Project title:	The Bedding and Pot Plant Centre – new product opportunities for bedding and pot plant growers. ***Objective 2****. To evaluate plant growth regulators for use on bedding and pot plants*
Project number:	PO 019a
Project leader:	Dr Jill England, ADAS Boxworth
Report:	Annual report, 31 March 2019
Previous report:	None
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Location of project:	Baginton Nurseries, Coventry, Warwickshire
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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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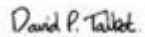
Signature  Date 29 March 2019

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Grower Summary

Headline

- Effective post-transplant plant growth regulator (PGR) treatments were identified for Geranium 'Horizon' red and *Osteospermum* 'Akila' purple.
- Although none of the treatments evaluated gave effective and crop-safe growth control of *Dianthus* 'Festival' violet or Pansy 'Matrix' red blotch, with rate adjustment, some of the products may prove effective.

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 2**. To evaluate plant growth regulators for use on bedding and pot plants*

Summary

The evaluation of new plant growth regulators (PGRs) for use on bedding and pot plants was prompted by label changes to the plant growth regulator Bonzi (paclobutrazol), including removal of the option for drench application, and the potential restrictions or loss of approval for the use of chlormequat in protected ornamental plant production. Growers sometimes apply PGRs as drenches, particularly during propagation, and have developed application rates specific to the crops grown, under nursery specific growing conditions. The PGRs included in this trial have either been trialled in Denmark with promising results on bedding and pot plants, are new to the market or have recently received CRD approval for use on related crops in the UK. However, any phytotoxic effects and efficacy of these chemicals on bedding and pot plants grown under UK conditions are currently unknown.

A range of plant growth regulators were trialled on four seed-raised bedding plant species (*Dianthus* 'Festival' violet, Geranium 'Horizon' red, Pansy 'Matrix' red blotch and *Osteospermum* 'Akila' purple). Plants were transplanted in week 21 (22 May 2018), at

Baginton Nurseries, using standard six-packs for the *Dianthus*, Geranium and Pansy, and jumbo six-packs for the *Osteospermum*.

Products tested are listed in **Table 1**. Sprays were applied by hand using a backpack and single nozzle lance, with an 02f110 nozzle, to achieve a fine spray quality, in a water volume of 300 L/ha (note this may be lower than the rate currently used by growers). All treatments were applied during late afternoon with shade screens over the crop prior to treatment. For the drenches, treatments were applied with a watering can at 10% of the pack volume, resulting in 135 ml applied to each pack as the drench.

Treatments were applied as a foliar spray or drench at one week post-transplant, and then after a further 10 days (29 May and 08 June respectively).

Table 1. Approval status of PGR products tested in 2018

Product	Active ingredient	Approval status
HDC P005	-	Not approved on protected ornamentals in the UK
Moddus (MAPP 15151)	Trinexapac-ethyl	EAMU 3062/10 for spray application. One application only permitted per crop
Pirouette (MAPP 17203)	Paclobutrazol	On-label approval for spray application. EAMU 1269/17 for drench application
Primo Maxx II (MAPP 17509)	Trinexapac-ethyl	EAMU 0621/18 for spray application issued 22.03.18
Regalis Plus (MAPP 16485)	Prohexadione	EAMU 0181/15 for spray application. Three weeks must be allowed between applications
Terpal (MAPP 16436)	Ethephon + mepiquat chloride	EAMU 0151/18 for drench application issued 30.01.18

Unauthorised or off-label treatments applied under experimental permit.

Treatments applied in this trial were developed using the 2017 trial results as a guide, therefore the treatment list for each species was different (**Table 2** - **Table 5**). For *Osteospermum*, where there were no trials in 2017, products were applied at full label rate.

Table 2. PGR product and treatment list 2018 – *Dianthus*

Trt No.	Product	Active ingredient	Application method*	Dose rate (L/ha)	Dose rate (ml/L)
1	Water control	N/A	Spray	N/A	N/A
2	HDC P005	-	Spray**	0.505 L/ha	1.68 ml/L (3/4 rate)
3	HDC P005	-	Spray**	0.675 L/ha	2.25 ml/L (full rate)
4	HDC P005	-	Drench**	0.337 L/ha	1.12 ml/L (1/2 rate)
5	HDC P005	-	Drench**	0.505 L/ha	1.68 ml/L (3/4 rate)
6	Primo Maxx II	Trinexapac-ethyl**	Drench**	1.0 L/ha	3.33 ml/L (1/2 rate)
7	Primo Maxx II	Trinexapac-ethyl**	Drench**	1.5 L/ha	5 ml/L (3/4 rate)
8	Pirouette	Paclobutrazol	Spray	0.3 L/ha	1 ml/L
9	Pirouette	Paclobutrazol	Drench	0.3 L/ha	1 ml/L

*Foliar sprays applied in 300 L water/ha. Drenches were applied by hand with a watering can with a rose head fitting, at 10% of the pack volume. ** Treatments applied under experimental permit.

Table 3. PGR product and treatment list 2018 – Geranium

Trt No.	Product	Active ingredient	Application method*	Dose rate (L/ha)	Dose rate (ml/L)
1	Water control	N/A	Spray	N/A	N/A
2	HDC P005	-	Drench**	0.169 L/ha	0.56 ml/L (1/4 rate)
3	HDC P005	-	Drench**	0.337 L/ha	1.12 ml/L (1/2 rate)
4	Terpal	Ethephon + mepiquat chloride	Spray**	1.0 L/ha	3.33 ml/L (1/2 rate)
5	Terpal	Ethephon + mepiquat chloride	Spray**	1.5 L/ha	5 ml/L (3/4 rate)
6	Terpal	Ethephon + mepiquat chloride	Drench	0.5 L/ha	1.67 ml/L (1/4 rate)
7	Terpal	Ethephon + mepiquat chloride	Drench	1.0 L/ha	3.33 ml/L (1/2 rate)
8	Regalis Plus - **1 app only**	Prohexadione	Drench**	0.31 L/ha	1.03 g/L (1/4 rate)
9	Regalis Plus - **1 app only**	Prohexadione	Drench**	0.62 L/ha	2.08 g/L (1/2 rate)
10	Primo Maxx II	Trinexapac-ethyl	Drench**	0.5 L/ha	1.67 ml/L (1/4 rate)
11	Primo Maxx II	Trinexapac-ethyl	Drench**	1.0 L/ha	3.33 ml/L (1/2 rate)
12	Moddus - **1 app only**	Trinexapac-ethyl	Drench**	0.15 L/ha	0.5 ml/L (1/4 rate)
13	Moddus - **1 app only**	Trinexapac-ethyl	Drench**	0.3 L/ha	1 ml/L (1/2 rate)
14	Pirouette	Paclobutrazol	Spray	0.3 L/ha	1 ml/L
15	Pirouette	Paclobutrazol	Drench	0.3 L/ha	1 ml/L

*Foliar sprays applied in 300 L water/ha. Drenches were applied by hand with a watering can with a rose head fitting, at 10% of the pack volume. ** Treatments applied under experimental permit.

Table 4. PGR product and treatment list 2018 – Pansy

Trt No.	Product	Active ingredient	Application method*	Dose rate (L/ha)	Dose rate (ml/L)
1	Water control	N/A	Spray	N/A	N/A
2	HDC P005	-	Spray**	0.505 L/ha	1.68 ml/L (3/4 rate)
3	HDC P005	-	Spray**	0.675 L/ha	2.25 ml/L (full rate)
4	HDC P005	-	Drench**	0.337 L/ha	1.12 ml/L (1/2 rate)
5	HDC P005	-	Drench**	0.505 L/ha	1.68 ml/L (3/4 rate)
6	Terpal	Ethephon + mepiquat chloride	Spray**	1.0 L/ha	3.33 ml/L (1/2 rate)
7	Terpal	Ethephon + mepiquat chloride	Spray**	1.5 L/ha	5 ml/L (3/4 rate)
8	Pirouette	Paclobutrazol	Spray	0.3 L/ha	1 ml/L
9	Pirouette	Paclobutrazol	Drench	0.3 L/ha	1 ml/L

*Foliar sprays applied in 300 L water/ha. Drenches were applied by hand with a watering can with a rose head fitting, at 10% of the pack volume. ** Treatments applied under experimental permit.

