Project title:	The Bedding and Pot Plant Centre – new product opportunities for bedding and pot plant growers. Objective 4: To extend the marketing season for coloured varieties of pot-grown Hellebore to include the months prior to Christmas through cool treatments.
Project number:	PO 019a
Project leader:	Dr Jill England, ADAS Boxworth
Report:	Annual report, 31 March 2018
Previous report:	None
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Date project commenced:	1 April 2017
Date project completed (or expected completion date):	31 March 2019

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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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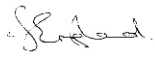
Senior Horticulture Consultant

ADAS

Signature  Date 31 March 2018

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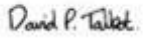
Signature  Date 31 March 2018

Report authorised by:

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CONTENTS

Grower Summary

Headline

- A cold treatment from mid-August advanced flowering in Hellebore ‘Anna’s Red’, ‘Madame Lemonnier’, ‘Paradenia’, ‘Penny’s Pink’ and ‘Royal Emma’, and advanced bud development in ‘Anna’s Red’ and ‘Royal Emma’.
- A cold treatment from mid-September advanced flowering in ‘Madame Lemonnier’ and ‘Paradenia’, and advanced bud development in ‘Molly’s White’, ‘Penny’s Pink’ and ‘Royal Emma’.
- Flowering of ‘Molly’s White’ was not advanced by either cold treatment.
- ‘Anna’s Red’ and ‘Paradenia’ were too tall, based on a height specification of 20-30cm.
- The cost benefit of using cold storage to advance flowering in Hellebores is estimated at 66p-£1.85 per plant (excluding labour costs).

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 4: *To extend the marketing season for coloured varieties of pot-grown Hellebore to include the months prior to Christmas through cool treatments.*

Summary

The market for Hellebore as pot plants has increased in recent years as new seed and micro-propagated varieties have become available. Previously, only white varieties have been marketed prior to the New Year, but new English bred pink and red varieties are now available that may be manipulated to flower before Christmas by subjecting plants to cold treatments.

A trial was run from April to December 2017 to see if it was possible to bring coloured varieties into flower before Christmas.

Forty plug plants of six micro-propagated Hellebore varieties (**Table 1**) were transplanted into 1.5L terracotta coloured plastic pots in week 16, and established within a polythene tunnel until week 21, when they were moved outdoors.

Table 1. Hellebore varieties used in the pre-Christmas production trial, 2017

Variety No.	Variety	Supplier	Breeder
1	'Anna's Red'	Exceptio bv	Rodney Davey
2	'HGC Madame Lemonnier'	Heuger	Heuger
3	'Molly's White'	Exceptio bv	Rodney Davey
4	'Paradenia'	Heuger	Heuger
5	'Penny's Pink'	Exceptio bv	Rodney Davey
6	'Royal Emma'	Just Must Perennials	Thierry van Paemel

Fifteen plants of each variety were subjected to a six-week cold store treatment (2°C, 12 hour day/night, 100 watt incandescent light) from 16 August (week 33, CS1) with an additional fifteen plants of each variety subjected to another six-week cold store treatment from 13 September (week 37, CS2). After the cold store treatment, both sets of plants were left to acclimatise outdoors before being moved under heated glass in week 44. The plants were monitored for bud and flower development, and a final assessment for flowering, plant height and plant quality was completed in week 51.

For **'Anna's Red'** no flowers or buds were recorded in the outdoor and indoor controls prior to week 51 when the first coloured buds were recorded. In treatment CS1, buds showing colour were recorded from week 45 through to week 51, with the first flowers recorded from week 46, earlier than for treatment CS2, where bud development had only just commenced.

For **'Madame Lemonnier'** no buds showing colour or flowers were recorded in the outdoor control until the final assessment in week 51, buds showing colour were recorded on one plant only in the indoor control prior to week 48. 'Madame Lemonnier' produced the earliest buds showing colour (CS1, week 42) than any other variety. Although flowers and buds showing colour were recorded in both the CS1 and CS2 treatments from week 45, more were produced and earlier in plants that had undergone the cold treatment from mid-August (CS1). Both treatments CS1 and CS2 advanced flower and bud production.

'Molly's White' was slower to produce buds and flowers than all the other varieties throughout this trial. No fully open flowers and minimal buds were recorded in the control treatments (weeks 45 to 51, inclusive). Although more flowers and buds showing colour were recorded

for plants that had undergone treatment CS1 than CS2, numbers were low for both throughout the trial.

For '**Paradenia'** although buds showing colour were recorded in both control treatments from week 45 (one plant in each), no flowers had opened by week 51. Buds showing colour were also recorded from week 45 for plants that underwent both cold treatments, however the flowers opened three weeks earlier than plants that underwent treatment CS1 (from week 45) than CS2 (from week 48).

