Project title:	**Hardy Herbaceous Perennials: Validation of a screening protocol for factors that manipulate flowering.**
Project number:	**HNS 103a**
Project leader:	Miss Carolyn Hawes (initially Dr Jim Monaghan) HRI Efford Lymington SO41 0LZ
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PRACTICAL SECTION FOR GROWERS

Background and objectives

The rate of plant growth and development, and the initiation and expression of flowers, are influenced by environmental factors such as daylength, light intensity, and temperature. By adjusting these factors (e.g. by extending daylength) plants can be manipulated into flowering out of season. This approach is well known by growers of pot, bedding and cut flowers but has rarely been used by growers in the HNS sector. However, with improvements in HNS growing facilities (i.e. more production under protection), and the growth of the hardy herbaceous perennial market, there is greater opportunity for HNS growers to schedule flowering in plants.

A recent review (HNS 103) proposed the development of **suitable screening protocols** for use by growers on their nurseries, with their own range of crops. This approach allows growers to establish the environmental requirements for flowering of their specialist species without the widespread dissemination of growing 'blueprints' and the potential over production and loss of competitive advantage that could be associated with this. This work follows on directly from that review.

Important information, essential for the manipulation of flowers, can be ascertained from a relatively simple screening protocol, the use of which will enable the grouping of herbaceous perennial species by their responses; e.g. plants that require cold followed by long days. Plants from these groups can then be manipulated to produce flowers over an extended season. Inevitably, varietal responses will differ with fixed regimes. Experience and experimentation by growers themselves will be necessary to establish optimal conditions for their range of varieties. It is envisaged that, initially, the best approach will be to concentrate on long day plants and to encourage flowering in spring or early summer, before their natural flowering period.

The **overall aims** of this project were to:

- **Validate and demonstrate** a screening protocol of plant environmental requirements for flowering, that can realistically be undertaken on grower holdings.

- Establish the **flowering requirements** for a representative range of eight hardy herbaceous perennial species.

Summary of results

The aims of this project were to validate and demonstrate the screening protocol and to establish the flowering requirements for a representative range of eight hardy herbaceous perennial species. The screening protocol considered plant responses to four factors and the respective plant responses:

Factor	**Plant response to**
Supp : Supplementary lighting (SUPP) 08:00 to 16:00	Light energy
LD : Night Break lighting 23:00 to 01:00	Extended Photoperiod: Long Day (LD) versus natural Short Day (SD)
Cold storage	Vernalization
Heating	Temperature

Eight species were selected for study. All **flower late in the season**, after the main sales period. It was felt that if these plants were available earlier in the season, customers would be willing to buy them, **leading to increased sales**.

1. *Anemone x hybrida* (Jap anemone) 'Whirlwind'
2. *Aster* 'Marie Ballard'
3. *Crocosmia* 'Star of the East'
4. *Gaura lindheimerii*
5. *Lobelia* 'Queen Victoria'
6. *Penstemon* 'Mother of Pearl'
7. *Rudbeckia fulgida* var. *sullivantii* 'Goldsturm'
8. *Sedum* 'Autumn Joy'

Overall results are presented in Table A.

Table A – Overall Results Summary (1 of 2)

Subject Species	Fundamental effect on hastening of flowering	Interactions with fundamental effects	Pest & Disease issues
1. *Anemone x hybrida* (Japanese anemone) 'Whirlwind'	LD	1. Enhanced by cold-store treatment (unheated environment) 2. Enhanced by Supp (except after 4 weeks cold-store)	None
2. *Aster* 'Marie Ballard'	LD (unheated)	Enhanced by Supp	None
	Supp (unheated)	Not as good quality as LD	
	Cold-store (unheated)	Not as good quality as LD	
	Heated	Not as good quality as LD	Powdery mildew problem
3. *Crocosmia* 'Star of the East'	LD (unheated)	1. Heating inhibited flower development 2. Cold-store treatment inhibited flower development	Thrips a problem in heated environment
4. *Gaura lindheimerii*	LD (unheated/heated)	Enhanced by Supp (when unheated)	Aphids problematical in heated environments
	Supp (unheated/heated)	Not as good quality as LD	

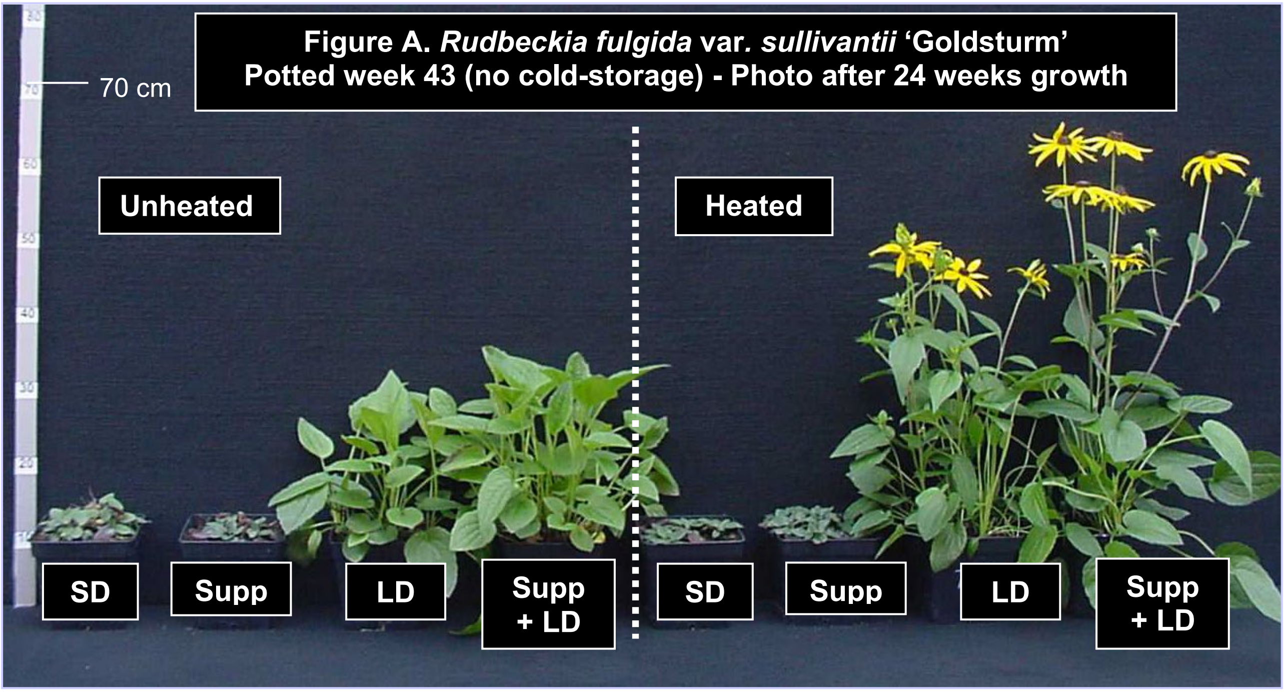
Table A – Overall Results Summary (2 of 2)

Subject Species	**Fundamental effect on hastening of flowering**	**Interactions with fundamental effects**	**Pest & Disease issues**
5. *Lobelia* 'Queen Victoria'	LD (unheated/heated)	Enhanced in heated environment	Whitefly in heated environment
	Cold-store treatment then heated environment	Not as effective as LD, while: » Likely to be more expensive » Whitefly a possible issue	Whitefly
6. *Penstemon* 'Mother of Pearl'	LD (unheated/heated)	1. Marginal improvement if Supp added 2. Marginal improvement if heating added	Aphids – in heated environment
	Supp (unheated/heated)	Not as effective as LD	
7. *Rudbeckia fulgida* var. *sullivantii* 'Goldsturm'	LD (unheated/heated)	Enhanced by Supp	Whitefly in heated environment
8. *Sedum* ' Autumn Joy'	No heat + no other treatment	Flowered readily without intervention	None
	Heat + LD	Flowered even earlier than above	Aphids (minor problem)

Long Day Effect (LD)

The treatment that stood out clearly was the effect of **night break lighting** to give a **long day length treatment (LD).** This was also by far the **cheapest** and most **practical** option for manipulating flowering that was tested :

- Beneficial responses were observed (from LD) with all the eight species tested in the absence of cold-store treatment (for example *Rudbeckia* Fig A).
- All eight species responded in differing manners to the combinations of treatments:
  - *Anemone* and *Crocosmia*, **flowered only in long days (LD)** (*achieved through night break lighting)*.
  - All the other species produced more budded plants and/or produced buds earlier in long days (LD) compared to short days (SD), ie *normal daylength*.



SD = normal (short) day; Supp = supplementary lighting; LD = long day

Supplementary Lighting (Supp)

Positive fundamental effects were seen from supplementary lighting with *Aster*, *Gaura* & *Penstemon.* However, plant quality did not match that for long day (LD) treatment.

Supplementary lighting enhanced fundamental effects seen from long day (LD) treatment with *Anenome, Aster*, *Gaura*, *Penstemon* and *Rudbeckia.* The cost effectiveness of this additional input would have to be very carefully checked.

Heating

Positive fundamental effects were seen with *Aster* and *Lobelia* with flower production brought forward, though the cost of heating a growing structure will far exceed using night-break lighting (LD).

Long day (LD) effects were in many cases enhanced to some extent by heating. With the very high costs involved however, this addition the economic benefits would need to be very carefully checked out

With *Sedum* heating spectacularly inhibited flowering and kept plants in the vegetative state. In this situation long day effect (LD) was able however, to override this effect completely!

Pest and/or disease problems were often encountered in the heated environments (but not in the unheated comparisons) and so the further costs and the practical issues of managing this would need very careful consideration before enlisting heating as route to manipulating flowering in these or similar species.

Cold-Store Treatment

Cold-store treatment was occasionally very effective (*Aster*, *Lobelia* and *Rudbeckia*) in bringing flowering forward. However, such treatment was never as good as long day (LD) effect and would require the availability of a suitable cold-store (and the need to cover running costs). Also, in the case of Lobelia, a heated environment (and yet more high cost) was also needed, following cold-store, to gain positive flowering effects.

Conclusion

Night break lighting can be used to **bring forward flowering** in a range of summer/autumn flowering herbaceous perennial species. Using this low cost technique growers can start to **schedule commercial production** of selected lines, extending the season of sale.

The screening protocol was shown to be effective. Not all treatments studied here would be achievable by all growers or on all products. By using the **long day versus normal (short) daylight** comparison however, **significant commercial information** could be obtained by growers.

Production in the heated glasshouse areas resulted in considerable pest and/or disease problems in some instances.

Action points

- Installation of **night break tungsten lighting** may benefit scheduling of crops to extend season of sale.
- Establish the response to day length for **your own species**
- Experiment with **timing** – Do you need night break lighting all the time, or just for a limited period, eg 4 weeks at the start of the programme?
- If growing plants under a heated environment take great care with pest and disease monitoring and control.

SCIENCE SECTION

Introduction

There is increasing scope for sales of quality hardy herbaceous plants, through garden centres and opportunity niche markets (e.g. multiples). This requires attention to detail in the production of batches of quality plants, usually in flower, at target maturity dates, with scope to extend marketing season by manipulation of flowering. Much is known about the manipulation of growth and flowering of protected ornamental plants. Growers of pot, bedding and cut flowers can influence the rate of plant growth and development, and the initiation and expression of flowers, by manipulating environmental factors such as daylength, light intensity, temperature and carbon dioxide concentration. Currently, these factors are being utilised to schedule some perennial plants, but mainly in the sectors that are producing high volumes of fast growing plants from seed, such as *Campanula*. In contrast, hardy herbaceous producers grow a greater range of plants but in smaller numbers, mainly from cuttings.

A wide range of facilities are also used for the production of hardy herbaceous perennials, from specialised near state of the art glass, to less expensive protection where precise control of the environment could prove more difficult to achieve. As a consequence of this, a move towards exerting greater influence over growth and flowering of herbaceous crops could require some capital investment.

Considerable interest has been expressed in the potential for manipulating growth and flowering of hardy herbaceous crops. At present, the natural flowering season of hardy herbaceous subjects is well known but little use is being made of techniques to manipulate flowering. However, the production of specific growing ‘blueprints’ to schedule species of hardy herbaceous plants could lead to over production and loss of competitive advantage. By developing a screening protocol for use by growers themselves, with their own range of crops, this is avoided.

