

Project title: The Bedding and Pot Plant Centre – new product opportunities for bedding and pot plant growers.

Objective 1. To extend the range of plants in flower available to growers for early spring marketing to include herbaceous perennials using minimal energy input.

Project number: PO 019a

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Report: Annual report, 31 March 2019

Previous report: None

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(or expected completion date):

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AUTHENTICATION

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

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Grower Summary

Headline

- To achieve flowering by week 14 and 16:
 - Apply heat from as late as mid-March for all of the species examined, except *Campanula persicifolia* 'Takion Blue' and *Gaura lindheimeri* 'Sparkle White'.
 - Apply heat from mid-January or mid-February to achieve flowering in week 14 in *C. persicifolia* 'Takion Blue'; from mid-February to achieve flowering in week 16.
 - *G. lindheimeri* 'Sparkle White' did not produce flowers by week 16.

Background

The Bedding and Pot Plant Centre (BPPC) has been established to address the needs of the industry via a programme of work to trial and demonstrate new product opportunities and practical solutions to problems encountered on nurseries. Knowledge transfer events including trial open days and study tours are also included in the programme.

The work programme is guided by a grower-led Management Group that includes members of the BPOA Technical Committee, and representatives from Baginton Nurseries, Coventry the host nursery for the BPPC, and growers representing both the bedding and pot plant sectors.

This is the Bedding and Pot Plant Centre report for:

Objective 1: *To extend the range of plants in flower available to growers for early spring marketing to include herbaceous perennials using minimal energy input.*

Summary

Research over a number of years has confirmed that high early spring light levels in some areas of the US and continental Europe allow the successful forcing of a range of perennials and these can then be marketed as seasonal colour in a similar manner to traditional bedding and pot plants. Under UK conditions, however, many species do not produce a marketable product without additional supplementary light, and unless there are special circumstances potential improved returns don't compensate for the installation and running costs of lighting. However, a limited range of species may be suitable for low energy forcing under UK conditions and these have been investigated in these trials.

There is an increasing trend, and interest among growers, to extend the herbaceous perennial season and product range so as to provide more flowering plants by early spring, ready for impulse sales. The objective of this trial was to identify perennials that may be produced

successfully under protection with minimal energy inputs, aiming to advance the natural marketing window. Six species were examined, applying heat from mid-January (Batch 1), mid-February (Batch 2) or mid-March (Batch 3), or maintaining frost protection only (Batch 4).

Seeds of six perennial species (*Campanula persicifolia* 'Takion Blue', *Gaura lindheimeri* 'Sparkle White', *Scabiosa japonica* var. *alpina* 'Ritz Blue', *Silene alpestris* 'Starry Dreams', *Arenaria montana* and *Geum coccineum* 'Koi') were sown into 104-cell trays in week 29 (21 July 2017) at Baginton Nurseries, Coventry and germinated at a minimum temperature of 15°C. Plants were transplanted (week 40) into black jumbo 6-packs and 1 L pots (Bulrush growing media, 15 mm peat, 25% Forest Gold, 2.5% clay + base fertiliser; Osmocote Exact High K, 5-6 m @ 2.5 g/L) and maintained under glass within the propagation area for two weeks to enable the plants to bulk up, and then moved into a polytunnel with frost protection (2°C, vent 4°C) in week 42 to provide a cold period. Plants were transferred to W.D. Smith & Sons (Battlesbridge, Essex) in week 50, where they were maintained under unheated glass with frost protection until treatments were applied. Plants were moved into heated glass (12°C, vent 15°C) in three batches (Batches 1-3), in weeks 2, 6 and 10, 2018, with Batch 4 remaining in unheated glass with frost protection only (2°C, vent 4°C) throughout the trial. Each plant species was represented within each batch, and half of each were available for plant growth regulator treatments; PGRs were applied as required to control stretch (**Table 1**).

Plants were monitored throughout the winter and assessed for number in flower, quality and height in weeks 14 and 16.

Table 1. Plant growth regulator application dates and dose rates

Treatment	Species	PGR	22/01/2018	20/02/2018
1	<i>Campanula persicifolia</i> 'Takion Blue'	Yes	Daminozide* 5 g/L	Daminozide* 5 g/L
2		No	-	-
3	<i>Gaura lindheimeri</i> 'Sparkle White'	Yes	Daminozide* 5 g/L	-
4		No	-	-
5	<i>Scabiosa japonica</i> var. <i>alpina</i> 'Ritz Blue'	Yes	Daminozide* 5 g/L	-
6		No	-	-
7	<i>Silene alpestris</i> 'Starry Dreams'	Yes	-	-
8		No	-	-
9	<i>Arenaria montana</i>	Yes	Paclobutrazol** 3 ml/L	Paclobutrazol** 3 ml/L
10		No	-	-
11	<i>Geum coccineum</i> 'Koi'	Yes	Daminozide* 5 g/L	-
12		No	-	-

* Daminozide as Dazide Enhance. **Paclobutrazol as Bonzi.

Batches of the species included in this trial that achieved flowering by weeks 14 and 16, with and without PGR application are summarised in **Table 2**.

Table 2. Summary effect of four heat treatments* (batches 1 to 4) with fully open flowers, with and without PGR application at the interim (week 14, 03/04/18) and final assessments (week 16, 18/04/2018)

Species	Week 14		Week 16	
	+ PGR	- PGR	+ PGR	- PGR
<i>Campanula persicifolia</i> 'Takion Blue'	0	1	1-2	1-2
<i>Gaura lindheimeri</i> 'Sparkle White'	0	0	0	0
<i>Scabiosa japonica</i> var. <i>alpina</i> 'Ritz Blue'	1-3	1-3	1-4	1-4
<i>Silene alpestris</i> 'Starry Dreams'	1-4	1-4	1-4	1-4
<i>Arenaria montana</i>	1-3	1-3	1-4	1-4
<i>Geum coccineum</i> 'Koi'	1-4	1-4	1-4	1-4

*Treatments: heating applied from week 2 (batch 1), week 6 (batch 2), week 10 (batch 3) or not at all (batch 4).

Campanula persicifolia 'Takion Blue' did produce flowers by week 14. PGR application was required to control plant height and prevent stretch, but caused some delay to flowering.

Gaura lindheimeri 'Sparkle White' did not achieve flowering by week 16 using the early heating regimes. However, buds were present in all batches, and there was potential to market the plants early although 'green'.

Scabiosa japonica var. *alpina* 'Ritz Blue' started to produce flowers as early as week 10, and flowers were present in all batches by week 14. However, plants would benefit from earlier sowing or provision of more warmth post-transplant to achieve bulkier plants.

Silene alpestris 'Starry Dreams' did produce flowers by weeks 14 and 16, with the first flowers present from week 2, in Batches 1-3, and with adjustments to scheduling such as earlier sowing or more heat prior to the cold period, bulkier plants could be produced that would be marketable earlier. However, tip burn developed in all treatments and whilst attractive, the plants were not considered to have the necessary impact to capture the attention of consumers.

Arenaria montana was in flower from week 10. However, it proved to be a very vigorous species, and growth was not sufficiently controlled with two applications of paclobutrazol (3 ml/L). Marketable plants may be produced for week 14 through adjustments to scheduling, for example lower temperature combined with earlier PGR application.

Geum coccineum 'Koi' produced flowers by week 10, and would have been marketable at this time had they bulked up sufficiently to achieve pot cover by this time. This variety flowers on

relatively short stems, and did not require PGR application. However, the *Geum* did appear to attract aphids, therefore growers will need to monitor crops closely.

Conclusions

The premise of this work was to produce plants in flower with minimal energy input such as heat and light. Many plants have critical vernalisation and photoperiod requirements to induce flowering, and such information is available for some but not all perennial species. Long day plants requiring >12 hour days are more likely to require supplementary, photoperiodic or night break lighting to induce flowering under short day conditions. Of the species examined here, it is known that *Campanula persicifolia* 'Takion Blue' and *Geum coccineum* 'Koi' are day neutral (will flower under any day length); all other species have been determined to require long days to initiate flowering. Careful selection of species in consideration of their requirements will enhance the prospects of achieving early spring flowering with minimal energy input.

The *Silene alpestris* 'Starry Dreams', *Scabiosa japonica* var. *alpina* 'Ritz Blue' and *Geum coccineum* 'Koi' require some attention to scheduling to bulk up plants for early marketing; for *Geum* in particular it would be possible to produce good quality plants for marketing earlier than week 14. This could include, for example, earlier seed sowing or allowing a longer period under heat prior to the cold period. Conversely, *Arenaria montana* was too vigorous for production under the parameters of this trial, and growth would need to be reduced through a combination of adjustments to scheduling and production temperature. *Gaura lindheimeri* 'Sparkle White' did not produce flowers by week 16, however plants would have been marketable 'green' prior to week 14. *Campanula persicifolia* 'Takion Blue' produced plants suitable for marketing by week 14 and 16, although PGRs were required to control growth and produce a consistent plant height.

- In summary, to achieve flowering by week 14 and 16:
 - Apply heat from as late as mid-March for all other species examined except *Campanula persicifolia* 'Takion Blue' and *Gaura lindheimeri* 'Sparkle White'.
 - Apply heat to 12°C from mid-January or mid-February to achieve flowering in week 14 in *C. persicifolia* 'Takion Blue'; from mid-February to achieve flowering in week 16.
 - *G. lindheimeri* 'Sparkle White' did not produce flowers by week 16, but was marketable 'in the green'.

Action points

- If there are opportunities for early impulse sales of flowering plant material, five of the six species examined may be brought into flower by weeks 14 and 16 with additional heat.
- The scheduling used in this trial may be amended to improve marketability:
 - Earlier sowing and a longer period of heat applied prior to the cold period would encourage bulking up in less vigorous species e.g. *Scabiosa japonica* var. *alpina* 'Ritz Blue', *Geum coccineum* 'Koi' and *Silene alpestris* 'Starry Dreams'.
- Trials should be carried out on different species and varieties on growers' own holdings prior to any large scale production.