For **'Penny's Pink'** no flowers were recorded in the control treatments, up to and including week 51. Prior to week 48, buds showing colour were recorded on one plant in the outdoor control only, after which numbers started to increase in both control treatments. More open flowers were recorded and earlier in CS1 (week 46) than in CS2 (week 48).

For **'Royal Emma'** no open flowers were recorded either in the outdoor or indoor control treatments throughout the trial (weeks 45-51). Open flowers were recorded in CS1 from week 46, and in all fifteen plants in week 48. For CS2, the number of buds with colour increased between weeks 48 and 51, but the main flush of flower on these plants did not appear prior to the end of the trial in week 51. Both treatments CS1 and CS2 did therefore advance bud and flower production compared with the control treatments, but the effect was more pronounced in those plants that had undergone the earlier cold treatment (CS1).

Plant quality was generally not affected by the cold treatments; the exceptions were 'Anna's Red' and 'Paradenia' which were stretched by both cold store treatments. Flower colour had stared to fade in 'Penny's Pink' and 'Anna's Red', likely due to the relatively warm glasshouse temperature.

Considering plant height, for all varieties, plants that had been subjected to the cold treatments were taller compared with those from the outdoor control treatment. Plants from the indoor control were generally only slightly taller than the outdoor control. This suggests that the cold treatments exerted the greatest influence on plant height. We are not aware of specific height specifications for Hellebore, but would expect 20-30 cm to be reasonable for cost effective transport and distribution on Danish trolleys; if using this parameter the height of the 'Anna's Red' and 'Paradenia' would not have been commercially acceptable. Many imported Hellebores from the continent have their foliage removed to expose the flower buds, so foliage height is not an issue at marketing.

In summary, flower buds had initiated naturally prior to the cold treatments, the treatments then advanced flowering for most of the varieties examined in this trial. However, the response appears to be variety dependent; the cold treatments did not advance the flowering of 'Molly's

White' for example compared with the outdoor control and had a detrimental effect on the quality of 'Anna's Red' and 'Paradenia' in terms of plant height. Flower colour and plant height were both affected by glasshouse temperature in some varieties; cooler glasshouse temperatures favour stronger flower colour and more compact plants.

In time, Hellebore breeding using traits from species that naturally flower before Christmas may result in coloured varieties that will flower before Christmas without cold treatments.

Recommended cold storage treatments to advance flowering in the varieties included in this trial are provided in **Table 2**.

Table 2. Recommended cold store treatments to advance flower production in Hellebores

Treatment	Variety
Mid-August	'Anna's Red', 'Madame Lemonnier', 'Penny's Pink', 'Royal Emma'
Mid-September	'Madame Lemonnier'
No cold store treatment*	'Molly's White', 'Paradenia'

*These varieties either did not respond to cold treatments, or lost quality

Financial benefits

This work with Hellebores will potentially broaden the range of plants in flower for the pre-Christmas marketing window to compliment Poinsettia, given appropriate variety selection for key house plant attributes (such as flowers facing upwards and attractive foliage as well as flowers). Consumers have the option to purchase Hellebores during this period, display them as a house plant and then subsequently plant them in the garden rather than disposing of them at the end of the season (as they would for Poinsettia).

Sold as pot plants in flower, some Hellebore varieties can demand higher retail prices with a 10% premium over green plants. Current retail prices for some of the varieties used in this trial include: *Helleborus* 'Emma' and *H*. 'Penny's Pink', £13.50 (1.5 L); *H.* 'Anna's Red' £12.49 – £19.99 (1.5 L); *H*. 'Madame Lemonnier', £14.44 (2 L), from various outlets.

Based on the retail price range for *H*. 'Anna's Red' in a 1.5 L pot, the grower could receive in the region of £5.20 to £8.33 per plant in the natural flowering season. By marketing this product in flower before Christmas it is considered that a premium of 10% may be achievable. This would be a new product line, and a hypothetical wholesale value of 50,000 plants would be estimated at £286,000 to £458,150.

The operating cost for a cold store has been calculated at £21.35/m^2 (Brown, 2003). This was calculated as the average annual cost to build and run a cold store when spread over a ten year pay-back period, and excludes costs associated with any building the store may be situated within). The cost of cold storage per plant (1.5 L pot, 15 cm diameter, 36 plants /m^2)

ranges between 15p and 59p, depending on the number shelves used, for example if using Danish trolleys (**Table 3**).

Hellebore growers would need to set the projected extra income against the associated costs of operating (or hiring) their own cold store at 2˚C for six weeks at current energy costs, and would need to include associated costs such as the labour cost to transfer plants to and from the cold store.

For the examples provided, the cost benefit of using cold storage to advance flowering in Hellebores is estimated at 66p - £1.85 per plant (excluding labour costs).

Table 3. Cost of cold storage treatment per plant.

