as has already occurred in some European countries. Application of growth regulators is expensive in material cost and labour use and ill-timed applications can seriously reduce the commercial value of crops. Nevertheless, control of plant stature will remain a vital element in the growing of high value ornamental pot and bedding plants.

An alternative approach, suggested by past work at Littlehampton and current work in the USA and Europe, is based on the manipulation of day and night temperatures - the so-called DIF approach. The basis of this is that while leaf production and the speed of flowering are controlled by the average 24-hour temperature, stem extension is predominantly under the control of day temperature. Low day temperatures give compact plants and this effect is sustained even when a low day temperature is combined with a high night temperature. The latter is required to achieve the desired average 24-hour temperature so that flowering will occur at a normal time. Other workers have claimed that a negative difference (negative DIF) of this kind between day and night temperature gives even greater dwarfing than continuous low temperature (zero DIF).

It seems likely that the low temperature does not have to be given for the whole of the day to get maximum benefit; some research suggests that there may be periods of the day that elicit a more sensitive reaction to low temperature than others. Equally, our own studies suggest that certain periods of the night give a greater response to high temperature than others. Precise details of the timing of these periods need to be established if growers are to get maximum benefit from the technique.

The DIF approach entails the bulk of the energy for heating being provided at night, so that there is potential for making significant energy savings when thermal screens or black-out covers are used.

The commercial objective of this project would be: to establish the most effective way of controlling plant height by the use of low temperature for part of the day with the twin aims of reducing dependence on plant growth regulators and of saving energy.

3. POTENTIAL FINANCIAL BENEFITS TO THE INDUSTRY

- Production of high-quality plants with an environmentally desirable reduction in chemical plant growth regulant use.
- Reduced chemical costs.
- Lower labour inputs.
- Energy savings when thermal screens are used.
- Reduced exposure of staff to chemical sprays and residues.
- Reduced chemical contamination of soil/irrigation water.
- Reduced crop spoilage from ill-timed chemical applications.

4. SCIENTIFIC/TECHNICAL TARGETS OF THE WORK

The project aims to determine optimal procedures for the production of key pot and bedding plant species to market specifications of height and quality with no or reduced use of chemical growth regulants. Initial scientific targets will be to determine those times of day when inhibition of internode extension of plants is most sensitive to low temperature treatment, optimal durations of cool treatment and relationships between the duration of treatment and the temperature drop employed. Effects of cool period treatments on flowering, leaf chlorosis and shelf-life will also be established.

Low temperature treatments will, in practice, be most easily employed in glasshouse culture during autumn, winter and early spring. However, the need for growth regulation is greatest in summer when outside conditions will militate against this approach. The trials which are envisaged will determine whether plant height (internode length) is primarily regulated by lowest day temperature achieved at the most sensitive time, by average day temperature achieved, or by the absolute difference between day and night temperatures (DIF). If the latter, trials could be extended to determine whether brief periods of high temperature at night could be employed to regulate height, a practice which would be feasible during the summer period. The work will bear in mind the need for practical applications to take account of differing abilities of growers to manipulate temperature.

5. RELATED WORK

Work on this topic is in progress in the USA and in several European countries. Personal contacts are maintained with Dr

Royal Heins at Michigan State University who has developed practical growing protocols for poinsettia and Easter lily, but who has not, to date, investigated the use of short-duration, day temperature drops. In addition, visits have recently been made by Dr K.E. Cockshull to Aalsmeer (Dr. T. Blacquiere) and by Drs Cockshull and Langton to Hannover (Prof. Scharpf and Dr. L. Hendriks) to discuss collaborative trials. HDC funding in this area will improve UK access to research results obtained in these and other European centres.

Preliminary trials are being funded by CSG on bedding plant species at Efford. However, funding is due to end in March 1991. These trials are linked to others in progress in Europe and are concentrated on two-hour temperature drops before and after sunrise. It remains to be established, however, whether such treatments are optimal for the species under investigation.