Financial benefits

The objective of this trial was to advance flowering in a range of perennials to stimulate impulse purchases in early spring. This would increase sales opportunities during a marketing window traditionally filled with plants such as *Primula*, polyanthus, and *Viola*, and more recently with 'Senetti'. First marketed in Europe in 2001, 'Senetti' is a prime example of a new crop that has been brought to market that flowers at a time of year when there are fewer products available in flower and that now commands strong consumer demand each year. Whilst the overall value of UK 'Senetti' sales is not known, sales of 100,000 plants, with a trade price of around £2.00 - £2.50 per 2 L pot would generate a turnover of £250,000 – £300,000 where one did not previously exist.

It is estimated that for sales of perennials in flower in early spring, the trade price could be in the region of £1.00 - £1.25 (1 L pot), with sales of 100,000 plants generating £100,000 to £125,000. For comparison, perennials sold without flower may command £0.85 each, but demand would be less because of a lack of impact.

Science Section

Introduction

The Bedding and Pot Plant Centre (BPPC) has been established to address the needs of the industry via a programme of work to trial and demonstrate new product opportunities and practical solutions to problems encountered on nurseries. Knowledge transfer events including trial open days and study tours are also included in the programme.

The work programme is guided by a grower-led Management Group that includes members of the BPOA Technical Committee and representatives from Baginton Nurseries, Coventry the central host nursery for the BPPC. The agreed objectives for the Bedding and Pot Plant Centre, 2017-19 were:

Objective 1: To extend the range of plants in flower available to growers for early spring marketing to include herbaceous perennials using minimal energy input.

Objective 2: To evaluate the efficacy and phytotoxicity of a range of plant growth regulators (PGRs) either approved in the UK or in other European Countries on bedding and pot plants (spray and drench application).

Objective 3: To evaluate the efficacy and phytotoxicity of a range of plant growth regulators (PGRs) either approved in the UK or in other European Countries on bedding plant plugs (drench application) prior to transplant.

Objective 4: To evaluate the efficacy and phytotoxicity of a range of plant growth regulators (PGRs) (either approved in the UK or in other European Countries) and HDC P006 (adjuvant) on Poinsettia, and their effect on marketability.

This is the Bedding and Pot Plant Centre report for Objective 1.

Background

Research over a number of years has confirmed that high early spring light levels in some areas of the US and continental Europe allow the successful forcing of a range of perennials and these can then be marketed as seasonal colour in a similar manner to traditional bedding and pot plants. Under UK conditions, however, many species do not produce a marketable product without additional supplementary light, and unless there are special circumstances potential improved returns don't compensate for the installation and running costs of lighting. However, a limited range of species may be suitable for low energy forcing under UK conditions and these have been investigated in these trials.

There is an increasing trend and interest among growers to extend the growing season and product range using a range of seed / cutting raised perennials, grown under protection for marketing as early flowering spring plants for impulse sales in late March. Previous work in this area has included use of heat and light to control flowering to force perennials for early spring marketing (Fuller, 2007, Brough and Lambourne, 2009).

The previous trial carried out at the Bedding and Pot Plant Centre, completed in 2017, aimed for subjects to be marketable with flowers in weeks 13-14. Although none of the species were marketable as flowering plants, five varieties were at or close to flowering by week 14. *Scabiosa japonica* var. *alpina* 'Ritz Blue' and *Silene alpestris* 'Starry Dreams' both had open flowers by week 14'; *Campanula persicifolia* 'Takion Blue' was close to flowering. Earlier application of heat, for example from week 10 (instead of week 12), may have increased the number of flowers and the number of species with flower.

Although *Gaura lindheimeri* 'Sparkle White' suffered cold damage in the previous trial, it has no cold requirement and is reported to take six weeks to flower at 20°C (Cameron *et al.* 2000). UK trials achieved 85% flowering in ambient light, with no cold treatment, under glass heated to 15°C, vented at 18°C. Flowering was increased to 90%, 95% and 95% with cold treatments of 4, 8 and 12 weeks (4°C) respectively (Hawes, 2002).

Arenaria montana and *Geum coccineum* 'Cooky' were included in previous work (Fuller, 2007) as part of a trial carried out at Pillnitz, Germany which aimed to bring a range of perennials into flower by Valentine's Day. This trial concluded that minimal frost protection was required during the cooling phase (polythene tunnels would suffice) and produced better quality plants than those grown under glass in the majority of cases. After potting, plants were grown on under glass at 14°C, venting at 16°C to encourage rooting. Forcing took place from week 50 at the following temperatures: from week 50, 20°C, venting at 23°C, from week 51, 10°C, venting at 12°C; from week 1, 12°C, venting at 15°C. Treatments included supplementary (3000 lux, 20 hrs), photoperiodic (100 lux/m², 20 hrs) and ambient light conditions. *Geum coccineum* 'Cooky' flowered by Valentine's Day under ambient light, although the flowering stems were stretched. Breeding was under way at the time to produce shorter stemmed varieties; this variety also required vernalisation. *Geum coccineum* 'Koi' was selected for the 2017-18 trial, as it is a shorter variety than *G. c.* 'Cooky', that was likely to flower without additional light input and without the need for vernalisation.

Arenaria montana flowered earlier under supplementary lighting than periodic or ambient, but quality was better under ambient light, flowering from week 9-10. For *Scabiosa japonica* var. *alpina* 'Ritz Blue' supplementary lighting was necessary to produce flowers in weeks 9-10.

Six species were selected from the previous BPPC trial and from other work where there were indications that they may flower within the time frame and conditions proposed for this work. *Campanula glomerata* 'Acaulis', *Verbena rigida* (syn. *V. venosa*) and *Echinacea* 'Cheyenne Spirit' were not included in this trial as they either looked poor in a pot, performed badly or were unlikely to flower during the given timeframe. *Prunella grandiflora* 'Freeland Blue' and *Coreopsis grandiflora* 'Presto' were also not taken forward in this trial.

The trials in 2016/17 produced a number of findings that were incorporated in the trial plan for 2017/18. Week 27 was too early to sow seed for transplanting in week 40, but seeds sown in week 29 produced plug plants at a suitable development stage for transplanting by this time. In addition, one of the species, *Sphaeralcea coccinea*, experienced very poor germination (<10%) from both week 27 and week 29 (2016) sowings, and was removed from the trial. Species were identified that had started to flower or were close to flowering by week 14, 2017; and *Verbena rigida* and *Prunella grandiflora* were eliminated from the 2017/18 trial as unsuitable species; the plant list was revised to include additional species considered more likely to flower in early spring with minimal energy input. The growing media specification and nutrition were revised on the basis of the 2016/17 trial, with a more open growing media used and an Osmocote formulation selected for greater longevity.

This trial included selected perennial subjects that may be produced under protection, either glass or polytunnels, with minimal energy inputs, aiming to advance the natural marketing window of products grown without protection.

Aims and objectives

Objective 1: To evaluate the effect of environment (temperature) on flowering of a range of up to six herbaceous perennials.

Objective 2: To determine the effect on flowering of forcing from early January, February and March of a range of up to six herbaceous perennials.

Objective 3: To evaluate the effect of plant growth regulator application on plant quality and flowering in three sequential (January, February and March) batches of a range of six herbaceous perennials.

Objective 4: To provide growers with advice on the cultivation of promising species for early spring marketing in flower.

Methods and materials

Site and crop production details

The trial was conducted from July 2017 until April 2018. A diary of key events is given in **Table 3**. Seeds of six perennial species obtained from Moles Seeds UK Ltd and Jelitto Staudensamen GmbH (**Table 4**) were sown into 104-cell trays (eight trays per species) in week 29 (21 July 2017), and allowed to germinate in the propagation house at Baginton Nurseries, Coventry (minimum temperature 15°C). The sowing rate was two seeds per cell, except for *Campanula persicifolia* 'Takion Blue', which was sown at three seeds per cell. Plants were transplanted (week 40) into black jumbo 6-packs and 1 L pots (Bulrush growing media, 15 mm peat, 25% Forest Gold, 2.5% clay + base fertiliser; Osmocote Exact High K, 5-6 m @ 2.5 g/L) and maintained under glass within the propagation area for two weeks to enable the plants to bulk up (**Figure 1**), and then moved into a polytunnel with frost protection (2°C, vent 4°C) in week 42 to provide a cold period. Plants were transferred to W.D. Smith & Sons (Battlesbridge, Essex) in week 50, where they were maintained under unheated glass with frost protection until treatments were applied (**Figure 1**).

Temperature and humidity were recorded every 30 minutes throughout the trial using TinyTag data loggers, which were placed at plant height within the trial area (**Appendix 1**).

Treatments

Plants were moved into heated glass (12°C, venting at 15°C) in three batches (Batches 1-3), in weeks 2, 6 and 10, 2018, with Batch 4 remaining in unheated glass with frost protection only (2°C, venting at 4°C) throughout the trial (**Table 5**). Each plants species was represented within each batch, and half of each were available for plant growth regulator treatments (PGR); PGRs were applied as required to control stretch.