Table 5. PGR product and treatment list 2018 – *Osteospermum*

Trt No.	Product	Active ingredient	Application method*	Dose rate (L/ha)	Dose rate (ml/L)
1	Water control	N/A	Spray	N/A	N/A
2	HDC P005	-	Spray**	0.675 L/ha	2.25 ml/L (full rate)
3	Terpal	Ethephon + mepiquat chloride	Spray**	2.0 L/ha	6.67 ml/L (full rate)
4	Regalis Plus - **1 app only**	Prohexadione	Spray	1.25 L/ha	4.17 ml/L (full rate)
5	Primo Maxx II	Trinexapac-ethyl	Spray	2.0 L/ha	6.67 ml/L (full rate)
6	Moddus - **1 app only**	Trinexapac-ethyl	Spray	0.6 L/ha	2 ml/ L (full rate)
7	Pirouette	Paclobutrazol	Spray	0.3 L/ha	1 ml/L

*Foliar sprays applied in 300 L water/ha. Drenches were applied by hand with a watering can with a rose head fitting, at 10% of the pack volume. ** Treatments applied under experimental permit.

Of the products included in this trial, those containing chlormequat or mepiquat chloride (Terpal and HDC P005) were expected to have a similar effect on plant growth as Stabilan 750; those containing prohexadione calcium (Regalis Plus, HDC P005) or trinexapac-ethyl (Primo Maxx II and Moddus) were expected to have a similar effect to the more familiar daminozide products (e.g. B-nine, Dazide Enhance).

Results by plant species

Dianthus 'Festival' violet

- Height was significantly controlled by all treatments (apart from the Pirouette spray, 0.3 L/ha), but the effect was too strong and the plants were too compact. Reducing the dose rate, or the drench volume should provide acceptable height control.
- While Pirouette applied as a spray at 0.3 L/ha did not control growth, it is likely to prove effective with an adjustment to the dose rate. Pirouette did not cause phytotoxicity.
- There were more plants in flower in the Pirouette spray treatment compared to the untreated control by week 25; all other treatments had fewer plants in flower.
- All rates of HDC P005 and Primo Maxx II, as sprays or drenches, caused phytotoxicity, with foliage and / or petal bleach.

Geranium 'Horizon' red

- Spray treatments of Terpal at both rates tested were effective in controlling growth compared with the untreated control; Pirouette applied as a spray was less effective at the dose rates used.
- Drench treatments of Terpal, Regalis Plus, Primo Maxx II (high rate), Moddus (high rate) and Pirouette were all too strong; the plants were too compact.
- Sprays of Terpal and Pirouette did not cause phytotoxicity. All other treatments caused foliar and petal bleach. The high rate drenches of Terpal and Regalis Plus caused some plant death.
- Flowering was delayed in the Terpal spray treatments only.

Pansy 'Matrix' red blotch

- Although plants treated with Terpal (both spray dose rates) were shorter than the control, and did not cause phytotoxicity, they did not appear to provide sufficient growth control in this trial. However, with an adjustment to spray rates, Terpal may provide effective treatments.
- Similarly, HDC P005 (0.505 L/ha) applied as a spray may prove effective with an adjustment to dose rates, but it should be noted HDC P005 applied as a spray caused petal bleach on the early flowers; later flowers were not affected.
- The Pirouette spray rates were too low to control growth, while the drench treatment 0.3 L/ha was too strong.
- The HDC P005 (0.505 L/ha) drench caused severe phytotoxicity with petal bleach, while the lower dose rate drench 0.337 L/ha was not effective, but also caused phytotoxicity

- None of the treatments significantly reduced flowering compared with the untreated control.

Osteospermum 'Akila' purple

- The majority of treatments provided some growth control compared with the untreated control, most notably HDC P005 and Regalis Plus.
- The Moddus spray did not control height.
- None of the treatments caused phytotoxicity, and did not adversely affect either flowering time or the number of plants in flower.

Summary

- The most promising product on *Dianthus* was Pirouette, however further work is needed to determine the most effective spray rate for this species.
- Terpal applied as a spray was the most promising PGR on Geranium and has potential for use at rates between 1.0 – 1.5 L/ha.
- Terpal, Pirouette and HDC P005 applied as sprays had some potential on Pansy, however further work may be required to find the most appropriate rates. Given the fact that HDC P005 can cause petal bleach on Pansy, Terpal is likely to be a safer option.
- All of the new products produced too strong an effect when applied as drenches at the rates tested. Pirouette (paclobutrazol) was also too strong when applied as a drench, highlighting the importance of not applying high rates when using PGRs as drenches.

Financial benefits

The evaluation of plant growth regulators (PGRs) either approved in the UK or in other European Countries for use on bedding plants (spray and drench application), followed by appropriate AHDB EAMU applications will expand the range of active ingredients available to growers' for controlling plant growth. Whilst growers do use cultural methods (e.g. temperature, diff/drop, controlling irrigation and nutrient supply) to control plant growth where possible, they often induce species specific responses and a lack of cost effective PGRs approved for use on protected ornamentals would reduce the range of plants that can be produced profitably within client specifications. PGRs are particularly important when used to hold mature crops at specified height during periods of low demand where other methods would lead to unacceptable effects e.g. leaf yellowing. The cost per litre of spray solution applied as part of the trial, at the specified rates, range from 51.3p to 0.09p (**Table 6**) and provide greater opportunity to increase profit through reduced input cost.

Table 6. PGR costs (non-discounted, excluding VAT and labour costs for application)

Product and rate	Cost of active (p)	Cost / L of spray (p)
Bonzi	9.5 / ml	11.9
HDC P005 (0.56; 1.12; 1.68; 2.25 g/L)	2.2 / g	1.2; 2.5; 3.7; 5.0
Moddus (0.5; 1.0; 2.0 ml/L)	3.9 / ml	2.0; 3.9; 7.8
Pirouette (1.0 ml/L)	0.09 / ml	0.09
Primo Maxx II (1.67; 3.33; 5.0; 6.67 ml/L)	5.0 / ml	8.4; 16.7; 25; 33.4
Regalis Plus (1.03; 2.08; 4.17 g/L)	12.3 / g	12.7; 25.6; 51.3
Terpal (1.67; 3.33; 5.0; 6.67 ml/L)	1.7 / ml	2.8; 5.7; 8.5; 11.3

Regalis Plus and Moddus received a single treatment; all other products received two treatments due to label requirements.

Action points

- Growers should examine the potential of spray treatments of Terpal on Pansy and Geranium, and Pirouette on *Dianthus* to achieve growth control, but dose rates may need to be adjusted.
- Growers should also explore drench treatments of Terpal on Geranium at low rates, and at higher rates on Pansy.
- Growers should test new or unfamiliar products on a small number of plants before large scale use.
- Growers should familiarise themselves with and adhere to product labels, approvals and Extensions of Approval for Minor Use (EAMUs) prior to use. Note that a number of the treatments included in this trial have been carried out under experimental permit and are not currently authorised for nursery use in the UK.
- Growers should note that that the spray rate used in the trials (300 litres per hectare) may be lower than the rate currently use and as such application rates or volumes may need to be adjusted to maintain the same application rate of active ingredient.

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, 2018-19 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).

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 2.