6. DESCRIPTION OF THE WORK

A rolling programme is proposed, integrating controlled environment growth cabinet experiments at Littlehampton and glasshouse trials at Efford. The use of growth cabinets guarantees that temperature set points are achieved reliably and reproducibly whatever the ambient temperatures outside. These will be used to establish precise internode extension responses following cool temperature treatments and will guide subsequent follow-up trials in glasshouses at Efford (K Block) where plants will be taken through to flowering and where pre- and post-harvest quality characteristics will additionally be determined.

The proposal is that initial growth cabinet trials should be conducted at Littlehampton, starting in April 1991, to be followed by trials at Efford during the autumn, winter and spring of 1991/92 based principally on results from Littlehampton. Poinsettia will be the main species for study in these initial trials, together with the bedding plant species *Geranium*. The poinsettia cultivar to be used at Littlehampton will be Steffi; follow-up trials at Efford could use a wider range of cultivars.

A second round of trials will feature chrysanthemum and a second bedding plant species which has still to be decided. The growth cabinet trials will be conducted at Littlehampton during winter 1991/92 or in the following spring, with follow-up trials at Efford during winter/spring 1992/93.

Experimental treatments will be continuously reviewed with the project co-ordinator but initial plans for growth cabinet trials at Littlehampton (1991) are for two successional experiments. The first would establish which half of the day is most sensitive to a drop in temperature. A relatively large drop will be used and, for poinsettia, treatment will begin shortly after pinching and will last for c. 3 weeks. Effects on stem extension will be assessed by comparison with appropriate controls with, for example, the same overall 24-hour average temperature given at constant temperature, the same average temperature by day and the same high temperature in both halves of the day. The second experiment will take that half of the day that is more sensitive to low temperature and will establish which parts of this are most sensitive. In addition, it should be possible to establish the effects of the size of the drop in temperature and to quantify the overall effect of the timing, duration and degree of drop in temperature.

The first round of follow-up trials at Efford will utilise four compartments of K block (= 4 main treatments). Treatments are planned to comprise the optimal regime determined in prior growth cabinet experiments, the standard 'blueprint', a DIF regime based on constant day and night temperatures (i.e. no brief cool treatment) and an intermediate DIF regime utilising a longer period of cool treatment during the day. A trial of 'graphical tracking', a DIF method pioneered in the USA, will be carried out. Sub-treatments of nil, half and standard rate growth regulator applications will be superimposed. Precise details will depend on the observed responses in growth cabinets. An important element in these glasshouse trials will be the determination of effects on flowering and plant quality, in addition to effects on plant height.

At some stage it would be beneficial to examine the interaction of DIF regimes with supplementary lighting treatments, since light supplementation can also have a marked effect on internode elongation. No provision for such trials is included in the present proposal. Similarly, the proposal makes no provision for follow-on testing of the effects of temperature lifts at night which might prove beneficial under some circumstances.

7. COMMENCEMENT DATES AND DURATIONS

a)	April - September 1991	Growth cabinet experiments at Littlehampton on poinsettia and *Geranium*.
b)	August 1991 - December 1991	Follow-up glasshouse trials on poinsettia at Efford.
c)	January - April 1992	Follow-up glasshouse trials on *Geranium* and observational trials on other bedding plant species at Efford.
d)	October 1991 - March 1992*	Growth cabinet experiments at Littlehampton on chrysanthemum and a second bedding plant species.
e)	October 1992 - March 1993	Follow-up glasshouse trials on chrysanthemum at Efford.
f)	January - April 1993	Follow-up glasshouse trials

on bedding plant species at Efford.

* These trials could be delayed until spring/summer 1992 (subject to cabinet availability) without jeopardizing the follow-up Efford trials; payment for these to be deferred to 1992 financial year (see later).

8. STAFF RESPONSIBILITIES

Joint project leaders: K.E. Cockshull (Littlehampton) and E.J. Sapsed (Efford). One additional ASO member of staff would be assigned to the growth cabinet trials at Littlehampton. F.A. Langton (Littlehampton) to act as liaison officer for the project.

ADAS commodity leaders, H. Kitchener (pot plants) and J. Farthing (bedding plants), will act as commodity consultants to the project.

9. LOCATION

HRI Littlehampton (growth cabinet experiments) and HRI Efford (glasshouse trials).