Number of shelves	Cost of cold storage / m^2 (£)*	No plants / m^{2**}	Cold storage cost / plant (£)***
1	21.35	36	0.59
2	21.35	72	0.30
3	21.35	108	0.20
4	21.35	144	0.15

*HNS113 – the feasibility of using low temperature storage as a scheduling aid in nursery stock production. Figure represents the average annual cost to build and run a cold store, spread over a ten year pay-back period, excluding the cost of any building the store may be situated within. **Based on 1.5 L pots, 15 cm diameter, 36 plants/m^2. *** Figure does not include labour costs for moving plants to and from the coldstore.

Action points

- If customer height specifications allow, and a suitable price premium can be achieved, consider subjecting Hellebores to the following cold storage schedule to advance flowering:

Parameter	Treatment
Duration	Six weeks
Temperature	2°C
Day length	12 hour day / night
Lighting	100 watt incandescent light

Mid-August – ‘Anna’s Red’, ‘Madame Lemonnier’, ‘Penny’s Pink’, ‘Royal Emma’

Mid-September – ‘Madame Lemonnier’

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 were 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, 2017-18 were:

Objective 1: To evaluate a range of plant growth regulators (PGRs) either approved in the UK or in other European Countries for use on bedding and pot plants (spray and drench application).

Objective 2: To evaluate a range of products alone or in combination, to increase the success rate and reduce rooting time when striking un-rooted cuttings. This is a continuation of work carried out in 2016.

Objective 3: To evaluate plant nutrition, water quality, irrigation regime and environment as possible causes of necrotic spotting and associated symptoms in susceptible *Verbena* varieties. This is a continuation of work carried out in 2016.

Objective 4: To extend the marketing season for coloured varieties of pot-grown Hellebore to include the months prior to Christmas through cool treatments.

Objective 5: To evaluate the shelf life performance of micro-propagated Hellebores produced as pot plants for pre-Christmas marketing.

Objective 6: To evaluate a range of plant growth regulators (PGRs) and fungicides either approved in the UK or in other European countries for spray application on Poinsettia.

This is the Bedding and Pot Plant Centre report for Objective 4.

Background

The market for Hellebore as pot plants has increased in recent years as new seed and micro-propagated cultivars have become available. Previously, only white cultivars have been marketed prior to Christmas, but new English bred pink and red varieties are now available that may be manipulated to flower before Christmas by subjecting plants to cold treatments. This work has been developed from an idea based on the work of Christaens *et al* (2012) and Richardson *et al* (1974).

Project objectives

Objective 4. To extend the marketing season for coloured varieties of pot-grown Hellebore to include the months prior to Christmas through cool treatments.

Methods and materials

Site and crop production details

The Hellebore trial was carried out between April and December 2017. Forty plug plants of six micro-propagated Hellebore varieties (**Table 4**) were delivered to Baginton Nurseries in week 15, transplanted into 1.5 L terracotta coloured pots (week 16), and placed within a polythene tunnel in a randomised block design (10 plants/plot, four replications) until week 21. Growing media was supplied by Bulrush Horticulture (70% Bulrush peat, 30% Forest Gold; Nutricote 100 day (16-10-10, 2 kg/m3), Plantacote 12 month (18-06-12, 2 kg/m3), Base (15-10-20, 0.5 kg/m3), Add-N (0.3 kg/m3), Lime/Dolodust (4.5 kg/m3)). The trial was then moved outside onto a hardstanding area, with green shade netting overhead for protection. The plants were provided with overhead irrigation and temperature and humidity were recorded every 30 minutes using a Tinytag data logger.

Table 4. Hellebore varieties used in the pre-Christmas production trial, 2017

Variety No.	Variety	Supplier	Breeder
1	‘Anna’s Red’	Exceptio bv	Rodney Davey
2	‘HGC Madame Lemonnier’	Heuger	Heuger
3	‘Molly’s White’	Exceptio bv	Rodney Davey
4	‘Paradenia’	Heuger	Heuger
5	‘Penny’s Pink’	Exceptio bv	Rodney Davey
6	‘Royal Emma’	Just Must Perennials	Thierry van Paemel

All plants were transported to ADAS Boxworth in week 32, where they were set down on a shaded (green shade netting) standing out area. Fifteen plants of each variety were subjected to a six-week cold store treatment (2°C, 12 hour day / night, 100 watt incandescent light) from

16 August (week 33, CS1). Plants were set down on the floor in a randomised block design with five plants per plot (**Figure 1**). They were watered overhead the day prior to entering the cold treatment to allow the foliage to dry, and transferred at 7 am whilst still cool. Temperature and humidity within the cold store was recorded every 30 minutes using a Tinytag data logger.

Figure 1. Hellebore plants placed into the cold store at ADAS Boxworth in week 33, 2017

On 13 September (week 37) a further 15 plants of each variety were subjected to a separate cold treatment for six weeks (CS2). The remaining 10 plants of each variety remained outdoors on the standing out area as a control.