Background

The evaluation of new plant growth regulators (PGRs) for use on bedding and pot plants was prompted by label changes to the plant growth regulator Bonzi (paclobutrazol), including removal of the option for drench application, and the potential loss of approval for the use of chlormequat in protected ornamental plant production. Many growers sometimes apply PGRs as drenches and have developed application rates specific to the crops grown under nursery specific growing conditions. New PGRs have either been trialled in Denmark with promising results on bedding and pot plants, are new to the market or have recently received HSE approval for use on related crops in the UK; any phytotoxic effects and efficacy of these PGRs under UK conditions are unknown. The products included in this trial programme were:

HDC P005 (-) was developed for use on cereals and grass seed. It was found to be less effective at controlling the growth of *Pelargonium* 'Dronning Ingrid' than Caryx (210 g/L mepiquat (as chloride) and 30 g/L metconazole), both of which have been trialled in Denmark, however, it did reduce growth of *Bacopa* 'Carolin' when applied at a dose rate of 0.375%. HDC P005 did not reduce the number of *Bacopa* flowers produced although they were slightly smaller (Paaske, 2015). AHDB has confirmed that an EAMU application will be progressed for HDC P005 for use on protected ornamentals.

Terpal (155 g/L ethephon + 305 g/L mepiquat chloride, BASF) is a new product which was originally approved for use on protected ornamentals in Denmark, where results were promising on *Osteospermum* 'Naomi' (Paaske, 2013). In the UK, EAMU 0151/18 was issued on 30 January 2018, giving authorisation for use in ornamental plant production on container grown plants.

Cutaway (121 g/L trinexapac-ethyl, Syngenta Crop Protection UK Ltd) is approved for spray application in ornamental plant production (EAMU 2140/16) in the UK. This EAMU was sought following promising results under AHDB project HNS 187 and HNS 187a on tree species using Cutaway, which reported leaf yellowing on *Populus* and to a lesser extent *Alnus;* slight narrowing of the leaves occurred on *Sorbus*; other species were not affected. However, Cutaway's authorisation for use is likely to be lost in the near future as some of its co-formulants are likely to be revoked. Cutaway has been replaced in the trial with **Primo Maxx II** (116.4 g/L trinexapac-ethyl, Syngenta UK Ltd), approved for use in ornamental plant production in the UK under EAMU 0621/18.

Moddus (250 g/L trinexapac-ethyl, Syngenta Crop Protection UK Ltd) is approved for use on cereals in the UK and has approval (EAMU 3062/10) for use on ornamentals. However, the formulation and application rates differ from the EAMU for Cutaway. Danish work has indicated that Moddus was too strong for *Osteospermum* 'Naomi', with dose rates of 0.5% to 1.0%, causing plant death (Paaske, 2013). However, it was not effective on Marguerites at the rates tested (Paaske, 2010).

Regalis Plus (100 g/kg prohexadione, BASF) is approved for use on protected ornamentals in the UK (EAMU 0181/15). It is in the same chemical group as daminozide, although with greater activity. Previous trials have indicated that Regalis, applied either as a drench or spray, is effective in controlling plant growth within some bedding plant species. However, its use can also result in flower petal bleaching in some plant species (Brough, 2011). Regalis Plus is the new formulation which includes a built-in water conditioner which will reduce the time required for rain fastness from six hrs to two hrs. The new formulation will supersede Regalis once

existing stocks have been sold. In Danish work, Regalis produced compact Marguerites (*Argyranthemum frutescens* 'Dana') at 0.1% (Paaske, 2010).

The active ingredients of the products included in this trial were predominately anti-gibberellins, which prevent production of gibberellin at various points in its biosynthesis. The three PGR groupings are: 1) Quaternary Ammonium Compounds (QAC) e.g. chlormequat chloride (Stabilan 750) and mepiquat chloride (a component of Terpal) which prevent gibberellin production early in its biosynthesis; 2) triazoles e.g. paclobutrazol (Bonzi, Pirouette); and 3) a group which prevents gibberellin production late in its biosynthesis: prohexadione calcium (Regalis Plus), trinexapac-ethyl (Primo Maxx II, Moddus and Cutaway) and daminozide (B-Nine). The exception is ethephon (a component of Terpal) which breaks down within the plant to produce the plant hormone, ethylene. Of the three groups the triazoles are the most active, although levels of activity varies within this group.

The evaluation of plant growth regulators (PGRs) either approved in the UK or in other European Countries for use on bedding plants (spray and drench application), followed by appropriate AHDB EAMU applications will expand the range of active ingredients in the growers' armoury for controlling plant growth. The inclusion of drench treatments in the trial will provide growers with alternative products following the loss of approval for drench application of Bonzi.

DIY stores and multiple retailers generally specify plant height in the region of 40 – 80 mm for the majority of the species included in this trial; up to 100 mm for taller varieties such as *Dianthus* (excluding 'flower stems') and 100% pack cover for pack bedding. Garden centres can have a less rigid approach and accept product with less pack cover, while reject primarily 'stretched' or 'floppy' plants. The distance between Danish trolley shelves (typically 8 shelves plus base) presents a practical limitation on plant height of around 160 mm.

In 2017, treatments were applied as sprays and drenches to a range of species post transplanting into packs, and pots / jumbo packs. Terpal + Activator 90 (2 L/ha + 40 ml/100 L spray solution) was perhaps the most promising product tested, controlling the growth of all subjects (compared to the untreated control) when applied as both a spray and drench. However, spray applications at the rate used did result in some delayed flowering in both Pansy and *New Guinea Impatiens*, and drench applications at this rate had too strong an effect.

Spray applications of HDC P005 showed promise controlling growth in *Dianthus*, Pansy, *New Guinea Impatiens* and *Zantedeschia*, while Primo Maxx II controlled the growth of *Pelargonium* and *New Guinea Impatiens*. Drench applications all had a strong effect controlling height to

varying degrees, for some species the effect was too strong resulting in excessive plant growth regulation and associated phytotoxicity. Treatments were therefore refined for the 2018 trial.

A range of PGRs (**Table 7**) were tested on pot and bedding plant subjects via spray and / or drench application as appropriate under UK conditions. Treatment rates were based on the 2017 Bedding and Pot Plant Centre PGR trial results, which resulted in a different treatment list for each plant species. As there had been no work on *Osteospermum* in 2017, each product was tested at the full rate only. Treatments were applied after transplant of plug plants into six-packs.

Table 7. PGR products tested in the 2018 trials

Product	Active ingredient	Approval status
HDC P005	-	Not approved on protected ornamentals in the UK
Moddus (MAPP 15151)	Trinexapac-ethyl	EAMU 3062/10 for spray application. One application only permitted per crop
Pirouette (MAPP 17203)	Paclobutrazol	On-label approval for spray application. EAMU 1269/17 for drench application
Primo Maxx II (MAPP 17509)	Trinexapac-ethyl	EAMU 0621/18 for spray application issued 22.03.18
Regalis Plus (MAPP 16485)	Prohexadione	EAMU 0181/15 for spray application. Three weeks must be allowed between applications
Terpal (MAPP 16436)	Ethephon + mepiquat chloride	EAMU 0151/18 for drench application issued 30.01.18

Unauthorised or off-label treatments applied under experimental permit.

Project objectives

Objective 2. 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 (via spray and / or drench application)

Specific objective 1: To evaluate efficacy of up to six PGRs for spray and drench application over seed raised bedding and pot plants.

Specific objective 2: To evaluate any phytotoxic effects of up to six PGRs due to spray and drench application over seed raised bedding and pot plants.

Specific objective 3: To carry out a financial impact assessment for the most promising treatments.

Methods and materials

Site and crop production details

Four seed-raised bedding plant species (*Dianthus* 'Festival' violet, Geranium 'Horizon' red, Pansy 'Matrix' red blotch and *Osteospermum* 'Akila' purple) were used for this trial. All plant species were transplanted into six-packs (jumbo six-packs for *Osteospermum*) in week 21 (22 May 2018) at Baginton Nurseries (**Figure 1**).