A previous review (HNS 103) collected currently available information on crop manipulation techniques, assessed which were of practical use for hardy herbaceous production and developed a screening protocol, for use in further R&D and/or on-nursery trialling. Thus a key aim of this project was to demonstrate this “screening” concept and show how growers could approach it, independently.

In the course of the work, outline indications of the flowering requirements for a range of eight hardy herbaceous perennial species were developed and the results reported here.

Screening Protocols

A large number of questions can be answered through a multi-factorial screening protocol. However, the more factors included, the larger and, hence, more difficult (and therefore expensive) a project becomes. Nevertheless, important information, essential for the manipulation of flowers, can be ascertained from a relatively simple screening protocol (whereas research style facilities are needed to establish the optimal light and temperature settings for cold-stores and growing on environments).

The following screening protocol was designed to be used by **growers independently**, with their own chosen range of species and target flowering dates. This should allow development of scheduled production, whilst maintaining confidentiality of the findings for the producer of specialist species, which he could then use for his competitive advantage.

This protocol was undertaken in the **winter months** to produce material in **bud or flower** in **early - late spring**, before the ‘natural’ flowering season of late summer / autumn. This is because it is relatively simple to impose long days against a background of short days.

The start point for the protocols is a cold-store. However, not all herbaceous perennials that flower in long days require a period of cold for initiation of flowers (see section 2.1.1 of review, HNS 103). For those that do, allowing plants to accumulate cold naturally for a proportion of the winter period may satisfy their requirements before they are placed under protection early in the new year. This approach, although apparently cheap, may be **unreliable between years** due to the variability in the weather. An alternative possibility is, once the cold requirement is known, to allow plants to accumulate cold naturally for a period of time and then to place them in cold-store for a short period of time (1-2 weeks), to ensure cold requirement is satisfied.

The following questions need answering for individual species:

- Do the plants require cold for initiation?
- What is the duration of cold required?
- Do plants develop flowers faster under long days or short days?
- Does temperature influence speed of flowering? If so -
    - Is heating necessary for commercial production?
    - Is supplementary lighting necessary to maintain plant quality ?

These questions vary in their relevance in a low cost production system and, as more of these factors are included, the level of complication (and the work required) to answer all of the above questions could become difficult to justify commercially. It is likely that a limited screening protocol would identify species worthy of further study, give a ‘rough’ indication of their requirements, while ‘fine’ details could then be established through small scale, detailed work.

Materials and Methods

All work took place at HRI-Efford on the south coast of the UK. The glasshouse employed (Efford ‘J Block’) was oriented in an east-west array with all compartments facing south, with doors to a corridor on the north.

1. Growing Environments

- **Cold store** at 4°C lit with fluorescent tubes for 8 hours a day (08:00 to 16:00).

Plants were potted at four dates, commencing on 22/10/01, with subsequent batches dealt with immediately after their respective cold-store treatments :

Duration in Cold-store	**Potting schedule**	
	Date	Week no.
0 weeks	22/10/01	43
4 weeks	19/11/01	47
8 weeks	17/12/01	51
12 weeks	14/1/02	03

Following cold-store treatments plants were placed into the glasshouse in one of two temperature regimes:

- **Unheated glasshouse** *(frost protection - Heating at 3°C, Venting at 8°C)*
- **Heated glasshouse** (*Heating at 15°C, Venting at 18°C*)

Each of the 2 temperature regimes were split into four areas with the following lighting programmes:

- no lighting (SD)
- 8 hours supplementary lighting (Supp)
- 2 hours night break lighting to give long day effects (LD)
- 8 hours supplementary lighting and 2 hours night break lighting (Supp+LD)

Thus there were a total of **eight glasshouse environments**.

Consequently the combination of **4 cold-store** treatments and **8 glasshouse** environments gave a total of **32 treatments** (as Table 1). These 32 treatments were replicated twice in a randomised block arrangement.

Table I. Experimental treatments (Key presented overleaf)

Treatment	*Potted week 43*	*Potted week 47*	*Potted week 51*	*Potted week 03*
1	SD			
2	Supp			
3	LD			
4	Supp+LD			
5	SD			
6	Supp			
7	LD			
8	Supp+LD			
9	CS	SD		
10	CS	Supp		
11	CS	LD		
12	CS	Supp+LD		
13	CS	SD		
14	CS	Supp		
15	CS	LD		
16	CS	Supp+LD		
17	CS	CS	SD	
18	CS	CS	Supp	
19	CS	CS	LD	
20	CS	CS	Supp+LD	
21	CS	CS	SD	
22	CS	CS	Supp	
23	CS	CS	LD	
24	CS	CS	Supp+LD	
25	CS	CS	CS	SD
26	CS	CS	CS	Supp
27	CS	CS	CS	LD
28	CS	CS	CS	Supp+LD
29	CS	CS	CS	SD
30	CS	CS	CS	Supp
31	CS	CS	CS	LD
32	CS	CS	CS	Supp+LD

Key to Table I

CS	= **Cold store** at 4°C lit with fluorescent tubes for 8 hours a day
SD	= **Heated** glasshouse with no lighting (assuming ambient daylength is SD)
Supp	= **Heated** glasshouse with 8 hours supplementary lighting
LD	= **Heated** glasshouse with 2 hours night break lighting (LD)
Supp+LD	= **Heated** glasshouse with 8 hours supplementary lighting with additional 2 hours night break lighting
SD	= **Unheated** glasshouse with no lighting (assuming ambient daylength is SD)
Supp	= **Unheated** glasshouse with 8 hours supplementary lighting
LD	= **Unheated** glasshouse with 2 hours night break lighting
Supp+LD	= **Unheated** glasshouse with 8 hours supplementary lighting with additional 2 hours night break lighting

To isolate lighting effects, the four glasshouse compartments (two heated, two unheated) were each divided into two areas by opaque plastic curtains to give a total of eight glasshouse environments. Plastic curtains were also hung at the sides of the compartments to prevent light from adjacent treatments falling on neighbouring plants.

2. Lighting Equipment and Regimes

Lighting regimes were imposed throughout the duration of the trial.

"Supp"

Supplementary Lighting was provided for eight hours a day (08:00 to 16:00 hours) using SON-T light 400 watt high pressure sodium lamps.

Probably the most common lamp in horticulture, however, the SON-T requires lamp gear i.e. ballast and ignitor and also a reflector. They produce significant levels of heat and in a plastic structure must not be fitted too close to cladding. These lamps are expensive to purchase and are not recommended as the key to providing photoperiod lighting, as incandescent lamps are much cheaper to install and run.

Figure B. SON-T lamp and luminaire

"LD"

Night Break Lighting was run for two hours per day (23:00 to 01:00 hours) to provide a long day effect. The lighting used consisted of 100 W tungsten filament bulbs which are ideal for photo-period lighting, putting out very rich red light.

These lamps are easy to install and maintain, and are cheap to run. They can be suspended in a line (festoon) very simply. Festoons are available with waterproof fittings at a set spacing.

Figure C. Tungsten filament lamp

3. Species Tested

Eight species were selected for study by the grower co-ordinators:

1. *Anemone x hybrida* (Jap anemone) 'Whirlwind'
2. *Aster* 'Marie Ballard'
3. *Crocosmia* 'Star of the East'
4. *Gaura lindheimerii*
5. *Lobelia* 'Queen Victoria'
6. *Penstemon* 'Mother of Pearl'
7. *Rudbeckia fulgida* var. *sullivantii* 'Goldsturm'
8. *Sedum* 'Autumn Joy'

Each species = 2 replicates of 10 plants per treatment* (all assessed)
= 20 plants x 32 treatments
= total 640 plants per species. **(see Table II)**
(* except *Gaura lindheimerii* only 8 plants per plot for Potting 4 - 12 weeks cold).

4. Cultural Methods

Plants were bought in September 2001 as young plants with the exception of *Penstemon* (from tissue culture) and *Rudbeckia* (open ground). Plants were initially held in an unheated glasshouse. At the start of treatments (week 43) the first batch of plants (no cold treatment) was potted into 1.6 litre pots and placed into the glasshouse environments. The remaining plants were cold-stored in the carriers (mainly plug trays) in which they were supplied. Care was needed with the open ground material to prevent desiccation. Subsequently, plants were potted as each batch was removed from the cold-store and placed into the glasshouse test environments.

Potting Mix (William Sinclair Horticulture UK)
85% peat
15% container bark
Sincrocell Top K 9 month CRF at 3.0 kg/m^3
SuSCon Green at 750 g/m^3

Plants were grown on benches covered with capillary matting. Initially plants were watered by hand, but as they established water was applied through dripper lines laid along the benches.

Pests and disease were controlled as and when observed. Biological controls were used throughout. See results sections for each variety for more detail on specific pest and/or disease problems encountered.

Table II. Number of plants per species in cold-store and in each glasshouse environment

Environment	*Start*	*+ 4 weeks*	*+ 8 weeks*	*+ 12 weeks*
CS	480	320	160	0
SD	20	40	60	80
Supp	20	40	60	80
LD	20	40	60	80
Supp+LD	20	40	60	80
SD	20	40	60	80
Supp	20	40	60	80
LD	20	40	60	80
Supp+LD	20	40	60	80
Total	***640***	***640***	***640***	***640***

Note: See Table I for key

Results

1. *Anemone x hybrida* 'Whirlwind'

<u>In Summary</u> :

- **Long day (LD) was the only treatment that had a *fundamental* effect in hastening flowering - 60% budded plants on assessment, versus none under normal day length (SD).**
- **If plants were previously cold-stored, some additional benefit (to LD treatment) was seen in an <u>unheated environment</u> – 75 to 85% budded plants by week 26. No benefit was seen if plants were cold-stored, then grown in a <u>heated environment</u>.**
- **Supplementary lighting did not add additional benefit (to LD treatment) except where plants had been previously cold-stored for 4 weeks – 85% budded when unheated, and 95% when heated.**
- **When heat was added to long day plants (LD and Supp+LD), flowers were produced on significantly taller stems. However, this elongation effect was reduced the longer plants were cold-stored.**

<u>In Detail</u> :

Note: "Percentage of plants with bud by week 26" (Table 1a) was a much more reliable indicator of how earlier flowering could be achieved than, "Average days to first visible bud" (Table 1b). Consequently, comments are largely focussed on the first data set.

Table 1a. *Anemone* 'Whirlwind' - Percentage of plants with buds by week 26

	Unheated				Heated			
	SD	Supp	LD	Supp+ LD	SD	Supp	LD	Supp+ LD
No cold	0	5	60	30	**0**	**0**	**70**	**60**
4 weeks cold	0	0	75	85	**5**	**0**	**75**	**95**
8 weeks cold	0	0	80	80	**0**	**5**	**70**	**75**
12 weeks cold	0	5	85	80	**0**	**0**	**65**	**55**

Table 1b. *Anemone* 'Whirlwind' - Average days to first visible bud*

	Unheated				Heated			
	SD	Supp	LD	Supp+ LD	SD	Supp	LD	Supp+ LD
No cold	-	117	243	223	**-**	**-**	**220**	**228**
4 weeks cold	-	-	236	238	**126**	**-**	**209**	**188**
8 weeks cold	-	-	223	223	**-**	**140**	**201**	**189**
12 weeks cold	-	222	232	238	**-**	**-**	**221**	**212**

* Includes period in cold store

Percentage of plants with flower buds at Week 26 (Table 1a & Figures 1a & 1b):

- Under normal day length (SD) no buds were visible in almost all cases at assessment.
- Supplementary lighting (Supp) alone did not improve this.
- Night break lighting (LD) promoted bud development substantially in both the unheated and heated environments, with between 60% and 85% of all plants having buds at the assessment time.
- No convincing additional benefit in terms of bud promotion was obtained when supplementary lighting was added to long day lighting (Supp+LD), except perhaps following 4 weeks cold-storage where the percentage of budded plants had increased from 75 to 85% (unheated environment) and from 75% to 95% (heated environment).
- Heating did not improve flowering when added to night break lighting (LD), following cold-storage of plants.
- Heating marginally increased flowering when added to night break lighting (LD) when plants had NOT been cold-stored. There were 70% budded plants with LD and heat, compared to 60% with unheated long day treatment.
- When heat was applied to plants grown under long days (LD and Supp+LD) flowers were produced on significantly taller stems - compare Figure 1a (unheated) and Figure 1b (heated).