Plants were removed from the cold treatment in weeks 39 (27 September) and 43 (25 October) (cold treatments 1 and 2 respectively). The plants were placed back on the hardstanding with the control plants until week 44 (30 October), when they were then moved into the glasshouse, along with six plants per variety from the outdoor control, to provide an indoor control. Temperature and humidity within the glasshouse were recorded every 30 minutes using a Tinytag data logger. The trial was monitored for pest and disease throughout, and biological control (*Aphidius ervi*) was introduced into the glasshouse from week 47 for aphid control.

Plant movements were as summarised in **Table 5**.

Table 5. Hellebore plant movements during 2017

Date	Action
Week 15	Delivery to Baginton Nurseries. Plants placed in prop house
Week 16 (19/04/17)	Plants potted and placed within a polythene tunnel
Week 21 (23/05/17)	Plants placed outside with shade netting overhead
Week 32 (08/08/17)	Plants moved to ADAS Boxworth. Shade netting placed over trial
Week 33 (16/08/17)	CS1 treatment plants placed in cold store (CS)
Week 37 (13/09/17)	CS2 treatment plants placed in CS
Week 39 (27/09/17)	CS1 plants moved to standing out area
Week 43 (25/10/17)	CS2 plants moved to standing out area
Week 44 (30/10/17)	CS1, CS2 and indoor control plants moved to glasshouse

Trial design and statistical analysis

At the beginning of the trial, varieties were arranged in a fully randomised plot design with six varieties x four replicate blocks and 10 plants per plot. This gave a total of 40 plants per variety.

For the first cold storage treatment, 15 plants per variety were removed from the main trial, and re-arranged in a fully randomised plot design, with six varieties x three replicate blocks and five plants per plot. This gave a total of 15 plants per variety.

For the second cold storage treatment, a further 15 plants per variety were removed from the main trial, and re-arranged in a fully randomised plot design, with six varieties x three replicate blocks and five plants per plot. This gave a total of 15 plants per variety. This meant that 10 plants per variety remained outside throughout the cold treatment period.

When the cold treated plants were moved into the glasshouse at the end of October, six plants per variety from the outdoor plants were also moved into the glasshouse, as an indoor control. The plants were re-arranged in a fully randomised plot design, with six varieties x three replicate blocks and two plants per plot.

Four plants per variety were left outside for the remainder of the trial, as an outdoor control.

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

Assessments

The plants were assessed prior to transplant for plant quality, height and root development on a sub-sample of plugs. Plants were assessed for quality prior to cold store treatment, and the plants were monitored for date of bud production and flowering for each variety during and after the cold storage treatments. The total number of plants with open flowers and coloured buds within each treatment was recorded in weeks 45, 46 and 48. A final detailed assessment was carried out in week 51 (19 December 2017). Plants were assessed for height and quality, and the number of stems with open flowers and buds were recorded.

Results

Pre-transplant

On arrival at Baginton Nurseries, all plants were of a very good quality, with no signs of pest and disease, or damage from transportation. All plants were developing good strong roots with plenty of root hairs, which were filling the plugs. There was a difference in plant size between the varieties, with 'Penny's Pink' and 'Anna's Red' being the largest, and 'Madame Lemonnier' the smallest (**Table 6** and **Figure 2**).

Table 6. Hellebore plug sizes prior to transplant, week 16 2017

Variety	Average plant size (height in mm)
'Anna's Red'	181.4
HGC 'Madame Lemonnier'	80.6
'Molly's White'	83
'Paradenia'	97.4
'Penny's Pink'	198
'Royal Emma'	85.6

Figure 2. Plugs of ‘Anna’s Red’ (left) and ‘Madame Lemonnier’ (right) prior to potting

Pre-cold treatments

The trial was monitored prior to the start of the cold treatments. None of the varieties began to flower early, and there was no deterioration in the quality of any of the varieties.

Post-cold treatments

Cold treatment 1 (CS1) – bud and flower development

Once the plants were removed from the cold store in week 39, they were monitored for bud and flower development, and any deterioration in plant quality. For CS1, the first buds showing colour were noticed in week 42, on one plant of ‘Madame Lemonnier’, three weeks after the end of the cold treatment. There were no buds showing colour on any other varieties, or in the outdoor control at this stage. By week 43, there were buds showing colour on nine of the 15 ‘Madame Lemonnier’ plants, and one ‘Paradenia’ plant. None of the buds on any variety in the outdoor control were showing colour.

By week 46, all of the ‘Madame Lemonnier’ had fully open flowers. ‘Anna’s Red’ and ‘Molly’s White’ were slower to flower, with open flowers in two out of the 15 ‘Anna’s Red’ and one ‘Molly’s White’ (**Table 7**).

At the week 48 assessment, all 15 ‘Royal Emma’ were in flower, and almost all of the ‘Penny’s Pink’ (13 out of the 15). ‘Molly’s White’ remained the slowest flowering variety, with only four out of 15 plants in flower.