Everris growing media (60% peat, 40% woodfibre, plus Osmocote Protect 5 to 6 months 14-8-11+2MgO+TE) was used and no liquid feeding was required for any of the varieties.

Spray treatments were applied by hand using a backpack and single nozzle lance, with an 02f110 nozzle, to achieve a fine spray quality, in a water volume of 300 L/ha. Spray boards were used to prevent drift onto neighbouring plots. Drenches were applied by hand with a watering can with a rose head fitting, at 10% of the pack volume (135 ml per pack).

For both the drenches and the sprays, treatments were applied during late afternoon with shade screens pulled over the plants if needed. Treatments (**Table 8** - **Table 11**) were applied one week post-transplant, and then after a further 10 days (29 May and 08 June respectively). Growing media was moist when treatments were applied, and plants were not watered for 24 hours after treatment.

Products not currently authorised for use on protected ornamentals or for drench application were applied under an experimental permit (2017/01098 and 2017/02964).

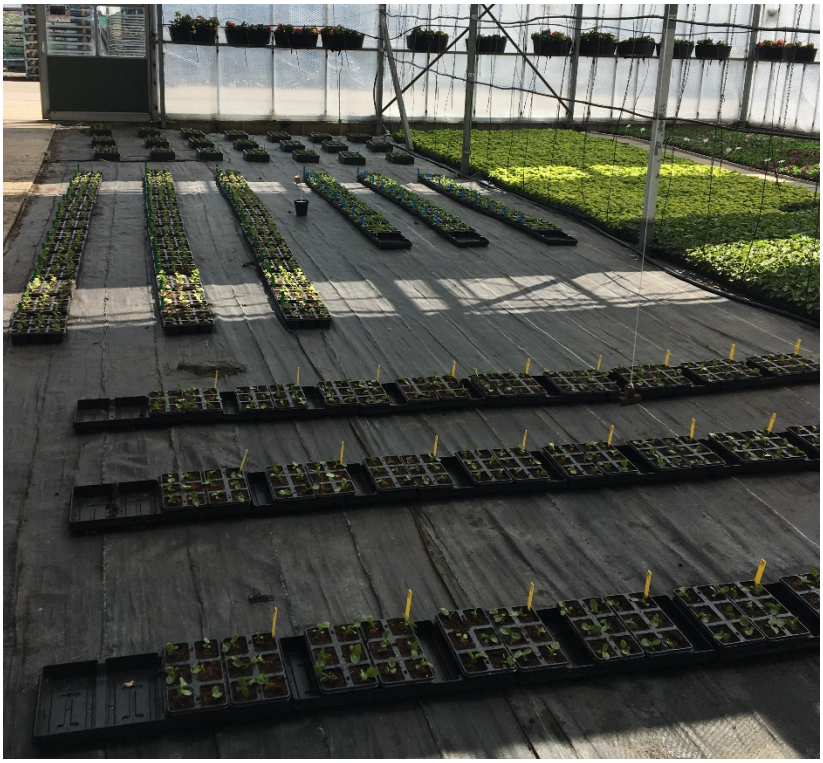

Figure 1. PGR trials set-up under glass at Baginton Nurseries, 2018.

Table 8. PGR product and treatment list 2018 – *Dianthus*

Trt No.	Product	Active ingredient	Application method*	Dose rate (L/ha)	Dose rate (ml/L)
1	Water control	N/A	Spray	N/A	N/A
2	HDC P005	-	Spray**	0.505 L/ha	1.68 ml/L (3/4 rate)
3	HDC P005	-	Spray**	0.675 L/ha	2.25 ml/L (full rate)
4	HDC P005	-	Drench**	0.337 L/ha	1.12 ml/L (1/2 rate)
5	HDC P005	-	Drench**	0.505 L/ha	1.68 ml/L (3/4 rate)
6	Primo Maxx II	Trinexapac-ethyl**	Drench**	1.0 L/ha	3.33 ml/L (1/2 rate)
7	Primo Maxx II	Trinexapac-ethyl**	Drench**	1.5 L/ha	5 ml/L (3/4 rate)
8	Pirouette	Paclobutrazol	Spray	0.3 L/ha	1 ml/L
9	Pirouette	Paclobutrazol	Drench	0.3 L/ha	1 ml/L

*Foliar sprays applied in 300 L water/ha. Drenches were applied by hand with a watering can with a rose head fitting, at 10% of the pack volume. ** Treatments applied under experimental permit.

Table 9. PGR product and treatment list 2018 – Geranium

Trt No.	Product	Active ingredient	Application method*	Dose rate (L/ha)	Dose rate (ml/L)
1	Water control	N/A	Spray	N/A	N/A
2	HDC P005	-	Drench**	0.169 L/ha	0.56 ml/L (1/4 rate)
3	HDC P005	-	Drench**	0.337 L/ha	1.12 ml/L (1/2 rate)
4	Terpal	Ethephon + mepiquat chloride	Spray**	1.0 L/ha	3.33 ml/L (1/2 rate)
5	Terpal	Ethephon + mepiquat chloride	Spray**	1.5 L/ha	5 ml/L (3/4 rate)
6	Terpal	Ethephon + mepiquat chloride	Drench	0.5 L/ha	1.67 ml/L (1/4 rate)
7	Terpal	Ethephon + mepiquat chloride	Drench	1.0 L/ha	3.33 ml/L (1/2 rate)
8	Regalis Plus - **1 app only**	Prohexadione	Drench**	0.31 L/ha	1.03 g/L (1/4 rate)
9	Regalis Plus - **1 app only**	Prohexadione	Drench**	0.62 L/ha	2.08 g/L (1/2 rate)
10	Primo Maxx II	Trinexapac-ethyl	Drench**	0.5 L/ha	1.67 ml/L (1/4 rate)
11	Primo Maxx II	Trinexapac-ethyl	Drench**	1.0 L/ha	3.33 ml/L (1/2 rate)
12	Moddus - **1 app only**	Trinexapac-ethyl	Drench**	0.15 L/ha	0.5 ml/L (1/4 rate)
13	Moddus - **1 app only**	Trinexapac-ethyl	Drench**	0.3 L/ha	1 ml/L (1/2 rate)
14	Pirouette	Paclobutrazol	Spray	0.3 L/ha	1 ml/L
15	Pirouette	Paclobutrazol	Drench	0.3 L/ha	1 ml/L

*Foliar sprays applied in 300 L water/ha. Drenches were applied by hand with a watering can with a rose head fitting, at 10% of the pack volume. ** Treatments applied under experimental permit.

Table 10. PGR product and treatment list 2018 – Pansy

Trt No.	Product	Active ingredient	Application method*	Dose rate (L/ha)	Dose rate (ml/L)
1	Water control	N/A	Spray	N/A	N/A
2	HDC P005	-	Spray**	0.505 L/ha	1.68 ml/L (3/4 rate)
3	HDC P005	-	Spray**	0.675 L/ha	2.25 ml/L (full rate)
4	HDC P005	-	Drench**	0.337 L/ha	1.12 ml/L (1/2 rate)
5	HDC P005	-	Drench**	0.505 L/ha	1.68 ml/L (3/4 rate)
6	Terpal	Ethephon + mepiquat chloride	Spray**	1.0 L/ha	3.33 ml/L (1/2 rate)
7	Terpal	Ethephon + mepiquat chloride	Spray**	1.5 L/ha	5 ml/L (3/4 rate)
8	Pirouette	Paclobutrazol	Spray	0.3 L/ha	1 ml/L
9	Pirouette	Paclobutrazol	Drench	0.3 L/ha	1 ml/L

*Foliar sprays applied in 300 L water/ha. Drenches were applied by hand with a watering can with a rose head fitting, at 10% of the pack volume. ** Treatments applied under experimental permit.