Figure 1. Trial layout at Baginton Nursery (left) and W.D. Smith & Sons (right)

Table 3. Diary of events

Date	Week no.	Action
21/07/2017	29	Seeds sown
04/10/2017	40	Plugs transplanted and trial set-up. Plants kept under glass to bulk up
18/10/2017	42	Plants moved to polytunnel with frost protection only
13/12/2017	50	Plants transferred to WD Smith & Son
11/01/2018	2	Batch 1 moved into heated area
05/02/2018	6	Batch 2 moved into heated area
07/03/2018	10	Batch 3 moved into heated area
18/04/2018	16	End of trial

Table 4. Plant species used in the overwintered perennials trial, 2017/18

Treatment	Plant species	Photoperiod response*
1	<i>Campanula persicifolia</i> 'Takion Blue'	Day neutral
2	<i>Gaura lindheimeri</i> 'Sparkle White'	Long day
3	<i>Scabiosa japonica</i> var. <i>alpina</i> 'Ritz Blue'	Long day
4	<i>Silene alpestris</i> 'Starry Dreams'	Long day
5	<i>Arenaria montana</i>	Long day
6	<i>Geum coccineum</i> 'Koi'	Day neutral

*Day neutral plants flower under any day length. Long day plants flower in days >12 hours, with a critical day length for the species. Facultative long day plants flower under any day length, but faster under long days. Short day/long day plants flower earlier if plants have been exposed to a period of short days followed by a period of long days.

Table 5. Trial treatment list

Batch	Treatments	
	Species	PGR application
Batches 1-4	<i>Campanula persicifolia</i> 'Takion Blue'	Yes
		No
	<i>Gaura lindheimeri</i> 'Sparkle White'	Yes
		No
	<i>Scabiosa japonica</i> var. <i>alpina</i> 'Ritz Blue'	Yes
		No
	<i>Silene alpestris</i> 'Starry Dreams'	Yes
		No
	<i>Arenaria montana</i>	Yes
		No
	<i>Geum coccineum</i> 'Koi'	Yes
		No

Plants were arranged in four batches, with batches 1-3 transferred into heated glass in either mid-January, mid-February or mid-March. Batch 4 remained under glass with frost protection only. Each batch was comprised of plants from each of the six species; species were transplanted into pots and packs.

Plant growth regulator (PGR) applications

This trial was carried out early in the year, with heat applied to crops under ambient, low light levels, the natural consequence of which is weak, stretched plants of unmarketable quality for some varieties. Plant growth regulator treatments were applied to species as required to prevent stretch and improve plant quality (**Table 6**). The decision to apply was taken by the grower. *Silene alpestris* 'Starry Dreams' did not require any PGR treatments.

Table 6. Plant growth regulator application dates and dose rates.

Treatment	Species	PGR	22/01/2018	20/02/2018
1	<i>Campanula persicifolia</i> 'Takion Blue'	Yes	Daminozide* 5 g/L	Daminozide* 5 g/L
2		No	-	-
3	<i>Gaura lindheimeri</i> 'Sparkle White'	Yes	Daminozide* 5 g/L	-
4		No	-	-
5	<i>Scabiosa japonica</i> var. <i>alpina</i> 'Ritz Blue'	Yes	Daminozide* 5 g/L	-
6		No	-	-
7	<i>Silene alpestris</i> 'Starry Dreams'	Yes	-	-
8		No	-	-
9	<i>Arenaria montana</i>	Yes	Paclobutrazol** 3 ml/L	Paclobutrazol** 3 ml/L
10		No	-	-
11	<i>Geum coccineum</i> 'Koi'	Yes	Daminozide* 5 g/L	-
12		No	-	-

* Daminozide as Dazide Enhance. **Paclobutrazol as Bonzi.

Pest and disease monitoring

Plants were monitored for pest and disease throughout the trial. The following pesticide treatments were applied:

Botrytis control:

- Iprodione (as Rovral, 33 g/100 L water), applied to all plants, 12 January 2018.
- Cyprodinil + fludioxonil (as Switch @ 70 g/100 L water), applied to batch 1 only, 15 January 2018.
- Iprodione (as Rovral, @ 67 g/100 L water), applied to batches 3 and 4 only, 28 February 2018.

Whitefly control:

- Thiacloprid (as Calypso 50 ml/100 L water), applied to batches 1 and 2 only, 12 February 2018.

Trial design and statistical analysis

Treatments (two PGR treatments, and six species) were arranged in a fully randomised plot design with three replicate blocks. Plots consisted of two 6-packs and 12 x 1 L pots (total 24 plants per plot); a total of 3456 plants (144 plots), 576 plants per species.

Results were examined by ANOVA with use of Duncan's multiple range test to separate treatments.

Assessments

Inspections and assessments are summarised in **Table 9** and below:

Pre-transplant: germination assessment (proportion of plants per tray with germinated seeds), plant quality (**Table 7**), root quality (**Table 8**, ten plugs per tray) and plant height.

Pre-batch movement: plant quality (**Table 7**), number of visible buds, buds showing colour, number of open flowers and plant height.

Weekly inspections: pest and disease, flower development, PGR requirement.

Interim and final assessments: weeks 14 and 16: plant quality (**Table 7**), number of visible buds, buds showing colour, number of open flowers and plant height.

Table 7. Plant quality scores

Score	Definition
0	Dead
1	Very poor quality
2	Poor quality
3	Good quality, no flower
4	Good quality saleable some flower / close to flower / buds
5	Excellent quality, 90% or more with flower

Table 8. Root development scores

Score	Definition
0	No root development
1	Rooting in up to 25% of plug
2	Rooting in 26 - 50% of plug
3	Rooting in 51 - 75% of plug
4	Rooting in 76 – 100% of plug

Table 9. Summary of overwintered perennials trial inspections and assessments, 2017/18

Date	Week no.	Action	Assessment
21/07/2017	29	Seeds sown	-
08/08/2017	32	Inspection	Pest and disease
26/08/2017	34	Inspection	Pest and disease
06/09/2017	36	Inspection	Pest and disease
04/10/2017	40	Pre-transplant	Plant quality, plant height, germination assessment and root development
18/10/2017	42	Inspection	Pest and disease
01/11/2017	44	Inspection	Pest and disease
14/11/2017	46	Inspection	Pest and disease
13/12/2017	50	Inspection	Pest and disease
11/01/2018	2	Interim assessment	Plant height, plant quality and flower development
24/01/2018	4	Inspection	Pest and disease, flower development

05/02/2018	6	Interim assessment	Plant height, plant quality and flower development
19/02/2018	8	Inspection	Pest and disease, flower development
07/03/2018	10	Interim assessment	Plant height, plant quality and flower development
21/03/2018	12	Inspection	Pest and disease, flower development
03/04/2018	14	Interim assessment	Plant quality, plant height, flower development
10/04/2018	15	Inspection	Pest and disease, flower development
18/04/2018	16	Final assessment	Plant quality, plant height, flower development

Results

Temperature

Frost protection (2°C, venting at 4°C) was applied during the cold treatment at Baginton Nurseries, and to Batch 4 at W.D. Smith. Glasshouse temperature was set at 12°C (venting at 15°C) for forcing. (**Appendix 1**).

Pre-transplant assessment

Plants were assessed on 4 October 2017 (week 40), prior to transplant. Germination was good, with >90% germination for all species except for *Campanula persicifolia* 'Takion Blue', which was slower to germinate (**Table 10**). Plant and root quality was generally good, with sufficient germination to select plants with high quality scores for transplant.

Table 10. Germination assessment, 4 October 2017 (week 40)

Species	Germination (%)
<i>Campanula persicifolia</i> 'Takion Blue'	82
<i>Gaura lindheimeri</i> 'Sparkle White'	97
<i>Scabiosa japonica</i> var. <i>alpina</i> 'Ritz Blue'	97
<i>Silene alpestris</i> 'Starry Dreams'	93
<i>Arenaria montana</i>	100
<i>Geum coccineum</i> 'Koi'	98

Interim and final assessments

Interim and final assessments were completed in weeks 14 (03.04.18) and 16 (18.04.18). Data and images are presented per species in **Appendices 2–7**, with general observations tabulated in **Appendix 8**, a summary of plants in flower for January to March (weeks 3, 6 and 10) in **Appendix 9**. Findings are summarised below.

Campanula persicifolia 'Takion Blue' (**Appendix 2, Appendix 8 and Appendix 9**)

Plant height and PGR effect

Plants were taller in pots than packs for all batches, including both plant growth regulator (PGR) treatments. By week 16, plants were significantly shorter in Batch 1 than all other batches, for pots ($p = 0.004$) and packs ($p = 0.019$). Daminozide (two applications) had a significant effect in controlling plant height ($p < .001$, pots and packs). For this species, the application of PGRs produced sturdier plants that were easier to handle and had darker foliage, however there was some delay in flowering (**Figure 2**).

Flowering

The first fully open flowers were recorded in week 14, in Batch 1 only (heating from week 2), in pots and packs, in treatments where PGR had not been applied. By week 16, flowers were also present in Batch 2 (heating from week 6), in pots and packs, in treatments with and without PGR. Buds were present on plants in all treatments in both week 14 and 16. The data indicates significant differences in the number of buds present across all batches ($p < .001$) in week 14, and significantly fewer buds present in Batch 1, than Batches 2-4 ($p < .001$) by week 16. This is due to slower bud development in Batches 2-4 as they had less time in the heated glasshouse, and by week 16 the buds had opened into flowers.

Plant quality

Plant quality was significantly better ($p < .001$) in Batch 1, primarily due to the presence of flowers, improving marketability. Plants in Batch 4 that had not been treated with PGR were soft. Root quality was good in all batches throughout.

Marketability for this species is dependent on a pack or tray of healthy plants of even height, with a fully open flower and buds present (**Figure 3**).