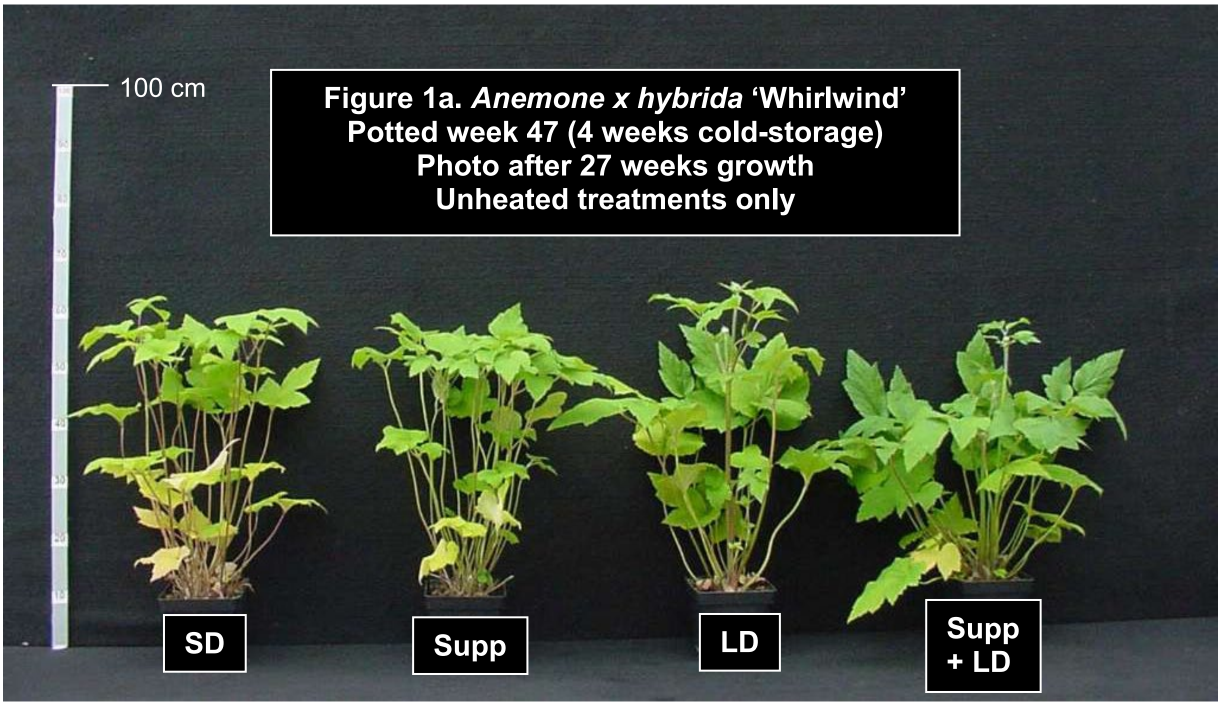
Plants grown under long days (LD and Supp+LD) with heat appeared to produce more flowers on shorter stems the longer the cold store period. Figure 1c shows effects following 12 weeks cold-store treatment.

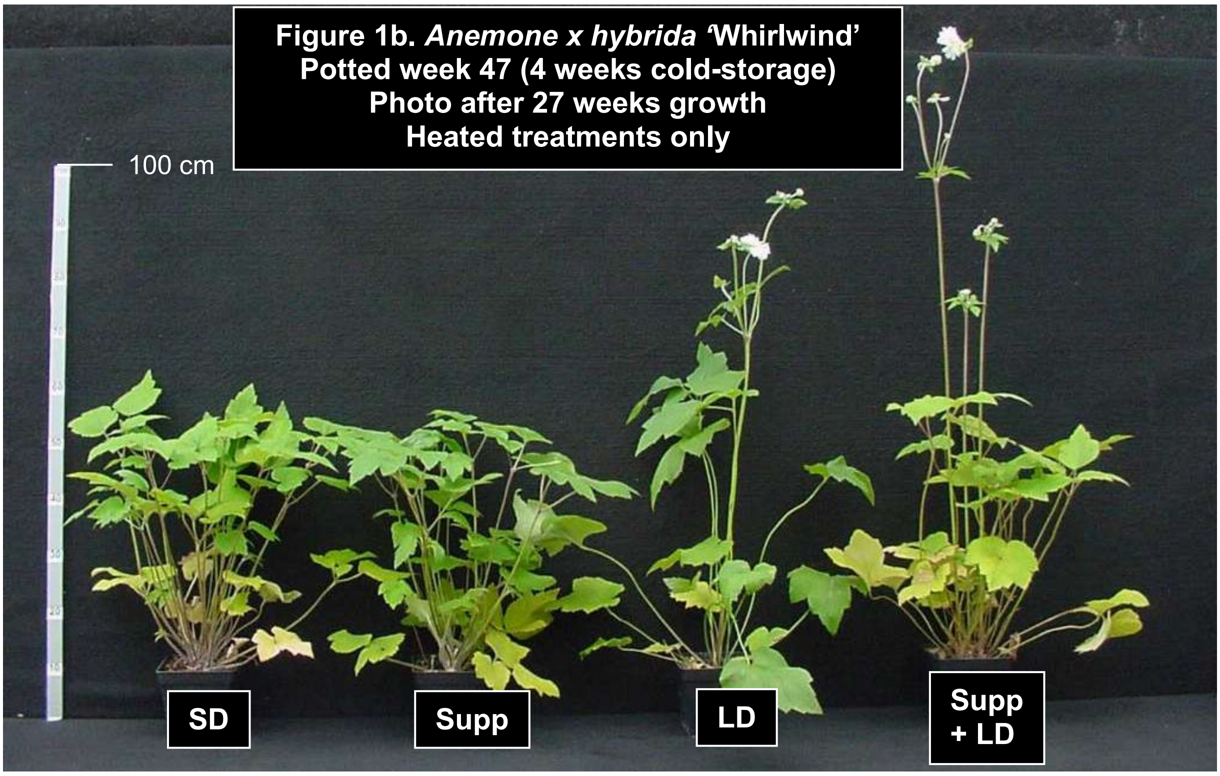
The time taken to visible bud (Table 1b):

- Early bud appearance was seen on some normal day (SD) and supplementary lighting (Supp) treatments, however bud occurrence was so infrequent by week 26 (see Table 1a) that this data appears of little practical value.
- In the unheated environment, where supplementary lighting was added to long day effect (Supp+LD), initial budding was brought forward by 20 days, where there had been no cold-storage. However, no additional benefit from supplementary lighting was seen after cold-store treatment,
- In the heated environment the addition of supplementary lighting (Supp+LD) was only of benefit after cold-store treatment, bringing first bud appearance forward by 9 to 21 days.

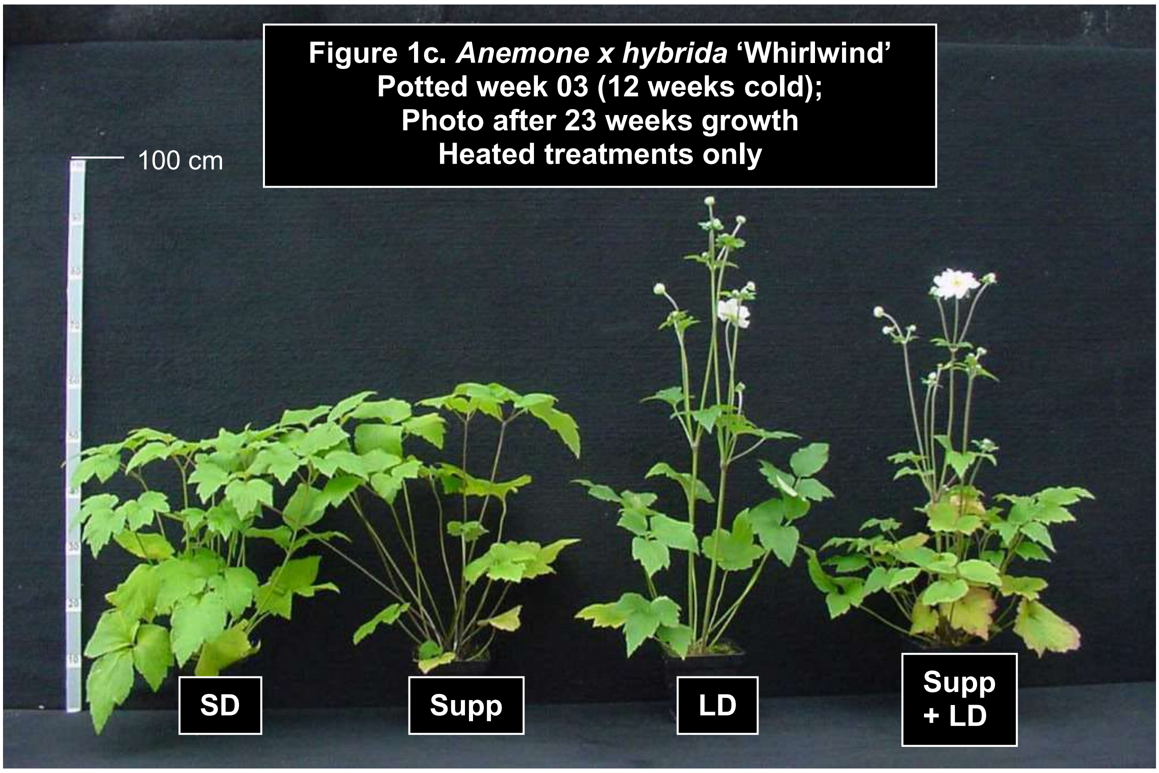
- **Pests and Disease**

No pest or disease problems were encountered.





SD = normal (short) day; Supp = supplementary lighting; LD = long day



SD = normal (short) day; Supp = supplementary lighting; LD = long day

2. Aster '*Marie Ballard'*

<u>In Summary</u> :

- **Long day (LD) treatment (without heat) hastened flowering and produced quality plants. The addition of supplementary lighting (Supp+LD) further hastened (initial) flowering.**
- **Supplementary lighting (Supp) or cold storage (for 12 weeks) alone was also very effective (without heat) in hastening flowering but flower numbers were not as high and shoot length shorter than LD treatment.**
- **A heated environment also encouraged earlier flowering, however powdery mildew reduced final plant quality.**

<u>In Detail</u> :

With the standard treatment (SD) and no cold-storage, the percentage of plants with bud at week 26 was 40% (Table 2a). Budded plants were increased to 90-100% by <u>any one</u> of the following options:

- Adding supplementary lighting (Supp)
- Adding long day effect (LD)
- Adding supplementary lighting and long day effect (Supp+LD)
- Cold storage for 12 weeks
- Heated environment

Table 2a*. Aster* 'Marie Ballard'- Percentage of plants with buds by week 19

	Unheated				Heated			
	SD	**Supp**	**LD**	**Supp+ LD**	**SD**	**Supp**	**LD**	**Supp+ LD**
No cold	40	95	100	100	**100**	**95**	**100**	**100**
4 weeks cold	55	100	100	100	**95**	**100**	**100**	**100**
8 weeks cold	70	100	100	100	**95**	**100**	**100**	**100**
12 weeks cold	90	100	100	95	**100**	**100**	**100**	**100**

LD plants produced more buds on longer stems than plants grown under normal (SD) day length (Figures 2a and 2b).

Plants grown under supplementary lighting (Supp) were of a lesser quality than those where night break lighting (LD) was applied, as plant height was shorter and bud numbers less (Figures 2a and 2b). Similar results were achieved following a cold-store treatment.

Powdery mildew was a problem in the heated environment – see "Pests & Disease" below.