Table 11. PGR product and treatment list 2018 – *Osteospermum*

Trt No.	Product	Active ingredient	Application method*	Dose rate (L/ha)	Dose rate (ml/L)
1	Water control	N/A	Spray	N/A	N/A
2	HDC P005	-	Spray**	0.675 L/ha	2.25 ml/L (full rate)
3	Terpal	Ethephon + mepiquat chloride	Spray**	2.0 L/ha	6.67 ml/L (full rate)
4	Regalis Plus - **1 app only**	Prohexadione	Spray	1.25 L/ha	4.17 ml/L (full rate)
5	Primo Maxx II	Trinexapac-ethyl	Spray	2.0 L/ha	6.67 ml/L (full rate)
6	Moddus - **1 app only**	Trinexapac-ethyl	Spray	0.6 L/ha	2 ml/ L (full rate)
7	Pirouette	Paclobutrazol	Spray	0.3 L/ha	1 ml/L

*Foliar sprays applied in 300 L water/ha. Drenches were applied by hand with a watering can with a rose head fitting, at 10% of the pack volume. ** Treatments applied under experimental permit.

No PGRs were applied to the young plants prior to dispatch or transplant. Plants were monitored for pests and diseases throughout the trial. No insecticides or fungicides were applied to the trial.

Trial design and statistical analysis

Each plant species was set-out separately, and treatments were arranged in a randomised plot design with either nine treatments (*Dianthus* and Pansy), 15 treatments (Geranium) or seven treatments (*Osteospermum*). Within each trial there were three replicate blocks, with an overall total of 1440 plants (36 per variety, per treatment). Plots consisted of two six-packs (12 plants).

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

Assessments

Prior to transplant, plug root development (**Table 12**), plant quality (**Table 13**), and height were assessed. Phytotoxicity was assessed from the first treatment application onwards (**Table 14**).

Inspections and assessments are summarised in **Table 15** and below.

Table 12. 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 100% of plug

Table 13. Plant quality scores

Score	Definition
0	Dead
1	Very poor quality
2	Poor quality
3	Good quality, some damage visible
4	Good quality, very little damage
5	Excellent quality, no damage visible

Table 14. Phytotoxicity scores

Score	Definition
0	Dead
1	Nearly dead
2	Severely damaged / reduced growth / lots of discolouration
3	Damaged / reduced growth / some discolouration
4	Damaged / reduced growth
5	Slightly damaged / stunting
6	Very slightly damaged / slight yellowing
7	Very slightly damaged but still commercially acceptable
8	Commercially acceptable - barely affected
9	Comparable with control

Table 15. Summary of bedding and pot plant trial inspections and assessments, 2018

Date	Week no.	Action	Assessment
22 May	21	Bedding transplanted trials set out	Root development score, plant quality score, plant height (mm)
29 May	22	Pre-treatment 1 assessment.	Plant height (mm), plant quality score
08 June	23	Pre-treatment 2 assessment	Plant quality score, phytotoxicity score, plant height (mm)
18 June	25	Post treatment 2 assessment	Plant quality score, phytotoxicity score, plant height (mm), no. of plants in flower

Results

The effect of each PGR treatment on the height, growth, quality and flowering of the four plant species included in the trial is compared with that of the untreated control. The effects of the different treatments is presented below including a summary listed by plant species. Temperature and humidity was monitored throughout the trial (**Appendix 1**).

All plants obtained for the trial were of good quality prior to transplant.

Plant height and growth

Plant height graphs are presented in **Appendix 2**. Plant growth between transplant and the final assessment, with a calculation of the percentage height difference compared with the untreated control are presented in **Table 16** - **Table 19**. It should be noted that the focus is on products that will control plants sufficiently to keep them within the required height specification.

The treatment effects on plant height and growth varied between plant species and application method. Spray treatments were generally less effective than drench treatments in controlling plant height.

Dianthus

All treatments significantly controlled height (**Table 16**, $p < 0.001$), apart from the Pirouette spray at 0.3 L/ha, where the plants were taller than the untreated control by week 25. However, the effect of these treatments was strong, particularly the Primo Maxx II treatments and the Pirouette drench.

Table 16. *Dianthus*: average plant height, growth (height increase from transplant) and average height reduction relative to the untreated control

	Treatment	Application method and no. of treatments*	Ave. height (mm)	Ave. growth (mm)	Height change (%)
1	Water control	Spray x 2	111.7	37.9	-
2	HDC P005 0.505 L/ha	Spray x 2	75.3	2.1	-94%
3	HDC P005 0.675 L/ha	Spray x 2	80.3	10.7	-72%
4	HDC P005 0.337 L/ha	Drench x 2	76.3	4.3	-89%
5	HDC P005 0.505 L/ha	Drench x 2	76.2	4.7	-88%
6	Primo Maxx II 1.0 L/ha	Drench x 2	65.0	3.2	-92%
7	Primo Maxx II 1.5 L/ha	Drench x 2	71.1	2.9	-92%
8	Pirouette 0.3 L/ha	Spray x 2	116.3	42.6	13%
9	Pirouette 0.3 L/ha	Drench x 2	65.5	4.7	-88%
	s.e.d. l.s.d. F pr		9.45 20.14 <0.001	n/a	n/a
	Values highlighted red are significantly different to the untreated control.				

Final assessment date was 18 June 2018, week 25, 20 DAT (days after first treatment). Height specification for pack bedding is 80 mm – 100 mm.

Geranium

All treatments controlled Geranium growth to some degree. There were significant differences between treatments (**Table 17**, p<0.001). Plants treated with Terpal (both drenches), Regalis Plus (both drenches), Primo Maxx II (1.0 L/ha drench), Moddus (0.3 L/ha drench) and Pirouette (0.3 L/ha drench) were significantly shorter than the water control. However, these plants were very compact, with the dose rates used proving too high for Geranium. Although not significantly different to the water control, the Terpal sprays (1.0 L/ha and 0.5 L/ha) both appeared to provide good growth control.

Table 17. Geranium: average plant height, growth (height increase from transplant) and average height reduction relative to the untreated control

	Treatment	Application method and no. of treatments*	Ave. height (mm)	Ave. growth (mm)	Height change (%)
1	Water control	Spray x 2	65.0	33.0	-
2	HDC P005 0.169 L/ha	Drench x 2	58.3	10.5	-68%
3	HDC P005 0.337 L/ha	Drench x 2	53.3	9.8	-70%
4	Terpal 1.0 L/ha	Spray x 2	57.2	19.0	-42%
5	Terpal 0.5 L/ha	Spray x 2	64.2	17.7	-46%
6	Terpal 0.5 L/ha	Drench x 2	41.3	12.7	-62%
7	Terpal 1.0 L/ha	Drench x 2	33.2	3.5	-89%
8	Regalis Plus 0.31 L/ha	Drench x 1	37.0	-2.0	-106%
9	Regalis Plus 0.62 L/ha	Drench x 1	29.5	-6.0	-118%
10	Primo Maxx II 0.5 L/ha	Drench x 2	51.5	16.3	-51%

11	Primo Maxx II 1.0. L/ha	Drench x 2	35.0	-0.3	-101%
12	Moddus 0.15 L/ha	Drench x 1	54.5	18.3	-44%
13	Moddus 0.3 L/ha	Drench x 1	41.8	6.0	-82%
14	Pirouette 0.3 L/ha	Spray x 2	65.7	31.2	-6%
15	Pirouette 0.3 L/ha	Drench x 2	39.8	6.0	-82%
	s.e.d.		5.82		
	l.s.d.		11.92	n/a	n/a
	F pr		<0.001		
	Values highlighted red are significantly different to the untreated control.				