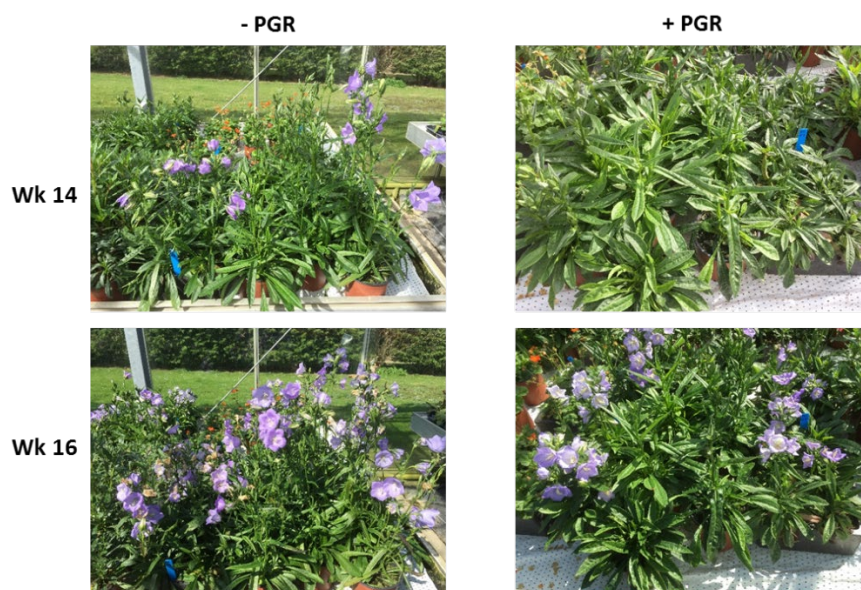


Figure 2. *C. persicifolia* 'Takion Blue' Batch 1, +/- PGR. Whole plot images including pots and packs.



Figure 3. *C. persicifolia* 'Takion Blue', Batch 2, + PGR (week 16)

Gaura lindheimeri 'Sparkle White' (Appendix 3, Appendix 8 and Appendix 9)

Plant height and PGR effect

Plants were shorter in packs than pots across all treatments. Plants were significantly shorter (or close to) in Batch 4 in week 14 (pots, $p = 0.051$; packs, $p = 0.007$) and week 16 (packs, $p < .001$), while plants were significantly taller in week 16, Batch 2 ($p = 0.013$) than all other batches. One PGR treatment was applied to the *Gaura lindheimeri* 'Sparkle White'. In week 14, plants were significantly shorter in all batches (pots) except for Batch 3; there was no significant effect of the PGR treatment in any batches by week 16, or in packs (week 14). By week 16, plants were too large and would have benefited from earlier marketing as 'green'.

Flowering

Gaura lindheimeri 'Sparkle White' did not produce any open flowers throughout the trial, and the first buds were recorded in Batches 1-3 week 16 (with and without PGR, pots and packs).

Plant quality

Plant quality was negatively affected by *Botrytis*. Although no flowers were produced plants were generally very vigorous. Root quality was good in all batches throughout the trial, but too full in the pot/pack by week 16.

Earlier sowing or more warmth early on may have advanced flowering. However, these plants would have been ready for marketing as 'green' prior to week 16. The plants were suitable for marketing in both pots and packs.

Scabiosa japonica var. *alpina* 'Ritz Blue' (**Appendix 4, Appendix 8 and Appendix 9**)

Plant height and PGR effect

There was no consistent difference in plant height either between batches, or pots and packs or PGR treatments (weeks 14 and 16). The single application of daminozide appears to have had a significant effect on plants in packs (week 14, $p = 0.013$; week 16, $p = 0.032$), however overall plants were significantly taller and daminozide appears to have promoted growth.

Flowering

Fully open flowers were recorded in very low numbers in week 10, in Batch 1 (pack) and Batch 4 (pot). By week 14 flowers were present in all batches, except for Batch 4 (packs), and significantly more flowers were present in Batch 1 (pots, $p = 0.006$; packs $p = 0.013$). Similarly by week 16, significantly more flowers were present in Batch 1 than any other batch (pots and packs, $p < 0.001$), and fewest in Batch 4. As with other species, by week 16 the number of buds was reduced as flowers opened.

Plant quality

For *Scabiosa*, plant quality was greater in plants that received more heat. By week 16, there was no significant difference in plant quality across all treatments. Root quality was good in all batches throughout. Plants were generally small early in the trial, and were slow to achieve pack cover, and may have benefitted from earlier sowing or a longer prior of warmth post-transplant to aid bulking up (**Figure 4**).



Figure 4. *Scabiosa japonica* var. *alpina* 'Ritz Blue', Batch 1 (left) and Batch 4 (right), week 10, -PGR

Silene alpestris 'Starry Dreams' (Appendix 5, Appendix 8 and Appendix 9)

Plant height and PGR effect

No PGRs were applied to this species. Plants were consistently larger in pots than packs, and significantly larger in Batches 1 and 2 in week 14 (pots, $p < .001$) and week 16 (pots and packs, $p < .001$); in week 14 packs in Batch 4 were significantly smaller than in all other batches ($p < .001$). By week 16, the number of plants with buds had increased, particularly in Batches 3 and 4, although the number of plants with flowers remained relatively low.

Flowering

The first fully open flowers were recorded in low numbers (pots and packs) in week 2 (11 January 2018) in Batches 1 to 3 and in week 10 (7 March 2018) in Batch 4. Flower numbers increased, with significantly more flowers in Batch 1 (pots, $p = 0.004$) in week 14, and in Batches 1 and 2 in week 16 ($p < .001$), approaching full flowering.

Plant quality

Plant quality was generally good, although this species was slow to bulk up and struggled to consistently achieve pot and pack cover by week 14, particularly plants in Batches 3 and 4. This variety of *Silene* does have a tendency for tip burn, which can detract from marketability. Root quality was good in all batches throughout.

Arenaria montana (Appendix 6, Appendix 8 and Appendix 9)

Plant height and PGR effect

Arenaria montana proved a very vigorous species, and growth was too great for the scheduling and pot/pack size combination used for the purpose of this trial. The two applications of the PGR paclobutrazol (3 ml/L) applied to the *Arenaria* were insufficient to control growth at the timings used for this trial. PGR application earlier in production may have been more effective.

Flowering

The earliest fully open flowers were recorded in week 10 in Batch 1 (with and without PGR, pots and packs). All plants in Batches 1 and 2 (with and without PGR, pots and packs) were in flower by week 14; significantly more than in Batches 3 and 4 ($p < .001$). In week 16 all plants in all batches and treatments were in flower. Plants in Batch 4 had significantly fewer flowers than all other batches ($p < .001$), suggesting that scheduling for this variety could be managed through production under cooler temperatures, but with earlier PGR application to control plant height.

Plant quality.

Root quality and plant quality were good in all batches throughout. However, the vigorous nature of the species meant that plants hung over the sides of the pots/packs, with a potential negative impact on quality at marketing.

Geum coccineum 'Koi' (Appendix 7, Appendix 8 and Appendix 9)

Plant height and PGR effect

One PGR application was made to this species. There was no consistent difference in plant height in pots compared with packs in week 14, however by week 16 plants in pots were consistently larger. There was no significant effect of the PGR application on plant height or flowering. In week 14, plants were significantly shorter in Batch 4 than all other batches (pots, $p = 0.005$), but although there were significant differences in plant height in week 14 (packs, $p = 0.004$) and week 16 (pots, $p = 0.004$; packs $p = 0.010$) there was no clear relationship with batch number, and therefore application of heat.

Flowering

The first fully open flowers were recorded in week 6 (5 February 2018) in Batch 1, when there were two pots in total with open flowers; by week 10 (7 March 2018) an average of 11 and 10 pots and packs respectively had fully open flowers. By week 14, flowers were present in the majority of pots and packs, although for packs there were significantly fewer present in Batch

1 ($p = 0.008$). The converse was true for buds, where for packs there were significantly more present in Batch 1 ($p = 0.008$) than all other batches. By week 16, there was no significant difference in the number of flowers or buds present across all batches and treatments.

Plant quality

Root quality was good in all batches throughout. There were no significant differences in plant quality. However, the Geum did suffer from aphid in all batches. Had plants been sufficiently bulky to achieve pot cover by week 10, then they would have been marketable.

Summary

Batches of the species included in this trial that achieved flowering by weeks 14 and 16, with and without PGR application are summarised in **Table 11**.

Table 11. Summary effect of four heat treatments* (batches 1 to 4) with fully open flowers, with and without PGR application at the interim (week 14, 03/04/18) and final assessments (week 16, 18/04/2018)

Species	Week 14		Week 16	
	+ PGR	- PGR	+ PGR	- PGR
<i>Campanula persicifolia</i> 'Takion Blue'	0	1	1-2	1-2
<i>Gaura lindheimeri</i> 'Sparkle White'	0	0	0	0
<i>Scabiosa japonica</i> var. <i>alpina</i> 'Ritz Blue'	1-3	1-3	1-4	1-4
<i>Silene alpestris</i> 'Starry Dreams'	1-4	1-4	1-4	1-4
<i>Arenaria montana</i>	1-3	1-3	1-4	1-4
<i>Geum coccineum</i> 'Koi'	1-4	1-4	1-4	1-4

*Treatments: heating applied from week 2 (batch 1), week 6 (batch 2), week 10 (batch 3) or not at all (batch 4).

Discussion

Campanula persicifolia 'Takion Blue' (**Appendix 2**, **Appendix 8** and **Appendix 9**) did produce flowers by week 14. PGR application was required to control plant height and prevent stretch, but caused some delay to flowering.

Gaura lindheimeri 'Sparkle White' (**Appendix 3**, **Appendix 8** and **Appendix 9**) did not achieve flowering by week 16 without additional inputs. However, buds were present in all batches, and there was potential to market the plants early although 'green'.

Scabiosa japonica var. *alpina* 'Ritz Blue' (**Appendix 4**, **Appendix 8** and **Appendix 9**) started to produce flowers as early as week 10, and flowers were present in all batches by week 14.

However, plants would benefit from earlier sowing, or provision of more warmth post-transplant to achieve bulkier plants.