Throughout the assessment period, the plants retained their high quality, with healthy green foliage. It was noted that ‘Anna’s Red’, ‘Madame Lemonnier’, ‘Paradenia’ and ‘Penny’s Pink’ all had extended flower stems, and these plants had all been tall when they were moved into the glasshouse in week 44.

Cold treatment 2 (CS2) – flower and bud development

Once the plants were removed from the cold store in week 43, they were monitored for bud and flower development, and any deterioration in plant quality. When the plants were first removed from the cold store, they appeared larger and fuller than the plants in the CS1 treatment and the outdoor control.

For CS2, the first coloured buds were noticed in week 43, on one plant of 'Madame Lemonnier', two days after the end of the cold treatment. There were no coloured buds on any other varieties, or in the outdoor control at this stage. By week 46, almost all of the 'Madame Lemonnier', 'Paradenia' and 'Penny's Pink' had coloured buds, however, 'Anna's Red', 'Molly's White' and 'Royal Emma' only had one plant each with coloured buds (**Table 7**). By week 48, 'Madame Lemonnier' and 'Paradenia' were flowering well (11 out of 15 and eight out of 15 respectively). Only one plant of 'Molly's White' and 'Royal Emma' had flowers, and there were no flowers in 'Anna's Red'.

Throughout the assessment period, the plants remained of a high quality, with healthy green foliage. As with CS1, 'Anna's Red', 'Madame Lemonnier', 'Paradenia' and 'Penny's Pink' all had tall flower spikes.

Table 7. Number of plants with buds or fully open flowers showing colour post cold treatment, assessed week 45 (09.11.17), week 46 (17.11.17) and week 48 (30.11.17). CS1 = cold treatment 1, 15 plants; CS2 = cold treatment 2, 15 plants; Control (I) = indoor control, six plants; Control (O) = outdoor control, four plants.

Variety		Week 45		Week 46		Week 48	
	Cold treatment / no. of plants	Buds	Flowers	Buds	Flowers	Buds	Flowers
‘Anna’s Red’	CS1 / 15	7	0	11	2	4	9
	CS2 / 15	0	0	1	0	6	0
	Control (I) / 6	0	0	0	0	0	0
	Control (O) / 4	0	0	0	0	0	0
HGC ‘Madame Lemonnier’	CS1 / 15	12	3	0	15	0	15
	CS2 / 15	5	1	13	1	3	11
	Control (I) / 6	1	0	1	0	2	0
	Control (O) / 4	0	0	0	0	0	0
‘Molly’s White’	CS1 / 15	3	0	4	1	1	4
	CS2 / 15	0	0	1	0	3	1
	Control (I) / 6	0	0	0	0	0	0
	Control (O) / 4	0	0	0	0	0	0
‘Paradenia’	CS1 / 15	8	1	5	6	2	10
	CS2 / 15	5	0	15	0	2	8
	Control (I) / 6	1	0	5	0	5	0
	Control (O) / 4	1	0	1	0	1	0
‘Penny’s Pink’	CS1 / 15	13	0	8	6	1	13
	CS2 / 15	2	0	12	0	10	4
	Control (I) / 6	0	0	0	0	0	0
	Control (O) / 4	0	0	1	0	1	0
‘Royal Emma’	CS1 / 15	11	0	9	5	0	15
	CS2 / 15	1	0	1	0	8	1
	Control (I) / 6	0	0	0	0	1	0
	Control (O) / 4	0	0	0	0	0	0

Final assessment week 51

Bud development

In CS1, only ‘Anna’s Red’ and ‘Royal Emma’ had significantly more stems with coloured buds than the outdoor control (p<.001).

For the CS2 treatment, ‘Molly’s White’, ‘Penny’s Pink’ and ‘Royal Emma’ had significantly more stems with coloured buds than the outdoor control (p <.001).

‘Royal Emma’ had the greatest amount of coloured buds across all varieties in both the CS2 (8.2 stems with buds per plant) and CS1 (5.7 stems with buds per plant) treatments. Both ‘Penny’s Pink’ and ‘Royal Emma’, had significantly more stems with coloured buds in the CS1 treatment than the CS2 treatment (p<.001). There were no significant differences between treatments regarding the number of stems with coloured buds for ‘Madame Lemonnier’ or ‘Paradenia’.

Flower number

When the final assessment was completed in week 51, there were no flowers in any variety in the outdoor control, and there were significantly more (p<.001) stems per plant with open flowers in the CS1 treatment compared to the outdoor control for all varieties apart from ‘Molly’s White’ (**Table 8**). In CS1, ‘Royal Emma’ produced the greatest number of stems with open flowers (10.3 stems with flowers per plant), and ‘Molly’s White’ the least (0.5 stems with flowers per plant). Only ‘Madame Lemonnier’ and ‘Paradenia’ produced significantly more stems per plant with open flowers compared with the outdoor control in the CS2 treatment.