Final assessment date was 18 June 2018, week 25, 20 DAT (days after first treatment). Height specification for pack bedding is 40 – 80 mm.

Pansy

While height of the Pansy plants was controlled by the majority of treatments (apart from the Terpal spray at 1.0 L/ha and the Pirouette spray at 0.3 L/ha), growth was controlled by the HDC P005 (0.505 L/ha) and Pirouette (0.3 L/ha) drenches only. The only treatment where height was significantly less than the water only control was the Pirouette drench (0.3 L/ha, **Table 18**, p =0.024), where the plants were too compact.

Table 18. Pansy: average plant height, growth (height increase from transplant) and average height change relative to the untreated control

	Treatment	**Application method and no. of treatments***	**Ave. height (mm)**	**Ave. growth (mm)**	**Height change (%)**
1	Water control	Spray x 2	40.8	10.3	-
2	HDC P005 0.505 L/ha	Spray x 2	35.0	10.7	3%
3	HDC P005 0.675 L/ha	Spray x 2	40.3	13.3	29%
4	HDC P005 0.337 L/ha	Drench x 2	40.5	13.7	32%
5	HDC P005 0.505 L/ha	Drench x 2	37.8	5.7	-45%
6	Terpal 1.0 L/ha	Spray x 2	48.0	17.8	73%
7	Terpal 1.5 L/ha	Spray x 2	37.0	10.7	3%
8	Pirouette 0.3 L/ha	Spray x 2	55.2	24.0	132%
9	Pirouette 0.3 L/ha	Drench x 2	22.2	-11.5	-211%
	s.e.d.		7.18		
	l.s.d.		15.23	n/a	n/a
	F pr		0.024		
	Values highlighted red are significantly different to the untreated control.				

Final assessment date was 18 June 2018, week 25, 20 DAT (days after first treatment). Height specification for pack bedding is 40 – 80 mm.

Osteospermum

There were no significant differences between treatments for height control for the *Osteospermum* (**Table 19**). However, HDC P005, Primo Maxx II and Regalis Plus applied as sprays did appear to provide varying degrees of growth control (not quite significant at 5% probability level). Moddus as a spray (0.6 L/ha) was the only treatment where plants were

taller than the untreated control at the end of the trial. Drenches were not tested in this trial, but it is likely that greater control may have been achieved with drenches of some products.

Table 19. *Osteospermum*: average plant height, growth (height increase from transplant) and average height reduction relative to the untreated control

	Treatment	Application method and no. of treatments*	Ave. height (mm)	Ave. growth (mm)	Height change (%)
1	Water control	Spray x 2	59.7	16.3	-
2	HDC P005 0.675 L/ha	Spray x 2	42.0	1.8	-89%
3	Terpal 2.0 L/ha	Spray x 2	53.8	18.2	11%
4	Regalis Plus 1.25 L/ha	Spray x 1	46.2	8.3	-49%
5	Primo Maxx II 2.0 L/ha	Spray x 2	52.7	14.2	-13%
6	Moddus 0.6 L/ha	Spray x 1	65.3	22.7	39%
7	Pirouette 0.3 L/ha	Spray x 2	58.2	16.2	-1%
	s.e.d. l.s.d. F pr		6.77 14.75 0.061	n/a	n/a
	None of the treatments were significantly different to the untreated control.				

Final assessment date was 18 June 2018, week 25, 20 DAT (days after first treatment). Height specification for pack bedding is 40 – 80 mm.

Phytotoxicity

Dianthus

At the first assessment 10 days after first treatment (10 DAT), there were significant differences between treatments (**Table 20,** $p < 0.001$), with phytotoxicity visible as small yellow spots on the foliage in the high rate HDC P005 (0.505 L/ha) drench treatment, and as slight yellow streaking and twisted foliage in the high rate Primo Maxx II (1.0 L/ha) drench treatment. Whilst the plants appeared to have grown away from this by the next assessment (20 DAT), once all the plants had flowered in week 30 phytotoxicity was more evident. All HDC P005 treatments caused bleaching to the plants, although less severe in the spray treatments. The petals were severely bleached in the drench treatments, rendering the flowers white (**Figure 2**). Both Primo Maxx II treatments also severely bleached the flowers, this treatment also caused some foliar chlorosis (**Figure 2**). Pirouette as a spray did not cause any phytotoxicity, and although the drench treatment did not cause any bleaching, the plants were very compact, and flowered very low, suggesting the dose rate was too high, resulting in unmarketable plants (**Figure 3**).

Table 20. *Dianthus* – average phytotoxicity scores

	Treatment	Application method and no. of treatments*	Phyto 08.06.18 10 DAT	Phyto 18.06.18 20 DAT	Phyto 24.07.18 56 DAT*
1	Water control	Spray x 2	9.0	9.0	9.0
2	HDC P005 0.505 L/ha	Spray x 2	9.0	8.7	6.0
3	HDC P005 0.675 L/ha	Spray x 2	9.0	7.7	6.0
4	HDC P005 0.337 L/ha	Drench x 2	9.0	9.0	2.0
5	HDC P005 0.505 L/ha	Drench x 2	7.3	9.0	2.0
6	Primo Maxx II 1 L/ha	Drench x 2	9.0	9.0	1.0
7	Primo Maxx II 1.5 L/ha	Drench x 2	8.3	9.0	1.0
8	Pirouette 0.3 L/ha	Spray x 2	9.0	9.0	9.0
9	Pirouette 0.3 L/ha	Drench x 2	9.0	9.0	4.0
	s.e.d.		0.2291	0.657	n/a
	l.s.d.		0.4856	1.394	n/a
	F pr		<0.001	0.529	n/a
	Values highlighted red are significantly different to the untreated control. Values highlighted blue were unmarketable in week 30.				

*Assessment was observational only, statistics are not available.

Assessment dates were prior to second treatment (08 June 2018, week 23, 10 DAT), at the final assessment (18 June 2018, week 25, 20 DAT) and in week 30 (24 July 2018, 56 DAT). Phytotoxicity score: scale of 0-9, where 0 = dead; 5 = slight damage, slight yellowing; 9 = comparable with untreated control. DAT = days after first treatment

Untreated (above) vs. HDC P005 0.505 L/ha spray (below)	Untreated (above) vs. HDC P005 0.505 L/ha drench (below)	Untreated (above) vs. Primo Maxx II 1.0 L/ha drench (below)

Figure 2. Phytotoxicity on *Dianthus* 'Festival' violet caused by HDC P005 and Primo Maxx II in week 30, 24 July 2018. Note the bleaching of flower colour following HDC P005 drench and Primo Maxx II drench treatments

Untreated (above) vs. Pirouette 0.3 L/ha spray (below)	Untreated (above) vs. Pirouette 0.3 L/ha drench (below)

Figure 3. Stunted growth on *Dianthus* 'Festival' violet caused by Pirouette drench (image right) in week 30, 24 July 2018.

Geranium

Phytotoxicity was evident at the first assessment date 10 DAT, and differences between treatments were statistically significant (**Table 21**, p <0.001). Both the Terpal drenches, the Regalis Plus drenches and the Primo Maxx II higher rate drench (1.0 L/ha) caused yellowing of the foliage, which continued to develop by the second assessment (20 DAT). Phytotoxicity was more noticeable across the majority of treatments once the plants had flowered (week 30). By week 30, only the Terpal sprays (1.0 L/ha and 0.5 L/ha) and the Pirouette spray (0.3 L/ha) had not caused any phytotoxicity, however flowering was delayed in the Terpal spray treatments. All other treatments caused petal bleaching varying from pale red, through to pink and white (**Figure 4**). The Terpal drench at 1.0 L/ha caused severe stunting with some plant death, and there was also some plant death in the high rate Regalis Plus drench treatment.