Silene alpestris 'Starry Dreams' (**Appendix 5, Appendix 8 and Appendix 9**) did produce flowers by weeks 14 and 16, with the first flowers present from week 2, in Batches 1-3, and with adjustments to scheduling such as earlier sowing or more heat prior to the cold period, bulkier plants could be produced that would be marketable earlier. However, tip burn developed in all treatments and whilst attractive, the plants were not considered to have the necessary 'wow' factor to capture the attention of consumers.

Arenaria montana (**Appendix 6, Appendix 8 and Appendix 9**) was in flower from week 10. However, it proved to be a very vigorous species, and growth was not sufficiently controlled with two applications of paclobutrazol (3 ml/L). Marketable plants may be produced for week 14 through adjustments to scheduling, for example lower temperature combined with earlier PGR application.

Geum coccineum 'Koi' (**Appendix 7, Appendix 8 and Appendix 9**) produced flowers by week 10, and would have been marketable at this time had they bulked up sufficiently to achieve pot cover by this time. This variety flowers on relatively short stems, and did not require PGR application. However, the *Geum* did appear to attract aphid, therefore growers will need to monitor crops closely.

Conclusions

The premise of this work was to produce plants in flower with minimal energy input such as heat and light. Many plants have critical vernalisation and photoperiod requirements to induce flowering, and such information is available for some but not all perennial species. Long day plants requiring >12 hour days are more likely to require supplementary, photoperiodic or night break lighting to induce flowering under short day conditions. Of the species examined here, it is known that *Campanula persicifolia* 'Takion Blue' and *Geum coccineum* 'Koi' are day neutral (will flower under any day length); all other species have been determined to require long days to initiate flowering. Careful selection of species in consideration of their requirements will enhance the prospects of achieving early spring flowering with minimal energy input.

The *Silene alpestris* 'Starry Dreams', *Scabiosa japonica* var. *alpina* 'Ritz Blue' and *Geum coccineum* 'Koi' require some attention to scheduling to bulk up plants for early marketing; for *Geum* in particular it would be possible to produce good quality plants for marketing earlier than week 14. This could include, for example, earlier seed sowing or allowing a longer period under heat prior to the cold period. Conversely, *Arenaria montana* was too vigorous for

production under the parameters of this trial, and growth would need to be reduced through a combination of adjustments including to scheduling and production temperature. *Gaura lindheimeri* 'Sparkle White' did not produce flowers by week 16, however plants would have been marketable 'green' prior to week 14. *Campanula persicifolia* 'Takion Blue' produced plants suitable for marketing by week 14 and 16, although PGRs were required to control growth and produce a consistent plant height.

- To achieve flowering by week 14 and 16:
 - Apply heat from as late as mid-March for all species except *Campanula persicifolia* 'Takion Blue' and *Gaura lindheimeri* 'Sparkle White'.
 - Apply heat from mid-January or mid-February to achieve flowering in week 14 in *C. persicifolia* 'Takion Blue'; from mid-February to achieve flowering in week 16.
 - *G. lindheimeri* 'Sparkle White' did not produce flowers, but was marketable 'in the green'.

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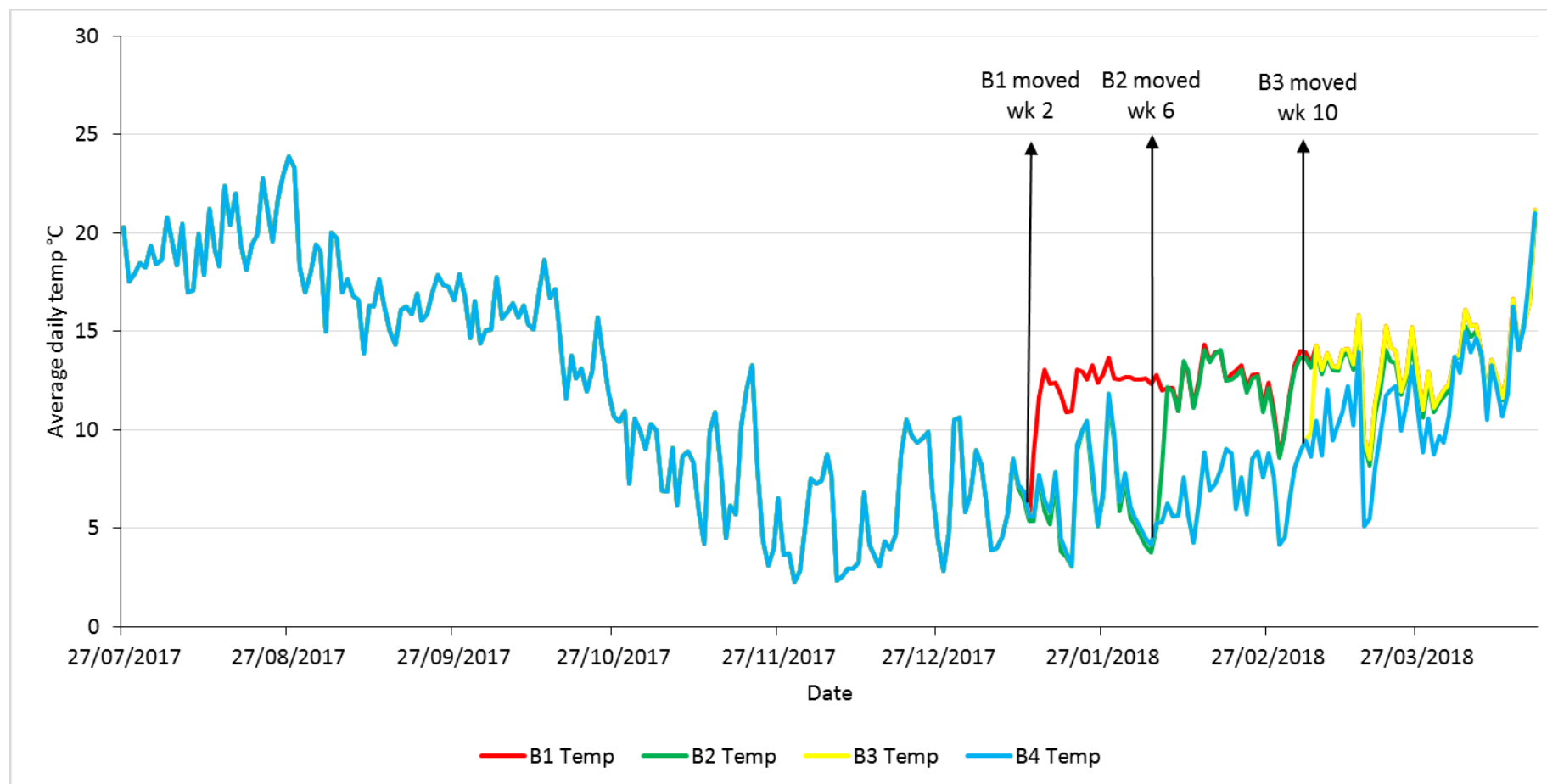
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Appendices

Appendix 1. Overwintered perennials: glasshouse and polytunnel temperature. Seeds were germinated and grown on in the propagation house at Baginton Nurseries, Baginton, Coventry until 2 weeks post-transplant, when they were moved into a frost protected polytunnel (week 42). Plants were transferred to W.D. Smith, Battlesbridge, Essex in week 50, where they remained in a frost-protected glasshouse until transfer into the treatment area in three batches in weeks 2 (B1), 6 (B2) and 10 (B3). A fourth batch remained in the frost protected area (B4).



Appendix 2a. *Campanula persicifolia* 'Takion Blue'. Interim and final assessments, weeks 14 (03.04.18) and 16 (18.04.18). Average plant height, average number of plants per plot with fully open flowers, average number of plants per plot with buds and average plant quality scores; scale of 0-5 (0 = dead, 1 = very poor quality, 2 = poor quality, 3 = good quality, no flower, 4 = good quality saleable some flower / close to flower / buds, 5 = excellent quality, 90% or more with flower).

PGR application		Interim assessment								Final assessment							
		Plant height (mm)		Plant quality		No in flower		No in bud		Plant height (mm)		Plant quality		No in flower		No in bud	
		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Batch 1	Pots	180.3	286.7	3.3	3.8	0.0	2.0	9.7 ^b	7.3 ^b	225.8 ^a	339.2 ^a	4.0 ^c	4.7 ^c	5.0 ^b	8.0 ^b	5.0 ^a	2.0 ^a
	Packs	140.0	150.8	3.5	3.3	0.0	2.0	8.7 ^b	7.0 ^b	171.7 ^a	162.5 ^a	4.0 ^c	4.0 ^c	4.3 ^c	6.0 ^c	5.0 ^a	3.0 ^a
Batch 2	Pots	201.3	416.3	3.7	4.0	0.0	0.0	12.0 ^c	12.0 ^c	282.9 ^b	530.4 ^b	3.0 ^b	4.0 ^b	0.0 ^a	2.7 ^a	12.0 ^b	9.3 ^b
	Packs	126.3	371.7	3.7	4.0	0.0	0.0	11.0 ^c	11.7 ^c	194.2 ^b	402.5 ^b	3.3 ^b	4.0 ^b	0.3 ^b	3.7 ^b	11.0 ^b	8.3 ^b
Batch 3	Pots	188.8	350.4	3.7	3.7	0.0	0.0	8.0 ^b	9.3 ^b	327.1 ^b	546.7 ^b	3.0 ^a	3.0 ^a	0.0 ^a	0.0 ^a	12.0 ^b	12.0 ^b
	Packs	131.7	286.7	3.3	3.7	0.0	0.0	5.3 ^b	10.7 ^b	216.7 ^b	399.2 ^b	3.0 ^a	3.0 ^a	0.0 ^a	0.0 ^a	12.0 ^c	12.0 ^c
Batch 4	Pots	131.7	295.7	3.0	3.0	0.0	0.0	0.7 ^a	4.7 ^a	317.5 ^b	490.0 ^b	3.0 ^a	3.0 ^a	0.0 ^a	0.0 ^a	11.3 ^b	12.0 ^b
	Packs	107.9	243.8	3.0	3.3	0.0	0.0	0.0 ^a	1.3 ^a	189.2 ^b	371.7 ^b	3.0 ^a	3.0 ^a	0.0 ^a	0.0 ^a	11.3 ^c	11.7 ^c
STATISTICAL ANALYSIS OF DIFFERENCES BETWEEN BATCHES (i.e. heating treatments)																	
Pots	s.e.d.	ns		ns		ns		0.993		30.18		0.118		1.344		0.565	
	2.290							69.6		0.272		3.099		1.303			
	<.001							0.004		<.001		0.004		<.001			
Packs	s.e.d.	ns		ns		ns		1.155		37.45		0.118		0.312		0.589	
	2.663							86.37		0.272		0.719		1.359			
	<.001							0.019		<.001		<.001		<.001			
In the table above, indices indicate significant differences. Values with the same indices within a treatment are not significantly different. ns = no significant differences.																	
STATISTICAL ANALYSIS OF DIFFERENCES DUE TO PGR APPLICATION																	
PGR application		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Pots	s.e.d.	21.44		ns		ns		n. sig		17.08		0.083		0.391		0.792	
	100.06		39.39							0.192		0.901		0.344			
	<.001		<.001							<.001		0.007		0.007			
Packs	s.e.d.	19.35		ns		ns		0.486		22.17		ns		0.493		0.449	
	44.61		51.12					1.137		1.035							
	<.001		<.001					0.035		0.042							