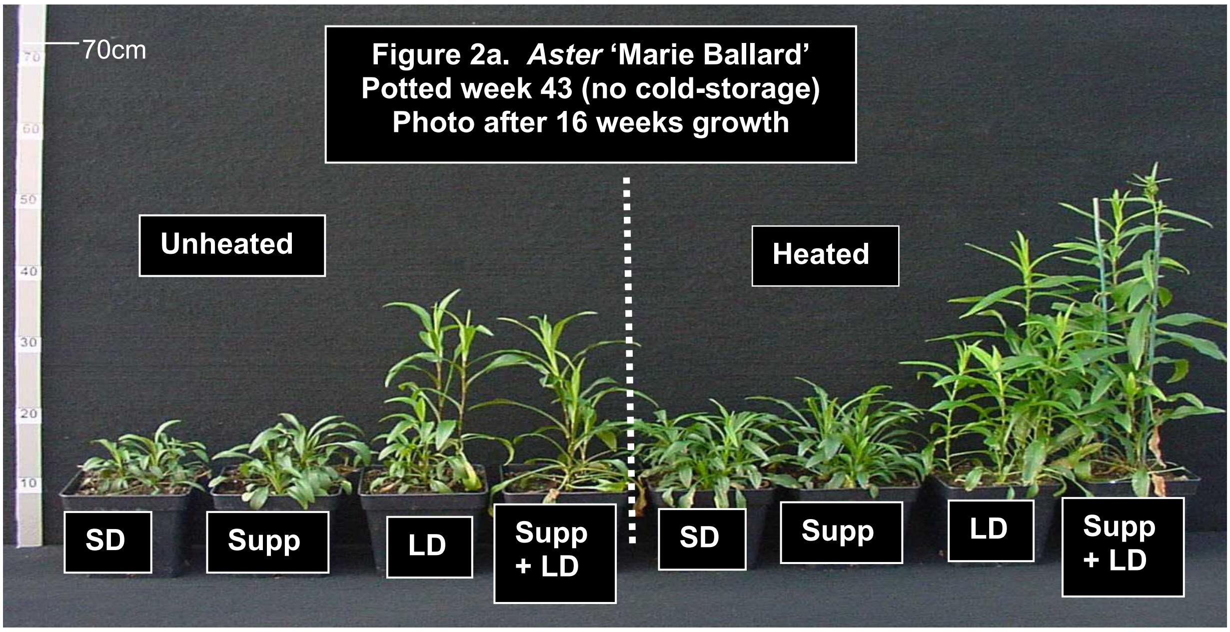


Figure 2a. *Aster* 'Marie Ballard'
Potted week 43 (no cold-storage)
Photo after 16 weeks growth

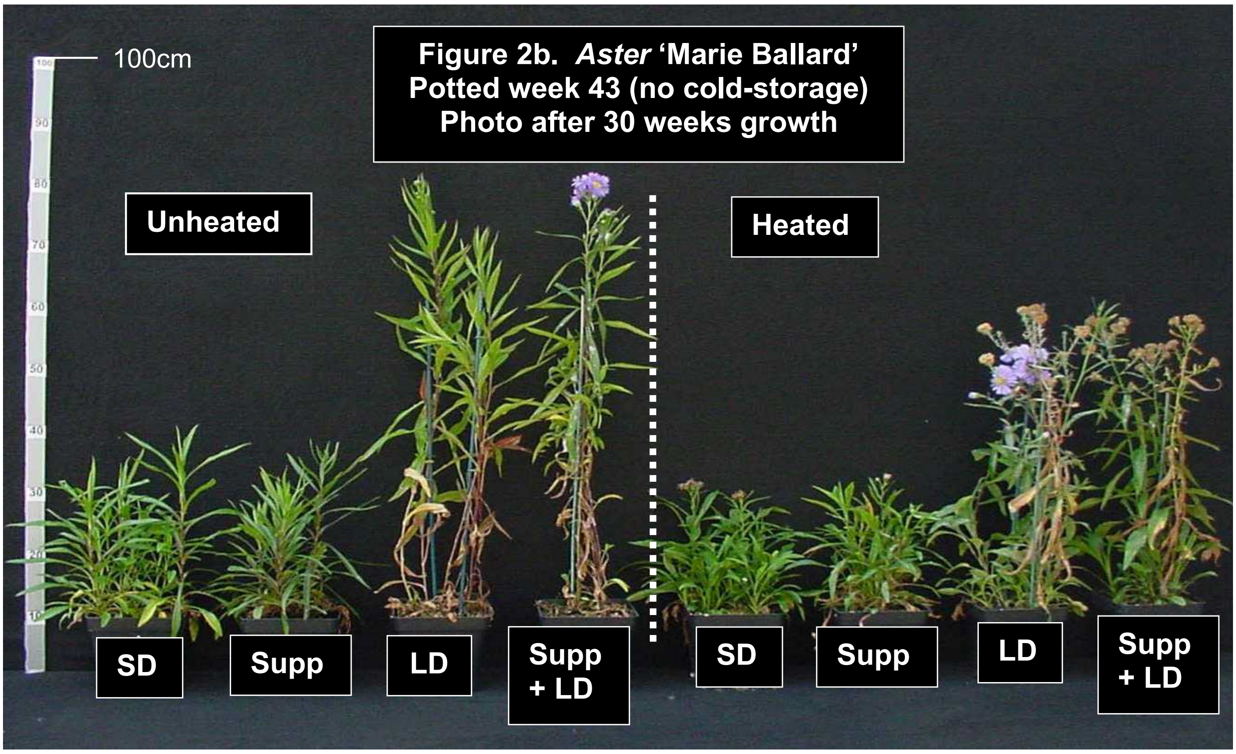


Figure 2b. *Aster* 'Marie Ballard'
Potted week 43 (no cold-storage)
Photo after 30 weeks growth

SD = normal (short) day; Supp = supplementary lighting; LD = long day

Where <u>no cold-storage applied</u>, *first bud* (Table 2b) was brought forward as follows:

- Supp : brought forward by 4 days (unheated); 73 days (heated)
- LD : brought forward by 13 days (unheated); 77 days (heated)
- Supp+LD : brought forward by 31 days (unheated); 90 days (heated)
- Heated (no lights) : brought forward by 51 days

Table 2b. *Aster* 'Marie Ballard'- Average days to first visible bud*

	Unheated				Heated			
	SD	**Supp**	**LD**	**Supp+ LD**	**SD**	**Supp**	**LD**	**Supp+ LD**
No cold	182	178	169	151	**132**	**109**	**105**	**92**
4 weeks cold	185	165	184	185	**137**	**113**	**140**	**127**
8 weeks cold	185	180	190	186	**138**	**134**	**155**	**147**
12 weeks cold	183	171	187	188	**148**	**145**	**167**	**160**

* Includes period in cold store

Adding heat to lighting treatments (Supp, LD and Supp+LD) hastened first visible bud. Heating long day treatments (LD and Supp+LD) also produced visibly more flowers on shorter stems (Figure 2b). However, powdery mildew reduced final plant quality in all heated treatments.

<u>Cold-store treatment</u> only showed effects in bringing first bud earlier when in combination with supplementary lighting and an <u>unheated environment</u> :

- First bud brought forward by 17 days, after 4 weeks cold-storage.
- First bud brought forward by 2 days, after 8 weeks cold-storage.
- First bud brought forward by 11 days, after 12 weeks cold-storage.

In the <u>heated environment</u> cold-store treatment delayed the first bud (by 4 to 68 days) and the longer the cold-storage period, the longer the delay.

- **Pests and Disease**

Significant mildew had developed on plants in the heated environments by week 19. Although plants were treated with 'Nimrod' this mildew was difficult to control and did affect final plant quality.

There were no particular pest problems.

3. *Crocosmia* ‘Star of the East’

<u>In Summary</u> :

- **Long day (LD) treatment, through night break lighting, was key in promoting the development of flower buds on *Crocosmia*, but only when applied in an unheated environment.**
- **Previous cold-store treatment generally reduced the benefit of long days (LD).**
- **The addition of heat generally inhibited floral development seen from long days (LD).**

<u>In Detail</u> :

With standard treatment (SD) no plants had produced buds by week 23 in an unheated environment, and only 5% had buds when heated (Table 3a).

Supplementary lighting (Supp), applied alone, had no benefit, whereas long day effect (LD) was instrumental in promoting flowering in an unheated environment.

Cold store treatment generally reduced the benefit of long day effect (LD).

Heating generally prohibited flowering (Table 3a) although in combination with supplementary and long day effect (Supp+LD) first visible buds were seen earlier (Table 2b). Thrips were an additional problem in the heated environments – see below.

Table 3a. *Crocosmia* ‘Star of the East’- Percentage of plants with buds by week 23

	Unheated				Heated			
	SD	Supp	LD	Supp+ LD	SD	Supp	LD	Supp+ LD
No cold	0	0	90	100	**5**	**10**	**25**	**15**
4 weeks cold	0	0	95	85	**0**	**0**	**0**	**5**
8 weeks cold	0	0	70	90	**0**	**0**	**10**	**20**
12 weeks cold	0	0	65	35	**0**	**0**	**40**	**70**

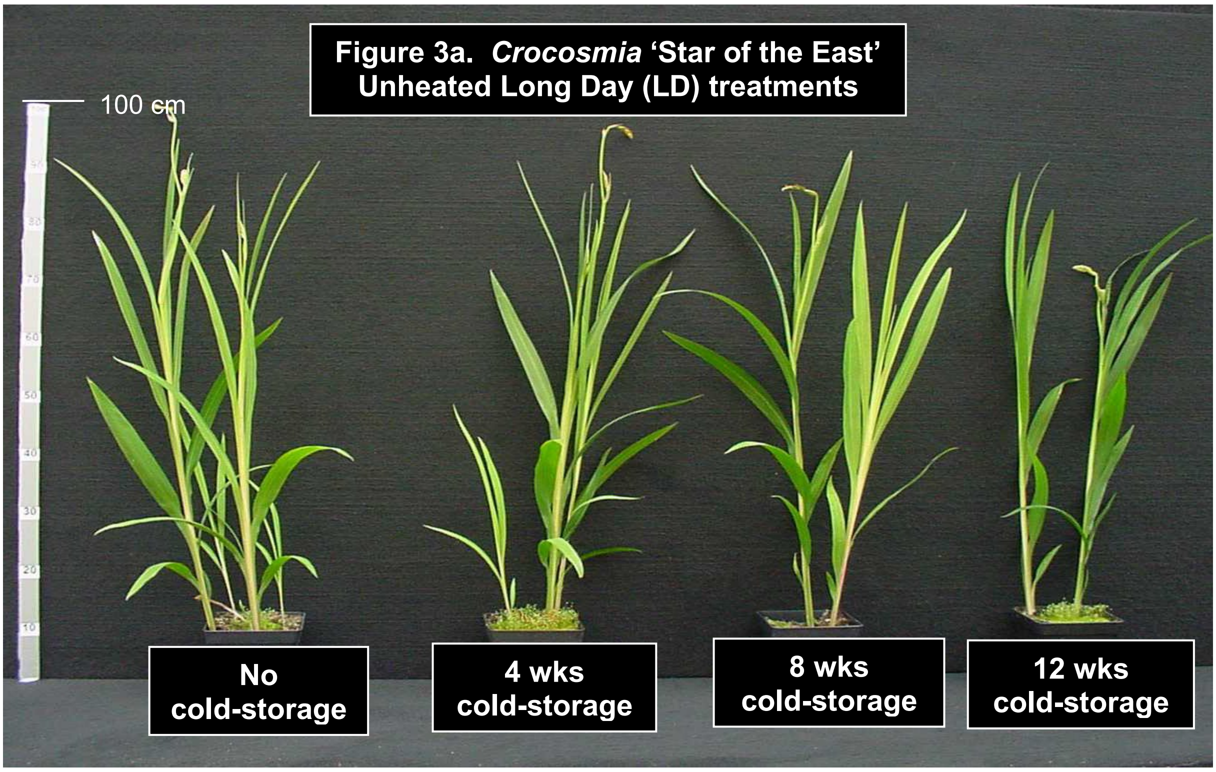
Table 3b. *Crocosmia* ‘Star of the East’- Average days to first visible bud*