In CS2, ‘Paradenia’ produced the greatest number of stems with open flowers (1.4 stems with flowers per plant), and ‘Molly’s White’ the least (0.1 stems with flowers per plant). ‘Anna’s Red’, ‘Paradenia’, ‘Penny’s Pink’ and ‘Royal Emma’ produced significantly more stems with open flowers in the CS1 treatment than the CS2 treatment (p<.001).

Plant height

In terms of plant height, all varieties in both CS1 and CS2 were significantly taller than the outdoor control (p <.001; **Table 8**). ‘Anna’s Red’ in the CS1 treatment produced the tallest plants overall, with an average plant height of 47.58 cm. ‘Paradenia’ produced the tallest plants in the CS2 treatment, with an average plant height of 33.51 cm. The most compact plants within each treatment were ‘Molly’s White’ (CS1, 19.58 cm) and ‘Royal Emma’ (CS2, 17.21 cm). There were significant differences in height between the CS1 treatment and the CS2 treatment for ‘Anna’s Red’ and ‘Royal Emma’.

Plant quality

The quality of the plants that had been subjected to cold store treatments was significantly poorer than the outdoor control for ‘Paradenia’ only ($p = 0.010$). In both CS1 and CS2, plants scored an average of 2.0/5.0. Although the ‘Paradenia’ provided good pot cover, plants from both cold store treatments were stretched, although more so in CS1. The flowers in CS1 were also turning green.

‘Royal Emma’ received the highest quality scores in both the CS1 and CS2 treatments (3.7 and 4.0 respectively) (**Table 9**). In CS1, these plants were fairly tall, but not stretched, and the flowers were only just turning green. In the CS2 treatment the plants remained compact with lots of new buds.

‘Anna’s Red’ and ‘Penny’s Pink’ were both tall in both CS1 and CS2, although more so in CS1. The flowers had faded in both treatments, again more so in CS1. However the colour of the foliage was maintained, for both varieties.

‘Molly’s White’ was more compact than ‘Anna’s Red’ and ‘Penny’s Pink’, with attractive foliage that provided good pot cover. Although the flowers were beginning to fade in both treatments, ‘Molly’s White’ was not stretched, and the plants were at pot cover, therefore they achieved a higher quality score of 3.7 for both CS1 and CS2.

For both cold store treatments, all varieties, apart from ‘Royal Emma’, tended to have flowers that faced down, and therefore their appeal as a pot plant was slightly reduced. The flowers produced by ‘Royal Emma’ were facing forwards in both cold store treatments.

Table 8. Final quality assessment, assessed week 51 (19.12.17). CS1 = cold treatment 1, 15 plants; CS2 = cold treatment 2, 15 plants; Control (I) = indoor control, six plants; Control (O) = outdoor control, four plants

	Treatment	Average height (cm)	No. stems with open flowers	No. stems with coloured buds	Quality (0-5)
'Anna's Red'	CS1 / 15	47.58*	3.0*	2.4	2.3
	CS2 / 15	30.47*	1.1*	2.1	2.3
	Control (I) / 6	12.62	0.0	0.0	2.3
	Control (O) / 4	11.65	0.0	0.0	2.3
'Madame Lemonnier'	CS1 / 15	29.78	2.5	1.1	3.0
	CS2 / 15	23.70	2.1	1.2	2.7
	Control (I) / 6	10.22	0.0	0.7	2.7
	Control (O) / 4	6.15	0.0	0.8	2.8
'Molly's White'	CS1 / 15	19.58	0.5	1.3	3.7
	CS2 / 15	17.73	0.1	2.3	3.7
	Control (I) / 6	10.60	0	0.0	2.7
	Control (O) / 4	9.32	0	0.3	3.3
'Paradenia'	CS1 / 15	40.11	3.3*	2.0	2.0
	CS2 / 15	33.51	1.4*	3.3	2.0
	Control (I) / 6	19.45	0	3.0	2.0
	Control (O) / 4	13.82	0	2.8	3.0
'Penny's Pink'	CS1 / 15	31.08	2.7*	1.8*	3.0
	CS2 / 15	27.94	0.7*	4.7*	3.0
	Control (I) / 6	10.98	0	0.3	2.7
	Control (O) / 4	11.62	0	1.8	2.8
'Royal Emma'	CS1 / 15	29.17*	10.3*	5.7*	3.7
	CS2 / 15	17.21*	0.8*	8.2*	4.0
	Control (I) / 6	8.40	0	2.0	2.0
	Control (O) / 4	8.25	0	1.5	3.3
	s.e.d.	3.35	0.50	0.90	0.39
	l.s.d.	6.72	0.99	1.79	0.79
	F pr	<.001	<.001	<.001	0.010

Figures highlighted red are significantly different to the outdoor control. * = treatments are significantly different to each other

Table 9. Differences in plant quality and flower development between the cold treatments and the outdoor control, week 51

	Outdoor control	CS1	CS2
'Anna's Red'			
HGC 'Madame Lemonnier'			

‘Molly’s White’

‘Paradenia’

‘Penny’s Pink’

‘Royal Emma’

Discussion

Flower buds initiated naturally prior to the cold treatments, the treatments then advanced flowering depending on variety and cold treatment.