Appendix 2b. *Campanula persicifolia* 'Takion Blue'. Interim and final assessments, weeks 14 and 16 2018.

Batch 1

Batch 2

Batch 3

Batch 4

Wk 14



Wk 16



Appendix 3a. *Gaura lindheimeri* 'Sparkle White'. Interim and final assessments, weeks 14 and 16 2018. Average plant height, average number of plants per plot with fully open flowers, average number of plants per plot with buds and average plant quality scores; scale of 0-5 (0 = dead, 1 = very poor quality, 2 = poor quality, 3 = good quality, no flower, 4 = good quality saleable some flower / close to flower / buds, 5 = excellent quality, 90% or more with flower).

PGR application		Interim assessment								Final assessment							
		Plant height (mm)		Plant quality		No in flower		No in bud		Plant height (mm)		Plant quality		No in flower		No in bud	
		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Batch 1	Pots	204.6	247.5	3.3	3.0	0.0	0.0	0.0	0.0	301.7	304.6	3.0	3.0	0.0	0.0	1.3	1.7
	Packs	167.9	239.2	3.3	3.0	0.0	0.0	0.0	0.0	231.7	268.8	3.0	2.7	0.0	0.0	1.0 ^a	1.3 ^a
Batch 2	Pots	208.8	280.0	3.0	3.0	0.0	0.0	0.0	0.0	463.3	430.8	3.0	3.0	0.0	0.0	4.3	4.3
	Packs	197.5	217.9	3.3	3.0	0.0	0.0	0.0	0.0	231.7	268.8	3.0	3.0	0.0	0.0	3.7 ^b	5.3 ^b
Batch 3	Pots	205.8	247.9	3.0	2.3	0.0	0.0	0.0	0.0	352.9	350.4	3.0	3.0	0.0	0.0	3.7	1.3
	Packs	191.7	194.6	3.0	3.0	0.0	0.0	0.0	0.0	283.3	288.3	3.0	3.0	0.0	0.0	3.0 ^a	1.0 ^a
Batch 4	Pots	147.5	194.2	3.0	3.0	0.0	0.0	0.0	0.0	263.8	331.5	3.0	3.0	0.0	0.0	0.0	0.0
	Packs	107.5	141.7	3.0	3.0	0.0	0.0	0.0	0.0	172.1	220.0	3.0	3.0	0.0	0.0	0.0 ^a	0.0 ^a

STATISTICAL ANALYSIS OF DIFFERENCES BETWEEN BATCHES (i.e. heating treatments)

Pots	s.e.d.	22.46	ns	nf	nf	37.43	ns	nf	nf
	l.s.d.	51.79				86.32			
	F pr	0.051				0.013			
Packs	s.e.d.	18.99	ns	nf	nf	22.97	ns	nf	1.047
	l.s.d.	43.78				52.96			2.416
	F pr	0.007				<.001			0.015

In the table above, indices indicate significant differences. Values with the same indices within a treatment are not significantly different.
ns = no significant differences. nf = no flowers

STATISTICAL ANALYSIS OF DIFFERENCES DUE TO PGR APPLICATION

PGR application		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Pots	s.e.d.	10.21	ns	nf	nf	ns	ns	nf	nf	ns	ns	nf	nf	ns	ns
	l.s.d.	23.55													
	F pr	0.001													
Packs	s.e.d.	ns	ns	nf	nf	ns	ns	nf	nf	ns	ns	nf	nf	ns	ns
	l.s.d.														
	F pr														

Appendix 3b. *Gaura lindheimeri* 'Sparkle White'. Interim and final assessments, weeks 14 and 16 2018.

Batch 1

Batch 2

Batch 3

Batch 4

Wk 14



Wk 16



Appendix 4a. *Scabiosa japonica* var. *alpina* 'Ritz Blue'. Interim and final assessments, weeks 14 and 16 2018. Average plant height, average number of plants per plot with fully open flowers, average number of plants per plot with buds and average plant quality scores; scale of 0-5 (0 = dead, 1 = very poor quality, 2 = poor quality, 3 = good quality, no flower, 4 = good quality saleable some flower / close to flower / buds, 5 = excellent quality, 90% or more with flower).

PGR application		Interim assessment								Final assessment							
		Plant height (mm)		Plant quality		No in flower		No in bud		Plant height (mm)		Plant quality		No in flower		No in bud	
		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Batch 1	Pots	60.4	52.6	3.8 ^b	4.0 ^b	4.0 ^b	5.0 ^b	7.3	6.3	72.1 ^b	71.3 ^b	4.0	4.0	9.3 ^d	11.0 ^d	2.0 ^a	0.3 ^a
	Packs	49.2 ^a	42.8 ^a	3.6	3.6	2.3 ^b	3.3 ^b	8.3 ^a	8.3 ^a	73.8 ^{ab}	57.1 ^{ab}	4.0	4.0	9.3 ^d	7.7 ^d	2.0 ^a	4.0 ^a
Batch 2	Pots	46.7	52.5	4.0 ^b	4.0 ^b	1.3 ^a	2.0 ^a	9.7	10.0	67.1 ^b	77.9 ^b	4.0	4.0	6.7 ^c	8.7 ^c	5.0 ^b	3.3 ^b
	Packs	47.9 ^a	47.1 ^a	3.7	4.0	1.0 ^a	1.3 ^a	10.3 ^b	10.7 ^b	70.8 ^b	71.3 ^b	4.0	4.0	6.0 ^c	4.7 ^c	5.3 ^b	7.3 ^b
Batch 3	Pots	51.7	52.9	3.7 ^b	3.7 ^b	0.3 ^a	0.0 ^a	9.3	9.0	74.2 ^b	80.8 ^b	4.0	4.0	3.3 ^b	5.0 ^b	8.0 ^c	6.7 ^c
	Packs	58.8 ^b	52.9 ^b	3.7	3.7	0.3 ^a	0.7 ^a	9.0 ^a	8.3 ^a	70.8 ^b	71.3 ^b	4.0	4.0	2.3 ^b	2.0 ^b	8.7 ^c	10.0 ^c
Batch 4	Pots	37.5	46.7	3.0 ^a	3.0 ^a	0.3 ^a	0.0 ^a	7.3	8.3	58.3 ^a	57.5 ^a	3.7	3.3	1.3 ^a	0.3 ^a	10.3 ^d	10.7 ^d
	Packs	44.6 ^a	42.1 ^a	3.0	3.0	0.0 ^a	0.0 ^a	6.7 ^a	8.7 ^a	57.5 ^a	49.3 ^a	3.3	4.0	0.3 ^a	1.7 ^a	9.0 ^c	10.3 ^c

STATISTICAL ANALYSIS OF DIFFERENCES BETWEEN BATCHES (i.e. heating treatments)

Pots	s.e.d.		0.2375	0.957		5.44		6.87	0.677
	l.s.d.	ns	0.5478	2.208	ns	12.55	ns	1.585	1.561
	F pr		0.011	0.006		0.035		<.001	<.001
Packs	s.e.d.	3.472		0.667	0.645	5.33		0.486	0.612
	l.s.d.	8.006	ns	1.537	1.489	12.3	ns	1.121	1.412
	F pr	0.033		0.013	0.012	0.026		<.001	<.001

In the table above, indices indicate significant differences. Values with the same indices within a treatment are not significantly different.
ns = no significant differences.

STATISTICAL ANALYSIS OF DIFFERENCES DUE TO PGR APPLICATION

PGR application		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Pots	s.e.d.														
	l.s.d.	ns		ns		ns		ns		ns		ns		ns	
	F pr														
Packs	s.e.d.	1.214						2.60							0.493
	l.s.d.	2.800	ns		ns		ns	5.99		ns		ns			1.137
	F pr	0.013						0.032							0.010

Appendix 4b. *Scabiosa japonica* var. *alpina* 'Ritz Blue'. Interim and final assessments, weeks 14 and 16 2018.