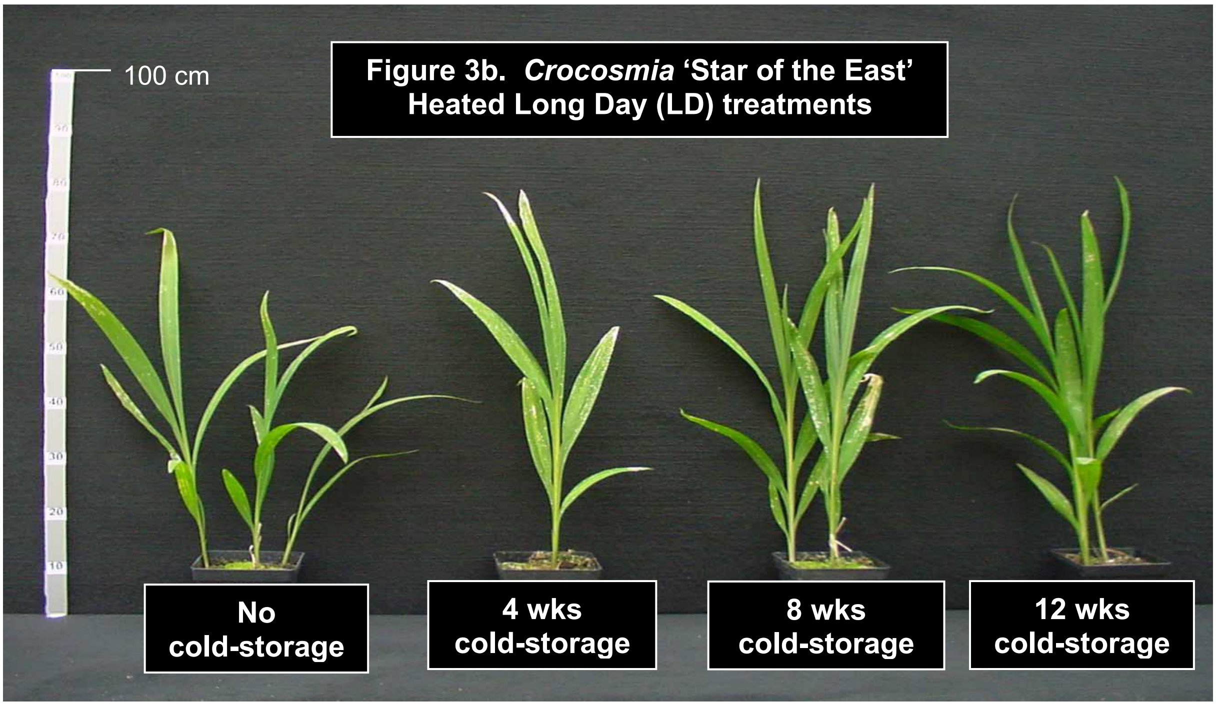
	Unheated				Heated			
	SD	Supp	LD	Supp+ LD	SD	Supp	LD	Supp+ LD
No cold	-	-	220	217	**227**	**228**	**217**	**191**
4 weeks cold	-	-	221	218	**-**	**-**	**-**	**169**
8 weeks cold	-	-	226	224	**-**	**-**	**196**	**176**
12 weeks cold	-	-	226	227	**-**	**-**	**204**	**194**

* Includes period in cold store

- **Pests and Disease**

Where no heating was applied thrips damage was minimal and did not affect plant quality (Figure 3a). In heated compartments, however, thrips caused very rapid and severe leaf scarring (Figure 3b). Although biological controls (*Amblyseius cucumeris*) were regularly introduced to the heated compartments these did not prove effective in combating the thrips and were possibly introduced too late.





SD = normal (short) day; Supp = supplementary lighting; LD = long day

4. *Gaura lindheimerii*

In Summary :

- **Night break lighting (LD) hastened budding and was also seen to improve plant quality in terms of shoot growth and number of flowers.**
- **The addition of supplementary lighting (Supp+LD) accelerated first bud production by 9 days (unheated glasshouse), however at no other time was the "straight" LD result convincingly improved upon by the addition of other inputs.**
- **Supplementary lighting (Supp) hastened bud production but plant quality was not as good as from LD.**
- **This species flowered very rapidly (within 4 weeks) and so cold-store treatment inevitably delayed first bud production.**
- **Aphids were problematical in the heated environments.**

In Detail :

With the standard treatment (SD) the percentage of plants with buds at week 18 was 75% in the unheated environment (Table 4a). Some improvements in numbers of budded plants were seen, as follows:

– Adding supplementary lighting (Supp) : 95%
– Adding cold-store treatment : 94 to 100%
– Adding heat : 85%

The most convincing benefit, however, was seen from long day (LD) effect, which produced 100% budded plants in the absence of any other input. Shoot growth and flower number were also improved (Figures 4a and 4b).

Adding heat exacerbated aphid problems – see below.

Table 4a. ***Gaura lindheimerii*- Percentage of plants with buds by week 18**

	Unheated				Heated			
	SD	**Supp**	**LD**	**Supp+ LD**	**SD**	**Supp**	**LD**	**Supp+ LD**
No cold	75	95	100	100	**85**	**65**	**100**	**100**
4 weeks cold	95	100	100	100	**90**	**90**	**100**	**95**
8 weeks cold	100	80	100	95	**95**	**100**	**100**	**100**
12 weeks cold	94	94	94	100	**95**	**100**	**100**	**100**

Early bud production was seen in the control plots (unheated SD) after 24 days. This was before the shortest cold-store treatment had been completed and consequently delays were inevitable from cold-store treatment (Table 4b).

The addition of long day effect and supplementary lighting (Supp+LD), particularly in the unheated environment, accelerated first bud production from the control's 24 days to 15 (Table 4b).

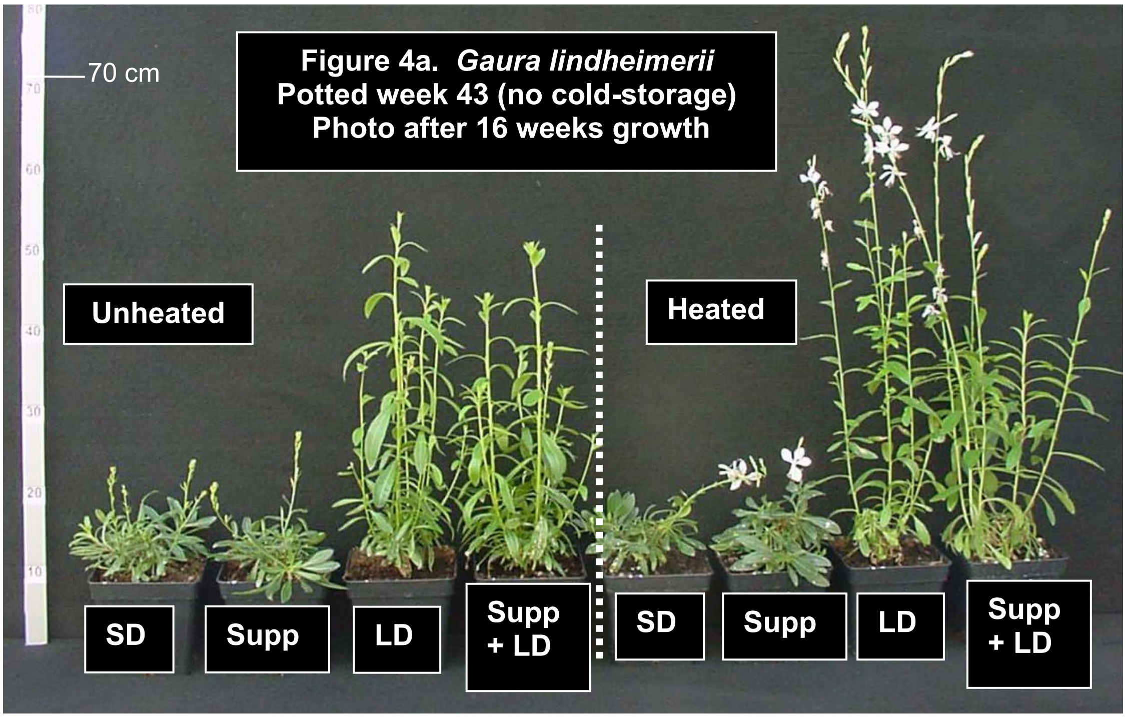
Table 4b *Gaura lindheimerii*- Average days to first visible bud*

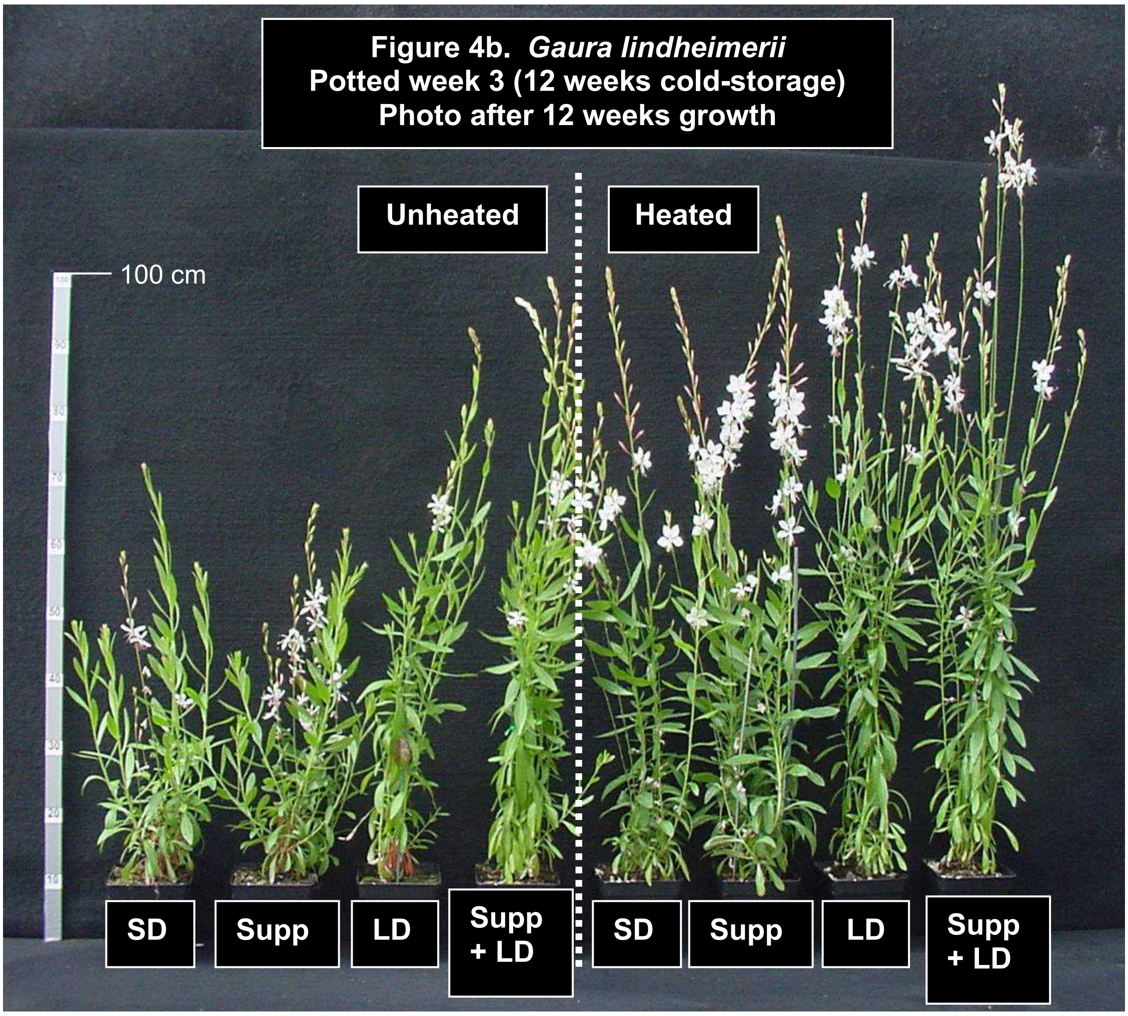
	Unheated				Heated			
	SD	**Supp**	**LD**	**Supp+ LD**	**SD**	**Supp**	**LD**	**Supp+ LD**
No cold	24	20	24	15	**23**	**23**	**22**	**19**
4 weeks cold	65	52	53	57	**54**	**43**	**50**	**48**
8 weeks cold	82	92	75	81	**75**	**88**	**74**	**68**
12 weeks cold	111	95	103	105	**107**	**106**	**104**	**103**

* Includes period in cold store

- **Pests and Disease**

The *Gauras* were significantly affected by aphids, which appeared relatively early on in the year. Biological controls (*Aphidius ervi, Aphidius colemani* and *Aphidoletes aphidimyza*) worked well against these pests in the unheated compartments, taking total control of the few aphids that appeared. However, aphid populations in the heated compartments were much higher and required additional regular spot treating with spray treatments such as 'Aphox', 'Chess' and 'Eradicoat'.