Table 21. Geranium – average phytotoxicity scores

	Treatment	**Application method and no. of treatments***	**Phyto 08.06.18 10 DAT**	**Phyto 18.06.18 20 DAT**	**Phyto 24.07.18 56 DAT***
1	Water control	Spray x 2	9.0	9.0	9.0
2	HDC P005 0.169 L/ha	Drench x 2	9.0	9.0	5.0
3	HDC P005 0.337 L/ha	Drench x 2	9.0	9.0	4.0
4	Terpal 1.0 L/ha	Spray x 2	9.0	8.7	8.0
5	Terpal 0.5 L/ha	Spray x 2	9.0	9.0	8.0
6	Terpal 0.5 L/ha	Drench x 2	6.7	5.0	4.0
7	Terpal 1.0 L/ha	Drench x 2	6.7	4.3	1.0

8	Regalis Plus 0.31 L/ha	Drench x 1	7.3	6.3	6.0
9	Regalis Plus 0.62 L/ha	Drench x 1	5.3	4.0	1.0
10	Primo Maxx II 0.5 L/ha	Drench x 2	9.0	9.0	3.0
11	Primo Maxx II 1.0 L/ha	Drench x 2	7.7	6.7	2.0
12	Moddus 0.15 L/ha	Drench x 1	9.0	8.3	4.0
13	Moddus 0.3 L/ha	Drench x 1	9.0	8.3	3.0
14	Pirouette 0.3 L/ha	Spray x 2	9.0	8.7	9.0
15	Pirouette 0.3 L/ha	Drench x 2	9.0	8.3	4.0
	s.e.d.		0.560	0.659	n/a
	l.s.d.		1.146	1.349	n/a
	F pr		<0.001	<0.001	n/a
	Values highlighted red are significantly different to the untreated control. Values highlighted blue were unmarketable in week 30.				

*Assessment was observational only, statistics are not available.

Assessment dates were prior to second treatment (08 June 2018, week 23, 10 DAT), at the final assessment (18 June 2018, week 25, 20 DAT) and in week 30 (24 July 2018, 56 DAT). Phytotoxicity score: scale of 0-9, where 0 = dead; 5 = slight damage, slight yellowing; 9 = comparable with untreated control. DAT = days after first treatment.

Untreated (above) vs. Terpal 0.5 L/ha spray (below)	Untreated (above) vs. Terpal 1.0 L/ha drench (below)	Untreated (above) vs. Primo Maxx II 0.5 L/ha drench (below)

Figure 4. Phytotoxicity on Geranium 'Horizon' red caused by Terpal and Primo Maxx II in week 30, 24 July 2018.

Pansy

Phytotoxicity was first observed on the plants treated with Pirouette as a drench 10 DAT. There was no evidence of petal or foliar bleaching, but there was distortion to the foliage; no other treatments resulted in phytotoxic symptoms. However, by the second assessment (20 DAT) phytotoxicity symptoms were more widespread, and at significant levels (**Table 22**, p <0.001, **Figure 5**). HDC P005 caused petal bleach at all rates, in both spray and drench treatments, and was noticeably more severe at the 0.505 L/ha drench rate, where flowers were bleached

yellow rather than red. The high rate spray (0.675 L/ha) also caused some yellow blotching to the foliage. Pirouette as a spray caused slight petal bleach and, as a drench, the plants were very compact, flower stem height was severely reduced, making them unmarketable.

By week 30, the plants treated with HDC P005 as a spray had recovered somewhat, and the new flowers coming through were no longer bleached. The drench treatments however remained yellow. The Pirouette treatments also remained slightly bleached, and the plants from the drench treatment were still very compact.

The Terpal did not cause phytotoxicity at either of the dose rates used.

Table 22. Pansy – average phytotoxicity scores

	Treatment	**Application method and no. of treatments***	**Phyto 08.06.18 10 DAT**	**Phyto 18.06.18 20 DAT**	**Phyto 24.07.18 56 DAT***
1	Water control	Spray x 2	9.0	9.0	9.0
2	HDC P005 0.505 L/ha	Spray x 2	8.7	4.3	7.0
3	HDC P005 0.675 L/ha	Spray x 2	9.0	3.7	7.0
4	HDC P005 0.337 L/ha	Drench x 2	9.0	4.7	4.0
5	HDC P005 0.505 L/ha	Drench x 2	9.0	3.7	3.0
6	Terpal 1.0 L/ha	Spray x 2	9.0	8.7	8.0
7	Terpal 1.5 L/ha	Spray x 2	9.0	7.3	7.0
8	Pirouette 0.3 L/ha	Spray x 2	9.0	7.0	6.0
9	Pirouette 0.3 L/ha	Drench x 2	6.0	5.0	2.0
	s.e.d.		0.2291	0.859	n/a
	l.s.d.		0.4856	1.821	n/a
	F pr		<0.001	<0.001	n/a
	Values highlighted red are significantly different to the untreated control. Values highlighted blue were unmarketable in week 30.				

*Assessment was observational only, statistics are not available.

Assessment dates were prior to second treatment (08 June 2018, week 23, 10 DAT), at the final assessment (18 June 2018, week 25, 20 DAT) and in week 30 (24 July 2018, 56 DAT). Phytotoxicity score: scale of 0-9, where 0 = dead; 5 = slight damage, slight yellowing; 9 = comparable with untreated control. DAT = days after first treatment.

HDC P005 0.675 L/ha spray | HDC P005 0.337 L/ha drench | Pirouette 0.3 L/ha spray

Figure 5. Phytotoxicity on Pansy 'Matrix' red blotch caused by HDC P005 and Pirouette in week 30, 24 July 2018.

Osteospermum

There was no sign of any phytotoxicity from any of the treatments on the *Osteospermum* at any of the assessment dates (**Table 23**). The foliage of the plants treated with Moddus appeared to be slightly paler at the 20 DAT assessment, but this was no longer visible by week 30. Plants were in flower by week 30 and there were no observable treatment effects on petal colour (**Figure 6**).

Table 23. *Osteospermum* – average phytotoxicity scores

	Treatment	**Application method and no. of treatments***	**Phyto 08.06.18 10 DAT**	**Phyto 18.06.18 20 DAT**	**Phyto 24.07.18 56 DAT***
1	Water control	Spray x 2	9.0	9.0	9.0
2	HDC P005 0.675 L/ha	Spray x 2	9.0	9.0	9.0
3	Terpal 2.0 L/ha	Spray x 2	9.0	9.0	9.0
4	Regalis Plus 1.25 L/ha	Spray x 1	9.0	9.0	9.0
5	Primo Maxx II 2.0 L/ha	Spray x 2	9.0	9.0	9.0
6	Moddus 0.6 L/ha	Spray x 1	9.0	8.3	9.0
7	Pirouette 0.3 L/ha	Spray x 2	9.0	9.0	9.0
	s.e.d. l.s.d. F pr		n/a n/a n/a	0.3563 0.7764 0.468	n/a n/a n/a
	None of the treatments were significantly different to the untreated control.				

*Assessment was observational only, statistics are not available.

Assessment dates were prior to second treatment (08 June 2018, week 23, 10 DAT), at the final assessment (18 June 2018, week 25, 20 DAT) and in week 30 (24 July 2018, 56 DAT). Phytotoxicity score: scale of 0-9, where 0 = dead; 5 = slight damage, slight yellowing; 9 = comparable with untreated control. DAT = days after first treatment.

Untreated (above) vs. Terpal 2.0 L/ha (below)	Untreated (above) vs. Primo Maxx II 2.0 L/ha (below)	Untreated (above) vs. Pirouette 0.3 L/ha (below)

Figure 6. *Osteospermum* 'Akila' purple treated with Terpal, Primo Maxx II and Pirouette in week 30, 24 July 2018.