Batch 1

Batch 2

Batch 3

Batch 4

Wk 14



Wk 16



Appendix 5a. *Silene alpestris* 'Starry Dreams'. Interim and final assessments, weeks 14 and 16 2018. Average plant height, average number of plants per plot with fully open flowers, average number of plants per plot with buds and average plant quality scores; scale of 0-5 (0 = dead, 1 = very poor quality, 2 = poor quality, 3 = good quality, no flower, 4 = good quality saleable some flower / close to flower / buds, 5 = excellent quality, 90% or more with flower). **No PGRs were applied to the *Silene*.**

PGR application		Interim assessment								Final assessment							
		Plant height (mm)		Plant quality		No in flower		No in bud		Plant height (mm)		Plant quality		No in flower		No in bud	
		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Batch 1	Pots	164.7 ^b	184.8 ^b	4.0	4.0	2.7 ^b	4.0 ^b	9.0 ^c	7.3 ^c	235.0 ^c	264.6 ^c	4.3 ^b	4.3 ^b	11.0 ^c	10.0 ^c	1.0 ^a	2.0 ^a
	Packs	130.8 ^c	132.1 ^c	3.7 ^b	3.7 ^b	1.7	1.7	9.3 ^c	10.0 ^c	217.5 ^{bc}	192.9 ^{bc}	4.0	4.3	9.7 ^c	9.7 ^c	2.0 ^a	2.3 ^a
Batch 2	Pots	174.6 ^b	149.6 ^b	4.0	4.0	1.3 ^a	2.0 ^a	10.7 ^c	8.7 ^c	269.6 ^b	250.0 ^c	4.0 ^b	4.3 ^b	10.0 ^c	10.3 ^c	2.0 ^a	1.7 ^a
	Packs	151.7 ^d	155.4 ^d	4.0 ^c	4.0 ^c	1.0	1.0	11.0 ^c	10.7 ^c	255.8 ^c	235.4 ^c	4.0	4.3	10.7 ^c	10.7 ^c	1.3 ^a	1.3 ^a
Batch 3	Pots	106.3 ^a	98.8 ^a	4.0	4.0	1.0 ^a	0.3 ^a	4.0 ^b	3.3 ^b	201.7 ^b	201.7 ^b	4.0 ^b	4.0 ^b	3.3 ^b	3.0 ^b	8.7 ^b	9.0 ^b
	Packs	114.2 ^b	85.8 ^b	4.0 ^c	4.0 ^c	1.0	1.0	4.3 ^b	3.0 ^b	190.0 ^b	164.2 ^b	4.0	4.0	3.0 ^b	3.3 ^b	9.0 ^b	8.3 ^b
Batch 4	Pots	76.7 ^a	80.4 ^a	3.0	3.0	0.0 ^a	0.5 ^a	1.0 ^a	0.3 ^a	156.8 ^a	142.5 ^a	3.3 ^a	3.7 ^a	0.3 ^a	1.0 ^a	11.7 ^c	11.0 ^c
	Packs	66.7 ^a	60.4 ^a	3.0 ^a	3.0 ^a	0.3	0.7	0.7 ^a	1.0 ^a	132.5 ^a	118.3 ^a	3.3	3.7	0.3 ^a	1.0 ^a	11.7 ^c	10.7 ^c
STATISTICAL ANALYSIS OF DIFFERENCES BETWEEN BATCHES (i.e. heating treatments)																	
Pots	s.e.d.	10.99				0.589		0.717		14.42		0.167		0.677		0.677	
	l.s.d.	25.34		ns		1.359		1.653		33.25		0.384		1.561		1.567	
	F pr	<.001				0.004		<.001		<.001		0.005		<.001		<.001	
Packs	s.e.d.	6.67		0.118				0.687		17.73				0.898		0.943	
	l.s.d.	16.39		0.272		ns		1.585		40.88		ns		2.070		2.174	
	F pr	<.001		<.001				<.001		<.001				<.001		<.001	
In the table above, indices indicate significant differences. Values with the same indices within a treatment are not significantly different. ns = no significant differences.																	

Appendix 5b. *Silene alpestris* 'Starry Dreams'. Interim and final assessments, weeks 14 and 16 2018.

Batch 1

Batch 2

Batch 3

Batch 4

Wk 14



Wk 16



Appendix 6a. *Arenaria montana*. Interim and final assessments, week 14 and 16 2018. Average plant height, average number of plants per plot with fully open flowers, average number of plants per plot with buds and average plant quality scores; scale of 0-5 (0 = dead, 1 = very poor quality, 2 = poor quality, 3 = good quality, no flower, 4 = good quality saleable some flower / close to flower / buds, 5 = excellent quality, 90% or more with flower).

PGR application		Interim assessment								Final assessment							
		Plant height (mm)		Plant quality		No in flower		No in bud		Plant height (mm)		Plant quality		No in flower		No in bud	
		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Batch 1	Pots	225.4	230.8	4.0	4.0	12.0 ^c	12.0 ^c	0.0 ^a	0.0 ^a	243.3	252.5	4.3	4.0	12.0	12.0	0.0	0.0
	Packs	212.5	193.8	4.0	4.3	12.0 ^c	12.0 ^c	0.0 ^a	0.0 ^a	246.3	191.3	4.5	4.7	12.0	12.0	0.0	0.0
Batch 2	Pots	229.2	230.4	4.3	4.0	12.0 ^c	12.0 ^c	0.0 ^a	0.0 ^a	262.9	235.8	4.0	4.0	12.0	12.0	0.0	0.0
	Packs	205.0	186.3	4.3	4.0	12.0 ^c	12.0 ^c	0.0 ^a	0.0 ^a	158.6	230.0	4.3	4.0	12.0	12.0	0.0	0.0
Batch 3	Pots	237.1	250.0	4.0	4.0	8.3 ^b	7.0 ^b	3.7 ^b	5.0 ^b	231.7	221.3	4.3	4.3	12.0	12.0	0.0	0.0
	Packs	196.7	243.3	4.0	4.0	6.3 ^b	5.7 ^b	5.7 ^b	6.3 ^b	233.3	206.7	4.3	4.3	12.0	12.0	0.0	0.0
Batch 4	Pots	185.4	199.2	3.7	3.7	0.0 ^a	0.3 ^a	12.0 ^c	11.7 ^c	219.2	217.5	4.3	4.3	12.0	12.0	0.0	0.0
	Packs	161.7	176.7	3.3	3.3	0.0 ^a	0.0 ^a	12.0 ^c	11.3 ^c	191.7	210.8	4.3	4.3	12.0	12.0	0.0	0.0

STATISTICAL ANALYSIS OF DIFFERENCES BETWEEN BATCHES (i.e. heating treatments)

Pots	s.e.d.			0.7817	0.7817				
	l.s.d.	ns	ns	1.8027	1.8027	ns	ns	ns	ns
	F pr			<.001	<.001				
Packs	s.e.d.			0.540	0.589				
	l.s.d.	ns	ns	1.245	1.359	ns	ns	ns	ns
	F pr			<.001	<.001				

In the table above, indices indicate significant differences. Values with the same indices within a treatment are not significantly different.
ns = no significant differences.

STATISTICAL ANALYSIS OF DIFFERENCES DUE TO PGR APPLICATION

PGR application		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Pots	s.e.d.														
	l.s.d.	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
	F pr														
Packs	s.e.d.														
	l.s.d.	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
	F pr														

Appendix 6b. *Arenaria montana*. Interim and final assessments, week 14 and 16 2018.

Batch 1

Batch 2

Batch 3

Batch 4

Wk 14



Wk 16



Appendix 7a. *Geum coccineum* 'Koi'. Interim and final assessments, weeks 14 and 16 2018. Average plant height, average number of plants per plot with fully open flowers, average number of plants per plot with buds and average plant quality scores; scale of 0-5 (0 = dead, 1 = very poor quality, 2 = poor quality, 3 = good quality, no flower, 4 = good quality saleable some flower / close to flower / buds, 5 = excellent quality, 90% or more with flower).

PGR application		Interim assessment								Final assessment							
		Plant height (mm)		Plant quality		No in flower		No in bud		Plant height (mm)		Plant quality		No in flower		No in bud	
		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Batch 1	Pots	201.3 ^b	146.7 ^b	3.9	4.3	11.0	9.3	1.0	2.0	236.7 ^{ab}	217.5 ^{ab}	4.0	4.0	11.7	10.7	0.3	1.3
	Packs	144.8 ^a	127.9 ^a	3.8	4.0	10.7 ^a	10.0 ^a	1.3 ^b	2.0 ^b	148.8 ^a	139.2 ^a	4.0	4.0	10.0	9.3	2.0	2.7
Batch 2	Pots	189.2 ^b	193.8 ^b	4.0	4.0	11.7	11.3	0.3	0.7	268.3 ^b	228.8 ^b	4.0	4.0	11.3	11.0	0.7	1.0
	Packs	207.5 ^b	167.5 ^b	4.0	4.0	12.0 ^b	10.7 ^b	0.0 ^a	1.3 ^a	232.5 ^{bc}	199.2 ^{bc}	4.0	4.0	11.0	10.0	1.0	2.0
Batch 3	Pots	182.5 ^b	151.7 ^b	4.0	4.0	11.0	12.0	1.0	0.0	257.9 ^b	235.4 ^b	4.0	4.0	12.0	12.0	0.0	0.0
	Packs	182.9 ^b	171.3 ^b	4.0	4.0	12.0 ^b	12.0 ^b	0.0 ^a	0.0 ^a	235.8 ^c	217.5 ^c	4.0	4.0	12.0	12.0	0.0	0.0
Batch 4	Pots	110.4 ^a	129.6 ^a	3.7	3.8	11.3	10.7	0.7	1.3	192.1 ^a	195.8 ^a	4.0	4.0	11.7	11.3	0.0	0.0
	Packs	125.4 ^a	130.8 ^a	4.0	4.0	12.0 ^b	12.0 ^b	0.0 ^a	0.0 ^a	176.7 ^{ab}	164.2 ^{ab}	4.0	4.0	12.0	12.0	0.0	0.0

STATISTICAL ANALYSIS OF DIFFERENCES BETWEEN BATCHES (i.e. heating treatments)

Pots	s.e.d.	13.71	ns	ns	ns	17.05	ns	ns	ns
	l.s.d.	31.61				39.31			
	F pr	0.005				0.041			
Packs	s.e.d.	13.0	ns	0.391	0.391	19.87	ns	ns	ns
	l.s.d.	29.98				45.82			
	F pr	0.004				0.01			

In the table above, indices indicate significant differences. Values with the same indices within a treatment are not significantly different.
ns = no significant differences.