SD = normal (short) day; Supp = supplementary lighting; LD = long day

5. *Lobelia* 'Queen Victoria'

<u>In Summary</u> :

- **Night break lighting, to give artificial long day effects (LD), was key in promoting flower development in *Lobelia.***
- **Additional benefit (to LD) was seen from heating, however pest problems (particularly whitefly) were then difficult to contain.**
- **A combination of a heating growing environment and plants that had previously been cold-store treated promoted flower development but effects were not as great as night break lighting (LD) used alone and whitefly was an issue.**

<u>In Detail</u> :

With standard treatment (SD) no plants had produced buds by week 21 in an unheated environment, and only 5% had buds when heated (Table 5a).

Long day effect (LD) was instrumental in promoting flowering with 65-100% of all LD plants with buds at week 21. Supplementary lighting applied alone (Supp) or in addition to long day effect (Supp+LD) had no convincing benefit in this regard (Table 5a).

Following cold store treatment, there was no convincing increase in the number of plants carrying buds, except in the normal day length treatment (SD) in the heated environment.

Heating generally enhanced the long day (LD and Supp+LD) treatments, further increasing numbers of budded plants to 80 to 100% (Table 5a) and bringing forward first bud production by 34 to 127 days (Table 5b). There were pest problems, however – see below.

Table 5a. *Lobelia* 'Queen Victoria'- Percentage of plants with buds by week 21

	Unheated				Heated			
	SD	**Supp**	**LD**	**Supp+ LD**	**SD**	**Supp**	**LD**	**Supp+ LD**
No cold	0	5	85	50	**5**	**10**	**90**	**80**
4 weeks cold	5	0	90	100	**55**	**20**	**100**	**95**
8 weeks cold	5	15	75	70	**65**	**55**	**100**	**100**
12 weeks cold	5	0	65	65	**60**	**35**	**100**	**100**

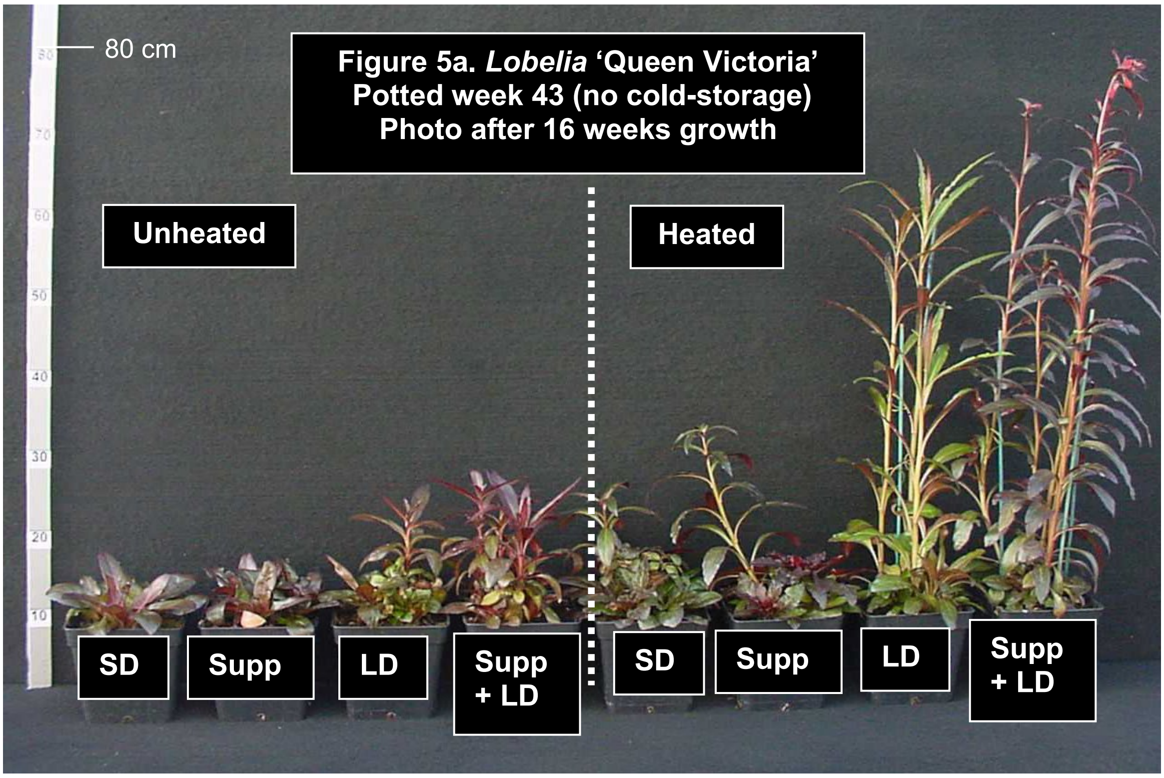
Table 5b. *Lobelia* 'Queen Victoria'- Average days to first visible bud*

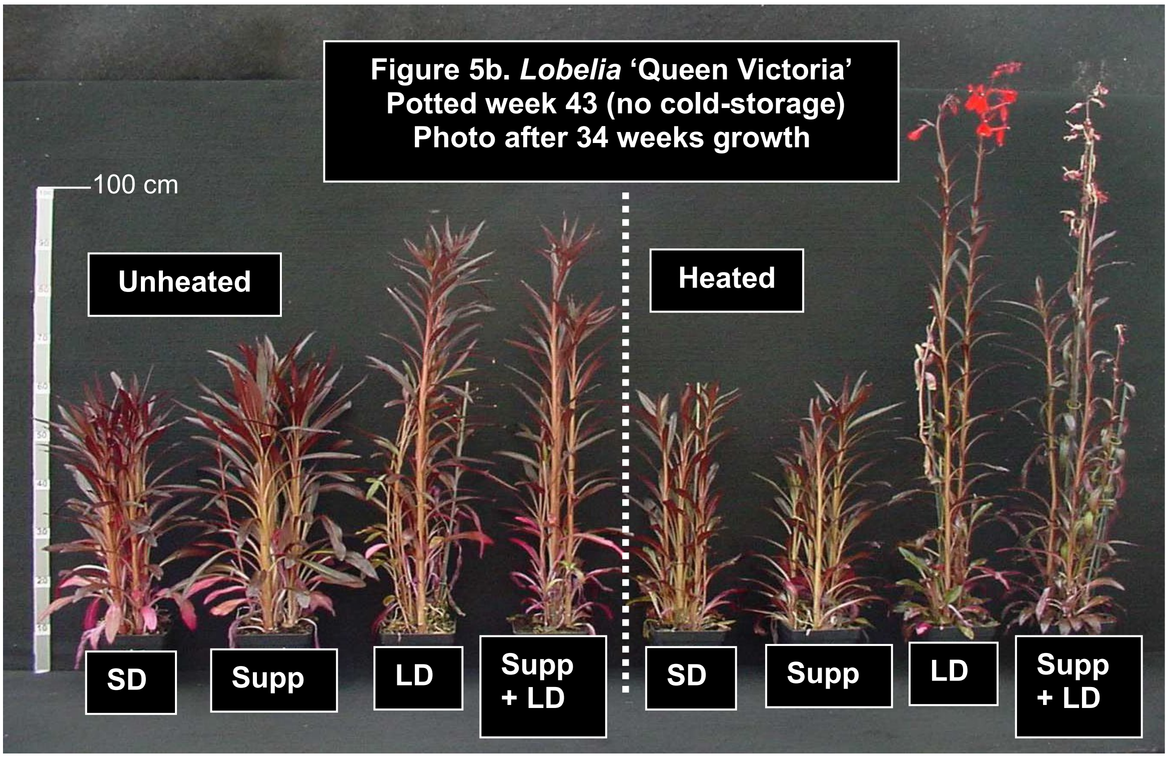
	Unheated				Heated			
	SD	Supp	LD	Supp+ LD	SD	Supp	LD	Supp+ LD
No cold	-	176	209	205	**113**	**164**	**161**	**78**
4 weeks cold	201	-	206	203	**215**	**206**	**151**	**142**
8 weeks cold	215	207	210	207	**197**	**207**	**165**	**160**
12 weeks cold	215	-	213	210	**209**	**209**	**179**	**172**

* Includes period in cold store

- **Pests and Disease**

Lobelias in the heated compartments were prone to attack from spider mite and whitefly. Biological control (*Phytoseiulus persimilis*) proved very successful against spider mites, but the whitefly proved very difficult to control by biological methods. Despite regular introductions of *Encarsia formosa* whitefly persisted and plants had to be regularly sprayed with Eradicoat, which helped to keep numbers in check.





SD = normal (short) day; Supp = supplementary lighting; LD = long day

6. *Penstemon* 'Mother of Pearl'

In Summary :

- **Night break lighting, to give artificial long day effects (LD), was the most effective treatment in promoting flowering in *Penstemon*.**
- **Supplementary lighting with long day effect (Supp+LD) marginally improved upon this and, on its own (Supp), was effective but less so than LD alone.**
- **Cold-store treatment of plants showed no benefits and, in some cases, inhibited flower development.**
- **Heating also generally gave no benefits in bud production, while also encouraging pest and disease problems.**

In Detail :

With standard treatment (SD) only 15% of plants had produced buds by week 26 in an unheated environment, and only 40% had buds when heated (Table 6a).

In the unheated environment :

- Supplementary lighting (Supp) increased flowering to 80%. Long day effect (LD) was slightly more effective at 90% of plants with bud, whereas under a combination of lighting (Supp+LD) all plants were in bud.
- Where plants had been cold stored for 4 weeks, no convincing benefit was seen. After 8 or 12 weeks cold-store periods, there were fewer budded plants at assessment when supplementary lighting was applied (Supp or Supp+LD). Cold storage did not however reduce benefits seen from long day effect (LD).

In the heated environment :

- The benefits of lighting (LD or Supp), seen in the unheated environment, were almost always reduced.
- Heating, without lights, did increase percentage of budded plants. The effect was only substantial, however, after the 4 weeks cold-store treatment.
- Pests and disease were problematical (see below).

Table 6a. *Penstemon* 'Mother of Pearl'- Percentage of plants with buds by week 26

	Unheated				Heated			
	SD	**Supp**	**LD**	**Supp+ LD**	**SD**	**Supp**	**LD**	**Supp+ LD**
No cold	15	80	90	100	**40**	**20**	**40**	**80**
4 weeks cold	35	90	90	95	**75**	**60**	**85**	**90**
8 weeks cold	5	50	90	60	**50**	**45**	**70**	**65**
12 weeks cold	0	20	100	25	**40**	**35**	**55**	**65**

Considering appearance of first bud - 223 days in the standard treatment - there were no convincing benefits from individual application of lighting, heating or cold-store treatment (Table 6b).

Combinations of treatment were also generally ineffective in bringing forward first bud appearance. An exception was the combination of:

- Long day effect + supplementary lighting (Supp+LD)
- Heated environment

In this case, first bud was brought forward by 20 days (overall). However, what also needs to be considered is that, in the heated environment, fewer plants had produced bud by week 26 (as seen in Table 6a) and pest and disease control became a significant issue (see below).