For **'Anna's Red'** no flowers or buds were recorded in the outdoor and indoor controls prior to week 51 when the first coloured buds were recorded. In treatment CS1, buds showing colour were recorded from week 45 through to week 51, with the first flowers recorded from week 46, earlier than for treatment CS2, where bud development had only just commenced.

For **'Madame Lemonnier'** no buds showing colour or flowers were recorded in the outdoor control until the final assessment in week 51, buds showing colour were recorded on one plant only in the indoor control prior to week 48. 'Madame Lemonnier' produced the earliest buds showing colour (CS1, week 42) than any other variety. Although flowers and buds showing colour were recorded in both the CS1 and CS2 treatments from week 45, more were produced and earlier in plants that had undergone the cold treatment from mid-August (CS1). Both treatments CS1 and CS2 advanced flower and bud production.

'Molly's White' was slower to produce buds and flowers than all the other varieties throughout this trial. No fully open flowers and minimal buds were recorded in the control treatments (weeks 45 to 51, inclusive). Although more flowers and buds showing colour were recorded for plants that had undergone treatment CS1 than CS2, numbers were low for both throughout the trial.

For '**Paradenia'** although buds showing colour were recorded in both control treatments from week 45 (one plant in each), no flowers had opened by week 51. Buds showing colour were also recorded from week 45 for plants that underwent both cold treatments, however the flowers opened three weeks earlier than plants that underwent treatment CS1 (from week 45) than CS2 (from week 48).

For **'Penny's Pink'** no flowers were recorded in the control treatments, up to and including week 51. Prior to week 48, buds showing colour were recorded on one plant in the outdoor control only, after which numbers started to increase in both control treatments. More open flowers were recorded and earlier in CS1 (week 46) than in CS2 (week 48).

For **'Royal Emma'** no open flowers were recorded either in the outdoor or indoor control treatments throughout the trial (weeks 45-51). Open flowers were recorded in CS1 from week 46, and in all fifteen plants in week 48. For CS2, the number of buds with colour increased between weeks 48 and 51, but the main flush of flower on these plants did not appear prior to the end of the trial in week 51. Both treatments CS1 and CS2 did therefore advance bud and

flower production compared with the control treatments, but the effect was more pronounced in those plants that had undergone the earlier cold treatment (CS1).

Plant quality was generally not affected by the cold treatments; the exception were ‘Anna’s Red’ and ‘Paradenia’ which were stretched by both cold store treatments. Flower colour had stared to fade in ‘Penny’s Pink’ and ‘Anna’s Red’, likely due to the relatively warm glasshouse temperature.

Considering plant height, for all varieties, plants that had been subjected to the cold treatments were taller compared with those from the outdoor control treatment. Plants from the indoor control were generally only slightly taller than the outdoor control. This suggests that the cold treatments exerted the greatest influence on plant height. We are not aware of specific height specifications for Hellebore, but would expect 20-30 cm to be reasonable for cost effective transport and distribution on Danish trolleys; if using this parameter the height of the ‘Anna’s Red’ and ‘Paradenia’ would not have been commercially acceptable. Many imported Hellebores from the continent have their foliage removed to expose the flower buds, so foliage height is not an issue at marketing.

Conclusions

- A cold treatment from mid-August advanced bud production in ‘Anna’s Red’ and ‘Royal Emma’ and advanced flowering in ‘Anna’s Red’, ‘Madame Lemonnier’, ‘Paradenia’, ‘Penny’s Pink’ and ‘Royal Emma’.
- A cold treatment from mid-September advanced bud production in ‘Molly’s White’, ‘Penny’s Pink’ and ‘Royal Emma’ and advanced flowering in ‘Madame Lemonnier’ and ‘Paradenia’.
- Although the cold treatments advanced flowering for most of the varieties used in this trial, this appears to be variety dependent; they did not advance flowering of ‘Molly’s White’ and the treatments had a detrimental effect on the quality of the ‘Paradenia’. Flower colour and plant height were both affected by glasshouse temperature in some varieties; cooler temperatures favour stronger flower colour and more compact plants.
- Further work would determine reproducibility of the treatments and could be used to improve scheduling and plant quality.
- In time, Hellebore breeding using traits from species that naturally flower before Christmas may result in coloured varieties that will flower before Christmas without cold treatments.

Recommended cold store treatments to advance flowering in the varieties included in this trial are provided in **Table 10**.