STATISTICAL ANALYSIS OF DIFFERENCES DUE TO PGR APPLICATION

PGR application		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Pots	s.e.d.	ns		ns		ns		ns		ns		ns		ns	
	l.s.d.														
	F pr														
Packs	s.e.d.	ns		ns		ns		ns		ns		ns		ns	
	l.s.d.														
	F pr														

Appendix 7b. *Geum coccineum* 'Koi'. Interim and final assessments, weeks 14 and 16 2018.

Batch 1

Batch 2

Batch 3

Batch 4

Wk 14



Wk 16



Appendix 8. Summary of general observations on plant species, Week 14 and 16

Species		Week	General	Batch 1	Batch 2	Batch 3	Batch 4
1	<i>Campanula persicifolia</i> 'Takion Blue'	14	Flowers in Batch 1. Good pot/pack cover in all batches. Good plant quality. Good rooting in all batches.	Fully open flowers present; more in pot than packs. PGR treatment appears to have delayed flowering. PGR treatment very effective, plants potentially too short and hard.	No flowers present. Buds in all batches, but none showing colour. PGR treatment very effective, plants potentially short and slightly hard.	No flowers. Buds present in all batches, but none showing colour. PGR treatment very effective, plants potentially short and slightly hard.	No flowers. Buds present in all batches; none showing colour. PGRs very effective, plants potentially short and slightly hard. Plants not treated with PGRs were soft.
		16	Fully open flowers present in batches 1 and 2. Good pot/pack cover in all batches. Plants in packs shorter than those in pots in all treatments, with or without PGR.	Flowers in all plots, but early flowers fading. Delay to flowering by PGR application	Fully open flowers present. PGR application delayed flowering; generally flowers only in treatments without PGRs. However, this treatment produced the best quality pack; one flower, good plant quality and appropriate, uniform, height.	No flowers. PGR treatment effective. Good quality plants	No flowers, but buds present. PGR treatment effective and prevented stretch. Plants without PGRs soft.
2	<i>Gaura lindheimeri</i> 'Sparkle White'	14	No flowers in any plots. A number of losses due to <i>Botrytis</i> . Plants shorter in packs than pots. PGR not effective.	No flowers. PGRs did not appear to be effective. Vigorous plants, good rooting.	No flowers. PGRs did not appear to be effective. Vigorous plants, good rooting.	No flowers. PGRs did not appear to be effective. Plants robust. Weaker rooting in this batch, and plants less vigorous.	No flowers. Pot cover achieved.
		16	Plants too large to sell, but were marketable earlier in trial. Roots too full in pot, growing medium growing out quickly. Earlier sowing or more heat prior to cold treatment may have produced earlier flowers. PGRs not effective.	No flowers but buds present. PGR not effective.	No flowers but buds present. PGR not effective.	No flowers but buds present. PGR not effective.	No flowers, but early buds present. PGR not effective. Plants shorter than in other batches.
3	<i>Scabiosa japonica</i> var. alpine 'Ritz Blue'	14	Flowers present batches 1-3. Good root development in all batches. Potential to sow earlier or provide warmth for longer after transplant to bulk plants.	Flowers present in all plots, with most in batch 1. Good flowering height. Some plants did not achieve pot/pack cover.	Flowers present in all plots. Pot/pack cover not consistently achieved.	Flowers present, but few and not full flowering. Pot/pack cover not consistently achieved.	No flowers, pot cover generally not achieved.
		16	One PGR application, and not effective. Fully open flower in all batches. Potential to sow earlier or provide warmth for longer after transplant bulk plants.	Fully open flowers in all plots, pots and packs. New buds present. Pot / pack cover improved since week 14. Good plant quality.	Not all plants with fully open flowers, but marketable. New buds present. Pot / pack cover improved since week 14. Good plant quality.	Not all plants with fully open flowers, but marketable. New buds present. Pot / pack cover improved since week 14. Good plant quality.	Limited number of fully open flowers. New buds present. Pot / pack cover generally not quite achieved, but improved since week 14. Otherwise good plant quality. Plants shorter than Batches 1-3.

4	<i>Silene alpestris</i> 'Starry Dreams'	14	Flowers present in all batches, but fewer in batches 2 & 3 & 4. Tip burn in all batches. Good root development. Potential to sow earlier or provide warmth for longer after transplant to produce bulkier plants. PGRs were not applied to any batches.	Fully open flowers in all plots, many more buds present.	Fewer flowers than Batch 1. Pot/pack cover better than Batch 3.	Plants more compact, but few flowers. Pot/pack cover not achieved by some plants.	Compact plants, few flowers. Pot/pack cover achieved by some plants.
		16	Tip burn in all batches. Although Batches 1 and 2 were in full flower, the plants didn't really have the 'wow' factor. No PGRs applied to any batches.	Fully open flowers approaching full flowering. Full pot and pack cover.	Plants similar to Batch 1. Fully open flowers approaching full flowering. Full pot and pack cover.	Plants coming into flower, with more present than in week 14. Many buds present. Good pot and pack cover.	Flowers starting to open, but in limited numbers. Many buds present. Plants shorter than Batches 1-3.
5	<i>Arenaria montana</i>	14	Flowers in Batches 1-3. Plants very vigorous.	Full flower, plants too large. PGRs not effective; earlier application may be required.	Full flower, plants too large. PGRs not effective; earlier application may be required.	Flowers present in all plots, approaching full flower. Plants appeared more upright and compact.	Flowers in bud, some with colour. Good plant quality, plants more compact than Batches 1-3, with more appropriate growth for pot.
		16	All batches: many flowers open, plants very vigorous and overgrown. PGR: two applications (3 ml/L) of paclobutrazol did not control growth. Earlier PGR application may have been more effective, or later sowing to produce smaller plants.	PGR not effective. All plants with fully open flowers.	PGR not effective. All plants with fully open flowers.	PGR not effective. All plants with fully open flowers.	Flowers present.
6	<i>Geum coccineum</i> 'Koi'	14	Flowers in all Batches. Aphids in all four Batches.	Full flowers in all Batches. Dead flowers as they had been flowering for a number of weeks. Good pot cover in most plants.	Full flowers in all Batches. Dead flowers as they had been flowering for a number of weeks. Good pot cover in most plants.	Full flowers in all Batches. Faded flowers present. Pot cover generally not achieved.	Flowers present in all plots, but pot/pack cover not achieved. Compact plants.
		16	Better pot and pack cover generally improved. Potential to improve pot and pack cover by sowing earlier or providing warmth for a longer period prior to cold treatment. One PGR application only, which had no effect on plant height. Plants in packs shorter than pots.	Full flowers in all batches. New buds present. Good plant quality	Plants still flowering, pot cover improved. Buds present. Good plant quality	Plants still flowering, pot cover improved. No new buds present. Good plant quality	Fully open flowers present, pot cover improved. No new buds present. Good plant quality.

Appendix 9. Average number of plants in flower, in pots and packs, with and without PGR application, week 2 (11 January 2018), week 6 (05 February 2018) and week 10 (7 March 2018). Species: *C.p.* = *Campanula persicifolia* 'Takion Blue'; *G.l.* = *Gaura lindheimeri* 'Sparkle White'; *S.j.* = *Scabiosa japonica* var. *alpina* 'Ritz Blue'; *S.a.* = *Silene alpestris* 'Starry Dreams'; *A.m.* = *Arenaria montana* and *G.m.* = *Geum coccineum* 'Koi'. Batches moved into heat: Batch 1, week 2; Batch 2, week 6; Batch 3, week 10; Batch 4 remained in unheated, frost protected area throughout the trial.

T	Species	PGR	Week 2								Week 6								Week 10							
			Batch 1		Batch 2		Batch 3		Batch 4		Batch 1		Batch 2		Batch 3		Batch 4		Batch 1		Batch 2		Batch 3		Batch 4	
			Pot	Pack	Pot	Pack	Pot	Pack	Pot	Pack	Pot	Pack	Pot	Pack	Pot	Pack	Pot	Pack	Pot	Pack	Pot	Pack	Pot	Pack	Pot	Pack
1	<i>C.p.</i>	Yes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2		No	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	<i>G.l.</i>	Yes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4		No	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	<i>S.j.</i>	Yes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	-	-	-	-	0.3	-
6		No	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	<i>S. a</i>	Yes	0.7	-	0.3	0.3	0.7	0.3	-	-	1.7	0.7	-	0.7	0.3	0.7	-	-	2.0	0.3	0.7	1.3	0.3	1.3	0.3	0.3
8		No	-	0.3	0.3	1.0	-	0.3	-	-	0.3	-	0.7	1.0	-	-	-	-	0.3	-	1.0	1.0	-	0.7	0.7	-
9	<i>A.m.</i>	Yes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.7	2.3	-	-	-	-	-	-
10		No	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.7	4.3	-	-	-	-	-	-
11	<i>G.c.</i>	Yes	-	-	-	0.3	-	0.3	-	0.3	1.0	2.7	-	0.3	0.3	0.7	0.7	0.7	10.7	10.3	8.7	10.3	4.3	4.7	3.7	3.7
12		No	-	-	0.3	-	-	-	0.3	0.3	2.0	2.7	0.3	-	-	3.3	0.3	0.3	9.3	8.0	9.3	10.7	3.3	2.3	3.0	2.3