Table 6b. *Penstemon* 'Mother of Pearl' - Average days to first visible bud*

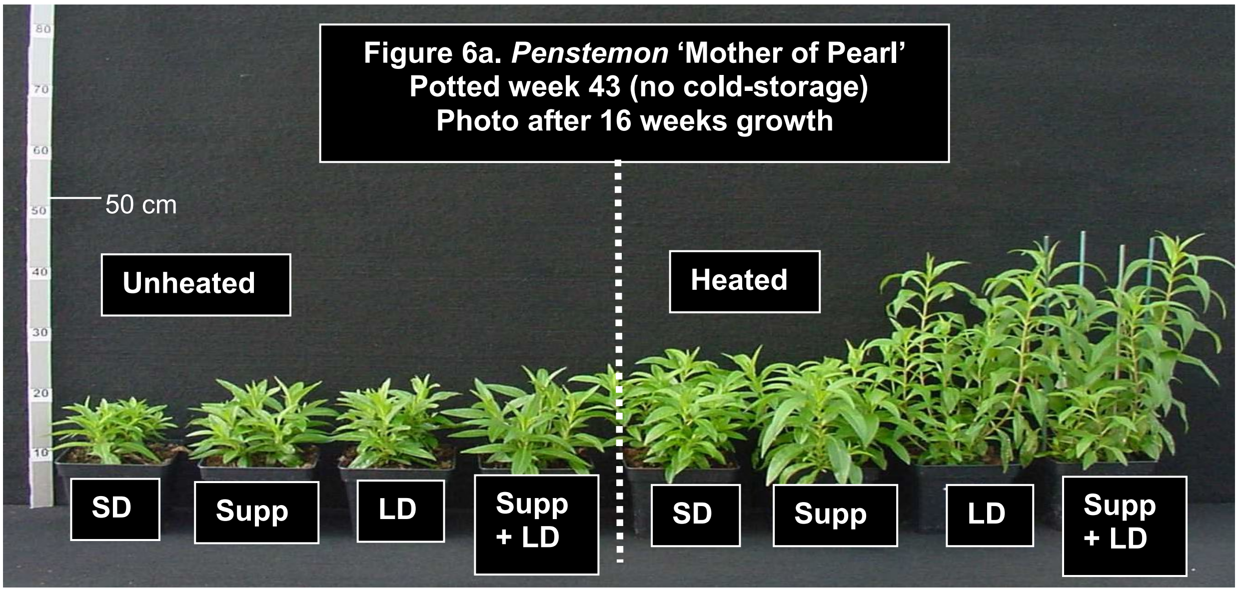
	Unheated				Heated			
	SD	**Supp**	**LD**	**Supp+ LD**	**SD**	**Supp**	**LD**	**Supp+ LD**
No cold	223	220	217	221	**225**	**222**	**220**	**203**
4 weeks cold	240	235	230	226	**233**	**236**	**229**	**216**
8 weeks cold	239	237	234	238	**237**	**234**	**228**	**226**
12 weeks cold	-	230	223	224	**223**	**227**	**219**	**216**

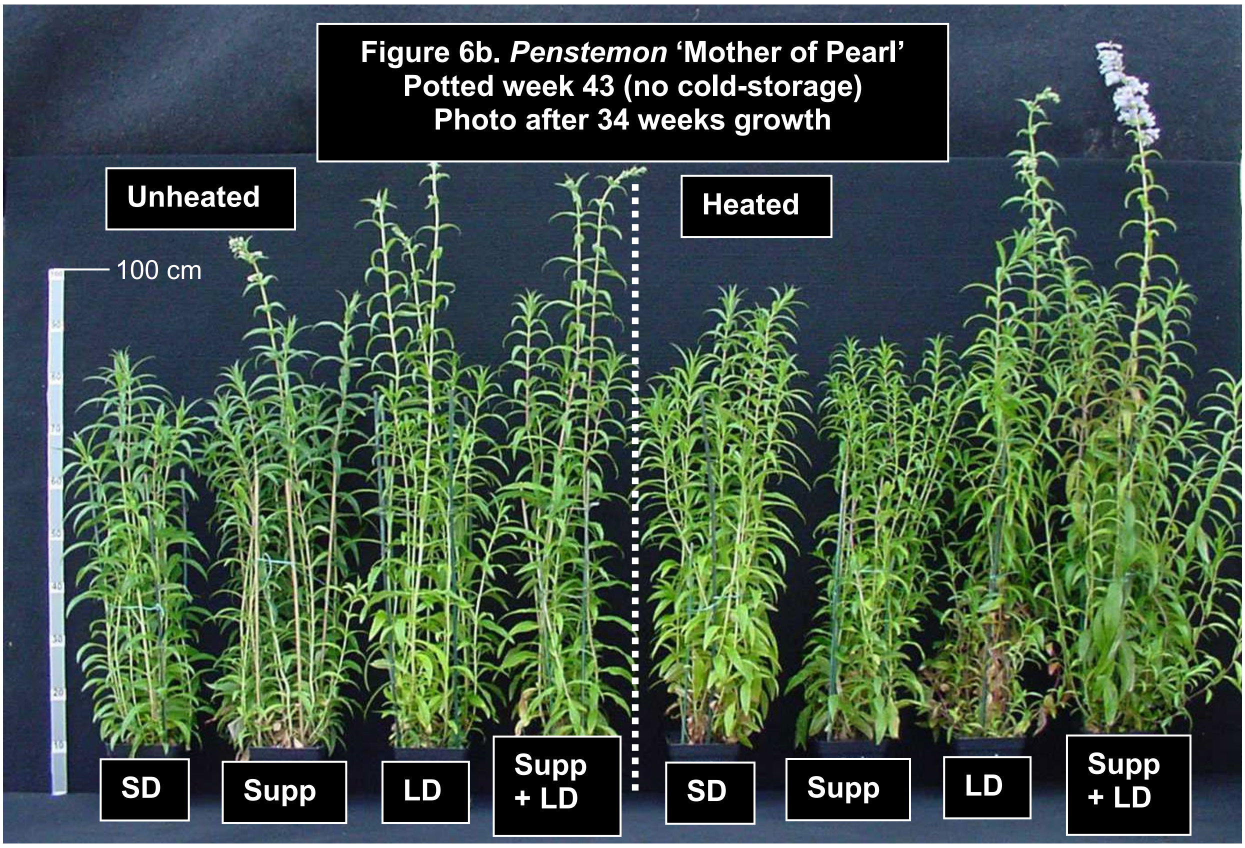
* Includes period in cold store

- **Pests and Disease**

Penstemon were attacked by spider mites and aphids in heated compartments. Biological control (*Phytoseiulus persimilis*) proved effective against spider mite. However, biological control of aphids (using *Aphidius colemani* and *Aphidius ervi)* was less effective and, as a result, there was a need for regular sprays with products such as 'Eradicoat' and 'Chess'.

Some plants in the heated environments also developed mildew later on in the trial and were treated with 'Nimrod'.





SD = normal (short) day; Supp = supplementary lighting; LD = long day

7. *Rudbeckia fulgida var. sullivantii* 'Goldsturm'

In Summary :

- **Night break lighting, to give artificial long day effects (LD), was the most effective treatment in promoting flowering.**
- **Adding supplementary lighting (Supp+LD) was slightly more effective than LD alone.**
- **Cold-store treatment increased bud production when applied alone.**
- **Adding cold-store treatment to long day effect (LD or Supp+LD) had a negative effect versus straight long day treatment**

In Detail :

A significant number of plants died following cold storage* (Table 7a) and so bud production results (Tables 7b and 7c), following cold-store treatment, need to be considered with caution, as means here have usually been derived from fewer (surviving) plants.

Rudbeckia were the only species studied that suffered damage from being held in cold store and this may be a result of the plants being bare rooted when first put in. As they were removed from store and potted, all plants had some visible shoot development, but then often no further growth was seen, with dieback subsequently occurring. The longer the duration of cold-storage then average survival rate declined - 87%, 63% and 55% for 4, 8 and 12 weeks storage, respectively (Table 7a). It is likely that cold-store treatment may have also adversely affected the growth of those plants that did survive, making interpretation of results less reliable.

Table 7a *Rudbeckia* 'Goldsturm'- Percentage of live plants at week 24

	Unheated				Heated			
	SD	Supp	LD	Supp+ LD	SD	Supp	LD	Supp+ LD
No cold	100	95	100	100	**90**	**95**	**100**	**100**
4 weeks cold	100	90	50	95	**80**	**95**	**95**	**90**
8 weeks cold	65	45	65	85	**80**	**35**	**80**	**50**
12 weeks cold	95	60	60	20	**25**	**65**	**70**	**45**

In the absence of cold-store treatment :

With standard treatment (SD) only 15% of plants had produced buds by week 24 in an unheated environment. No buds were seen at this point from the equivalent heated situation (Table 7b).

Long day effect (LD), through night-break lighting, increased budded plants numbers to 80% in the unheated environment and 95% when heated. Supplementary lighting alone (Supp) had no beneficial effect, whereas the addition of supplementary lighting to long day effect (Supp+LD) increased flowering further, to 90 and 100% in the unheated and heated environments, respectively.

After cold-store treatment :

Bud production at assessment (week 24) was increased following cold-store in both unheated and heated environments, in the absence of night-break lighting (LD). Where long day effect (LD or Supp+LD) had been applied however, cold-store treatment almost always reduced the number of plants in bud.

Table 7b *Rudbeckia* 'Goldsturm'- Percentage of all surviving plants with buds by week 24

	Unheated				Heated			
	SD	Supp	LD	Supp+ LD	SD	Supp	LD	Supp+ LD
No cold	15	0	80	90	**0**	**5**	**95**	**100**
4 weeks cold	100	94	70	63	**100**	**100**	**100**	**78**
8 weeks cold	100	78	62	65	**100**	**86**	**81**	**80**
12 weeks cold	95	83	17	25	**80**	**69**	**79**	**78**

Appearance of first bud (Table 7c) - 131 days in the standard treatment – was only reduced in the heated environment in plants not previously cold-stored. Supplementary lighting (Supp or Supp+LD) had the most effect in this regard. Plants from both these treatments were also significantly larger than those grown in the unheated environments (Figure 7b), though an increased whitefly risk was also apparent – see later.

What must also be remembered is that with supplementary lighting alone (Supp), very few plants had produced bud by week 26 (Table 7b). Where night-break lighting was also applied however (Supp+LD), first bud was brought forward by 34 days and, much more successfully, 100% of plants were in bud by week 26. Plant size was also increased (Figure 7b).

Where plants had had no cold-store treatment, long day effect applied alone (LD) brought first bud appearance forward in the heated environment and then by only 13 days.

Table 7c *Rudbeckia* 'Goldsturm'- Average days to first visible bud*

	Unheated				Heated			
	SD	Supp	LD	Supp+ LD	SD	Supp	LD	Supp+ LD
No cold	131	-	153	151	**-**	**61**	**118**	**97**
4 weeks cold	230	218	195	177	**227**	**227**	**171**	**143**
8 weeks cold	221	224	161	179	**225**	**224**	**208**	**177**
12 weeks cold	221	224	156	232	**219**	**205**	**185**	**159**

* Includes period in cold store

- **Pests and Disease**

Pests or disease did not significantly affect *Rudbeckia*, although towards the end of the trial, as ambient temperatures increased, small pockets of whitefly developed in the heated compartments. These were treated fairly successfully with 'Eradicoat'.