Table 10. Recommended cold store treatments to advance flower production in Hellebore

Treatment	Variety
Mid-August	'Anna's Red', 'Madame Lemonnier', 'Penny's Pink', 'Royal Emma'
Mid-September	'Madame Lemonnier'
No cold store treatment*	'Molly's White', 'Paradenia'

*These varieties either did not respond to cold treatments, or lost quality

Acknowledgements

Our thanks to:

- Will Lamb and Jack Olds and the team at Baginton Nurseries for their work and commitment to the project.
- Heuger, Bulrush Horticulture and Pöppelmann Plastics UK Ltd for the provision of plants and other materials.
- The Scientific Support team at ADAS.
- The Management Group for their steering of the project.

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Appendix 1. To extend the marketing season for coloured varieties of pot-grown Hellebore to include the months prior to Christmas through cool treatments.

Appendix 1.1 Temperatures throughout the Hellebore trial

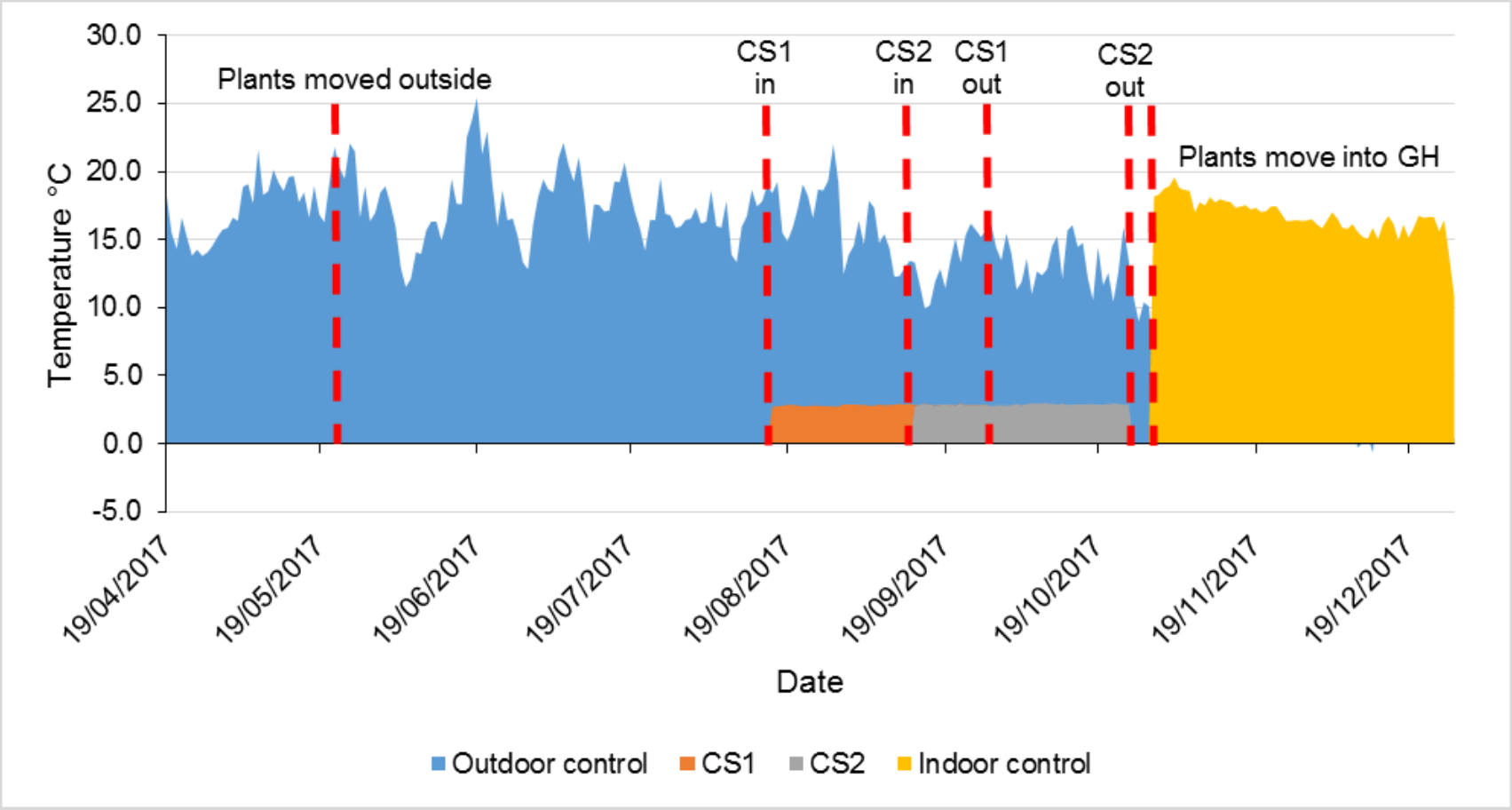

Figure i. Temperature throughout trial. 24-hour average