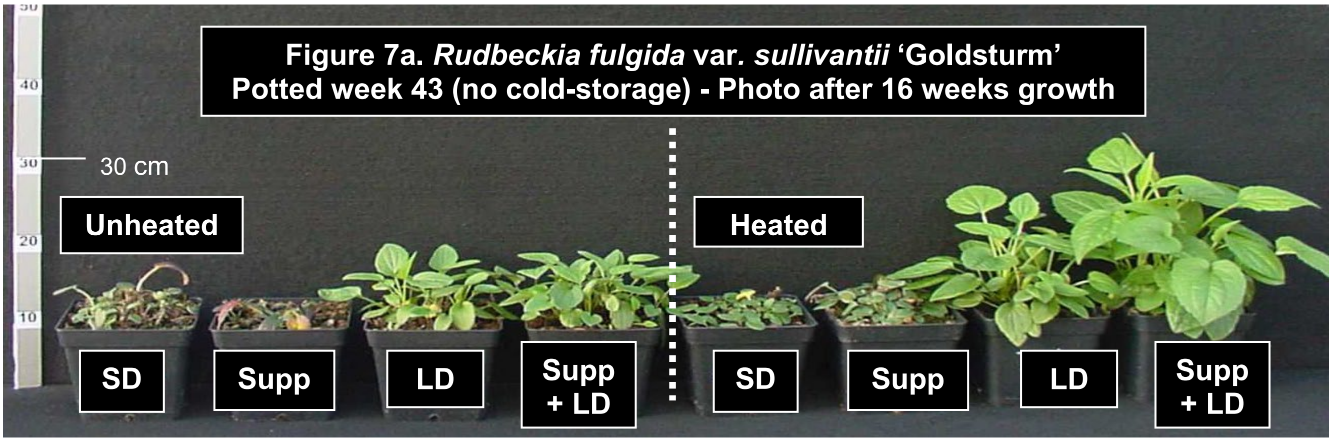


Figure 7a. *Rudbeckia fulgida* var. *sullivantii* 'Goldsturm'
Potted week 43 (no cold-storage) - Photo after 16 weeks growth

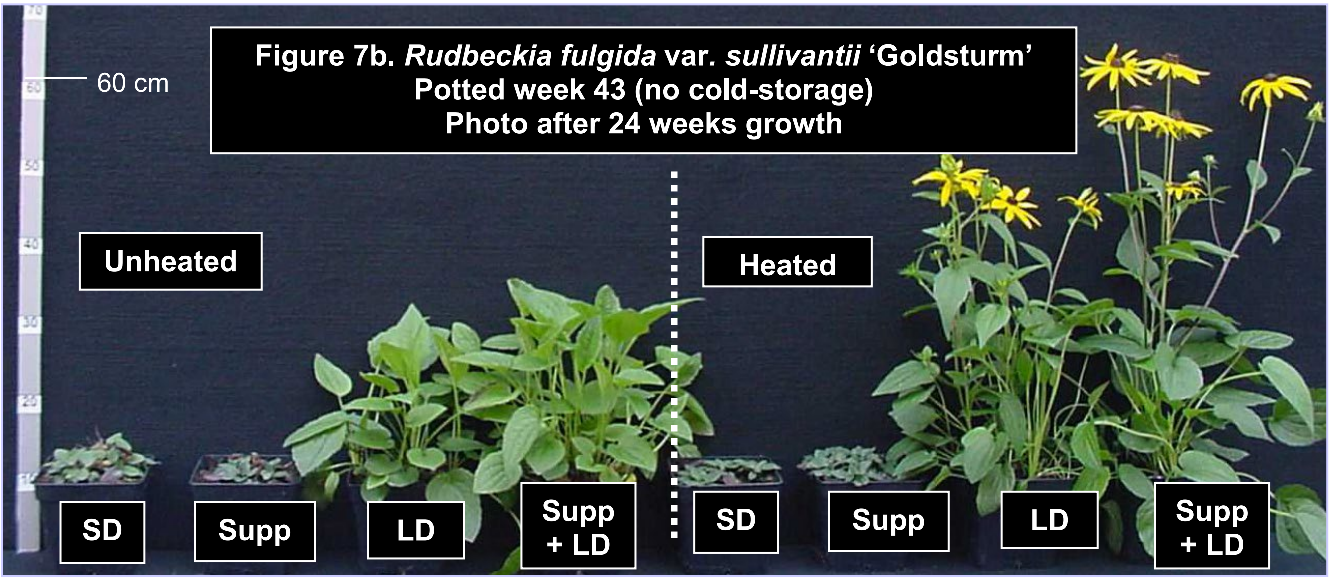


Figure 7b. *Rudbeckia fulgida* var. *sullivantii* 'Goldsturm'
Potted week 43 (no cold-storage)
Photo after 24 weeks growth

SD = normal (short) day; Supp = supplementary lighting; LD = long day

8. *Sedum* 'Autumn Joy'

<u>In Summary</u> :

- ***Sedum* flowered readily in the unheated environment, with most plants flowering by the assessment time (week 18) without the need for lighting (or cold-store treatment).**
- **Adding heat to plants grown under short days (SD and Supp) had a negative effect in that plants remained very small, compact and vegetative.**
- **In the heated environment, night-break lighting, to give artificial long days (LD), was very effective in promoting flowering and increased the amount of flower produced.**

<u>In Detail</u> :

Percentage of plants with buds by week 18 varied considerably between unheated and heated environments (Table 8a) :

When unheated :

- With standard treatment (SD) 95% of plants had produced buds, in absence of cold-store treatment.
- The addition of lighting (Supp, LD or Supp+LD) generally took the number of flowering plants to 100% - the main exception was with a combination of supplementary lighting and 8 weeks previous cold-store treatment (only 70%).
- Although flower numbers per plant were not recorded, it was noticed that in the unheated compartments, plants grown under long day lighting (LD and Supp+LD) developed more flower than those plants that flowered under short days (SD and Supp) (Figure 8a).
- Cold-store treatment on its own did not appear to add to the standard (SD) treatment (Figure 8a).

When heated :

- Plants grown under short days (SD and Supp) remained very small, compact and vegetative (Figure 8b) and
  - » With standard treatment (SD), no plants had produced buds by week 18. This was true whether or not cold-store treatment had been applied.
  - » The addition of supplementary lighting (Supp) had very little effect, with 0 to 10% plants in bud at the assessment date.
- Only the addition of night-break lighting (LD or Supp+LD) encouraged significant numbers (95 to 100%) to produce buds by week 18.

Table 8a. *Sedum* 'Autumn Joy'- Percentage of plants with buds by week 18

	Unheated				Heated			
	SD	Supp	LD	Supp+ LD	SD	Supp	LD	Supp+ LD
No cold	95	100	100	100	**0**	**10**	**100**	**95**
4 weeks cold	85	100	100	100	**0**	**5**	**100**	**100**
8 weeks cold	100	70	100	100	**0**	**0**	**100**	**100**
12 weeks cold	85	95	100	100	**0**	**0**	**95**	**100**

Appearance of first bud (Table 8b) – 117 days in the standard treatment in the unheated environment – was reduced somewhat (up to 14 days) by light treatments on plants not previously cold-stored.

Earlier production of first bud occurred in the heated regime and, in combination with long day effect (LD or Supp+LD) the results were quite marked, with almost all plants also flowering by week 18 (Figure 8b).

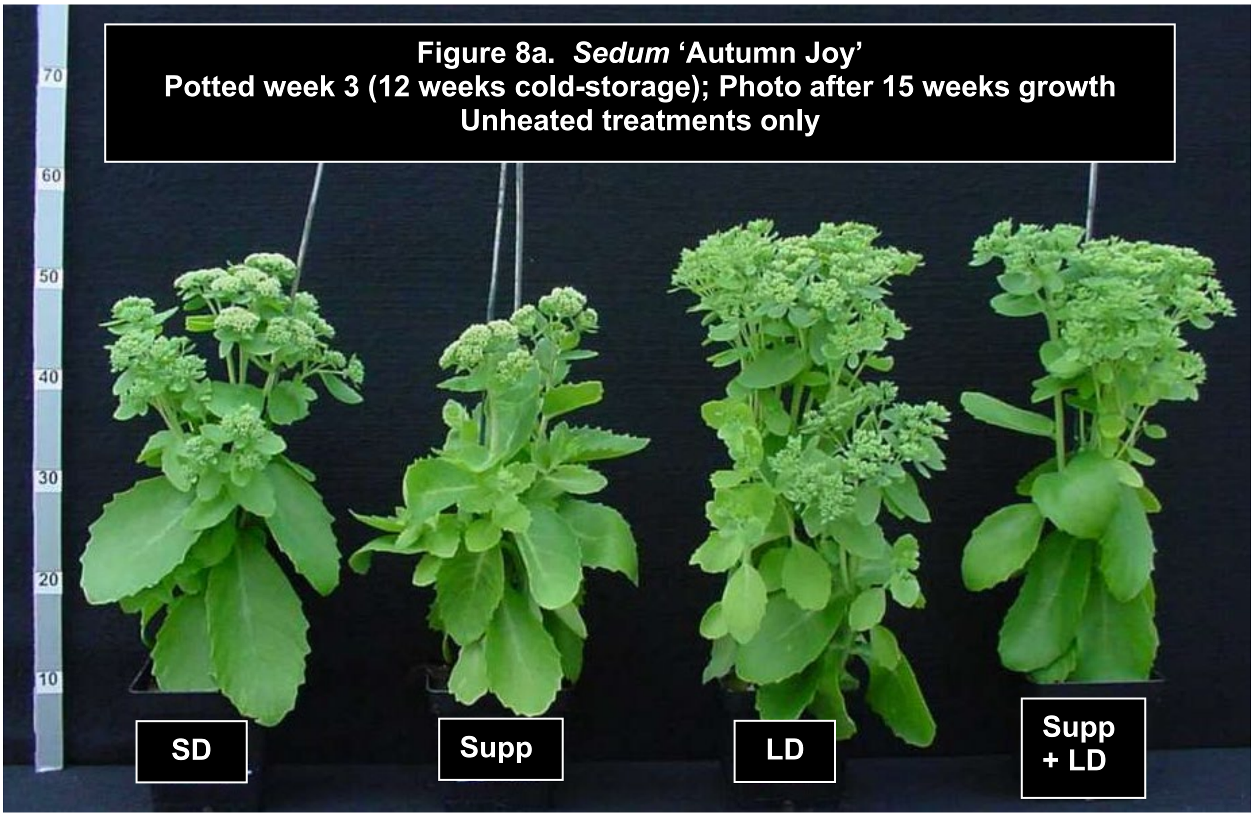
Table 8b. *Sedum* 'Autumn Joy'- Average days to first visible bud*

	Unheated				Heated			
	SD	Supp	LD	Supp+ LD	SD	Supp	LD	Supp+ LD
No cold	117	107	106	103	**-**	**10**	**73**	**62**
4 weeks cold	163	157	144	142	**-**	**68**	**118**	**102**
8 weeks cold	162	169	161	154	**-**	**-**	**132**	**125**
12 weeks cold	176	179	169	168	**-**	**-**	**149**	**142**

* Includes period in cold store

- **Pests and Disease**

Apart from a very small number of aphids in a few flower heads in the heated compartments, which were successfully spot treated with a mild soap solution, no pest or disease problems were encountered on *Sedum.*



SD = normal (short) day; Supp = supplementary lighting; LD = long day

Discussion

The aims of this project were to validate and demonstrate the screening protocol proposed in HNS 103, and to establish the flowering requirements for a representative range of eight hardy herbaceous perennial species

The result that stands out clearly is the effect of **night break lighting** to give a long day (LD) effect. Beneficial responses (earlier flowering) were observed with all eight species without the need for (previous) cold-store treatment. This form of lighting is also cheap to install and run.

The **duration of night break lighting** was not evaluated in this work and lighting regimes were imposed for the whole length of the time that plants were in the glasshouse. It may be possible to get similar effects on plant growth following a relatively short period of 'long days', perhaps as little as 4 weeks. This would reduce the cost of treatment further and so warrants further investigation.

The issue of plant quality was not fully addressed through this study. Although observations were made throughout, particularly plant height at budding and flower number, further work, to provide more detailed information would be needed for individual plant subjects.

Supplementary lighting gave positive (fundamental) effects in a few species, though plant quality did not match that form long day (LD) treatment. Supplementary lighting also enhanced effects seen from long day (LD) treatment in some cases. However, as no significant loss in plant quality was observed when plants were grown without supplementary lighting, the cost effectiveness of this additional input from SON-T lamps, which are expensive to run compared to night-break lighting, would have to be very carefully checked.

Heating had beneficial effect on flowering for most species, although this was not always the case (ie *Sedum*). Benefits from heating would be anticipated as the trial was carried out over winter to allow large differences in day-length to be studied. Heating is an expensive option however and not all growers of herbaceous perennials have access to heated structures (with the exception of some frost protection for tender crops).

Before considering the addition of heating as an option the producer must also be prepared for an increase in pest problems which would add to management time and costs to crop production, as well as the high direct costs involved in heating equipment and fuel.

Cold-store treatment was with some subjects very effective in manipulating flowering. However, such treatment was never as good as long day (LD) effect and would require the availability of a suitable cold-store (and the need to cover running costs).

It is clear from the results that all eight species responded in different manners to the combinations of treatments. Overall responses were identified and are presented in Table A (pages 3 and 4)

Conclusion

Of the eight summer/autumn flowering species studied the one factor that had greatest practical influence on flowering was day length, imposed by night break lighting using tungsten filament bulbs. However, not all effects were of convincing commercial significance e.g. *Gaura*.

Action Points

- Establish the response to day length for **your own species**
- Experiment with **timing** – Do you need night break lighting all the time, or just for 4 weeks at the start of treating?
- Installation of **night-break tungsten lighting**, to simulate long day lighting effect, as appropriate to individual plant needs.