Flowering

A full assessment of flowering was completed at the end of the trial in week 25 (18 June 2018). The plants were maintained until week 30 (24 July 2018) to see if any delayed treatments eventually came into flower.

In the *Dianthus* trial, significantly fewer flowers were produced in the HDC P005 and Primo Maxx II treatments (spray and a drench, **Table 24**, p =0.004) in week 25. For the Pirouette treatments, more open flowers were produced in the spray treatment than the water control by week 25, however fewer flowers were produced in the drench treatment than the untreated control.

Table 24. *Dianthus* – number of plants in flower at the final assessment date on 18 June 2018 (week 25, 20 DAT)

	Treatment	**Application method and no. of treatments***	**No in flower**
1	Water control	Spray x 2	2.3
2	HDC P005 0.505 L/ha	Spray x 2	0.3
3	HDC P005 0.675 L/ha	Spray x 2	0.3
4	HDC P005 0.337 L/ha	Drench x 2	0.0
5	HDC P005 0.505 L/ha	Drench x 2	0.3
6	Primo Maxx II 1.0 L/ha	Drench x 2	0.0
7	Primo Maxx II 1.5 L/ha	Drench x 2	0.3
8	Pirouette 0.3 L/ha	Spray x 2	3.7
9	Pirouette 0.3 L/ha	Drench x 2	0.7
	s.e.d.		0.816
	l.s.d.		1.731

	F pr		0.004
	Values highlighted red are significantly different to the untreated control.		

DAT = days after first treatment.

No Geraniums were in flower by the final assessment in week 25 (18 June 2018). In week 30 (24 July 2018), observations were made on flower development, and whether any of the treatments had delayed flowering, compared to the untreated control. For the majority of the treatments, there were no effects of the PGR on time to flower, flower size, or the number of plants in flower. However, both of the Terpal spray treatments delayed flowering and by week 30, these plants were only just starting to come into flower.

There was a significant effect on flowering in the pansy trial in week 25, with HDC P005 as both a spray and a drench at 0.505 L/ha producing more open flowers than the untreated control (**Table 25**, p =0.048). However, the flowers in the drench treatment were bleached, with yellow flowers rather than red. More open flowers were also produced in plots treated with HDC P005 as a spray at 0.675 L/ha, Terpal as a spray at 1 L/ha and Pirouette as both a spray and a drench at 0.3 L/ha.

Table 25. Pansy – number of plants in flower at the final assessment date on 18 June 2018 (week 25, 20DAT).

	Treatment	**Application method and no. of treatments***	**No in flower**
1	Water control	Spray x 2	1.3
2	HDC P005 0.505 L/ha	Spray x 2	4.7
3	HDC P005 0.675 L/ha	Spray x 2	2.0
4	HDC P005 0.337 L/ha	Drench x 2	1.3
5	HDC P005 0.505 L/ha	Drench x 2	4.7
6	Terpal 1.0 L/ha	Spray x 2	3.0
7	Terpal 1.5 L/ha	Spray x 2	1.3
8	Pirouette 0.3 L/ha	Spray x 2	3.7
9	Pirouette 0.3 L/ha	Drench x 2	4.0
	s.e.d.		1.244
	l.s.d.		2.636
	F pr		0.048
	Values highlighted red are significantly different to the untreated control.		

DAT = days after first treatment.

The *Osteospermum* were not in flower at the time of the final assessment in week 25 (18 June 2018). In week 30 (24 July 2018), observations were made on flower development, and whether any of the treatments had delayed flowering, compared to the untreated control. There was no noticeable effect of any of the treatments on the number of plants in flower or time to flowering.

Summary of results by plant species

Dianthus 'Festival' violet

- Height was significantly controlled by all treatments (apart from the Pirouette spray, 0.3 L/ha), but the effect was too strong and the plants were too compact. Reducing the dose rate, or the drench volume should provide acceptable height control.
- While Pirouette applied as a spray at 0.3 L/ha did not control growth, it is likely to prove effective with an adjustment to the dose rate. Pirouette did not cause phytotoxicity.
- There were more plants in flower in the Pirouette spray treatment compared to the untreated control by week 25; all other treatments had fewer plants in flower.
- All rates of HDC P005 and Primo Maxx II, as sprays or drenches, caused phytotoxicity, with foliage and / or petal bleach.

Geranium 'Horizon' red

- Spray treatments of Terpal at both rates tested were effective in controlling growth compared with the untreated control; Pirouette applied as a spray was less effective at the dose rates used.
- Drench treatments of Terpal, Regalis Plus, Primo Maxx II (high rate), Moddus (high rate) and Pirouette were all too strong; the plants were too compact.
- Sprays of Terpal and Pirouette did not cause phytotoxicity. All other treatments caused foliar and petal bleach. The high rate drenches of Terpal and Regalis Plus caused some plant death.
- Flowering was delayed in the Terpal spray treatments only.

Pansy 'Matrix' red blotch

- Although plants treated with Terpal (both spray dose rates) were shorter than the control, and did not cause phytotoxicity, they did not appear to provide sufficient growth control in this trial. However, with an adjustment to spray rates, Terpal may provide effective treatments.
- Similarly, HDC P005 (0.505 L/ha) applied as a spray may prove effective with an adjustment to dose rates, but it should be noted HDC P005 applied as a spray caused petal bleach on the early flowers; later flowers were not affected.
- The Pirouette spray rates were too low to control growth, while the drench treatment 0.3 L/ha was too strong.
- The HDC P005 (0.505 L/ha) drench caused severe phytotoxicity with petal bleach, while the lower dose rate drench 0.337 L/ha was not effective, but also caused phytotoxicity.

- None of the treatments significantly reduced flowering compared with the untreated control.

Osteospermum 'Akila' purple

- The majority of treatments provided some growth control compared with the untreated control, most notably HDC P005 and Regalis Plus.
- The Moddus spray did not control height.
- None of the treatments caused phytotoxicity, and did not adversely affect either flowering time or the number of plants in flower.

Discussion

Terpal was perhaps the most promising product of those tested, controlling growth of all subjects when applied as a spray. However, the drench rate used was too strong on Geranium, producing plants that were too small, and resulting in some plant death. The spray treatment delayed flowering in Geranium but no other species.

HDC P005, applied both as a spray and a drench caused phytotoxicity to *Dianthus*, and as a drench to Geranium and Pansy. When applied as a spray, however, it achieved useful effects on Osteospermum, and showed promise on Pansy without causing phytotoxicity.

Although only one application was made of Regalis Plus and Moddus, these treatments were too strong when applied as a drench on Geranium. However, when Regalis Plus was applied as a spray on *Osteospermum*, it gave good height control with no phytotoxicity. Moddus did not control *Osteospermum* height when applied as a spray. Regalis Plus may prove useful as part of a PGR spray programme, particularly for plant species with a longer production time such as *Osteospermum.*

Primo Maxx II as a drench caused severe phytotoxicity to *Dianthus* and Geranium at the rates tested, although it appeared to be safe on *Osteospermum* in this trial and controlled height reasonably well.

Pirouette as a drench was too strong, causing phytotoxicity on *Dianthus,* Geranium and Pansy, and height control was too strong at the rates used. There is the potential to reduce the rate further to achieve good growth control without phytotoxicity.

Conclusions

- The most promising product on *Dianthus* was Pirouette, however further work is needed to determine the most effective spray rate for this species.
- Terpal applied as a spray was the most promising PGR on Geranium and has potential for use at rates between 1.0 – 1.5 L/ha.

- Terpal and HDC P005 applied as sprays had some potential on Pansy, however further work may be required to find the most appropriate rates. Given the fact that HDC P005 can cause petal bleach on Pansy, Terpal is likely to be a safer option.
- All of the new products produced too strong an effect when applied as drenches at the rates tested. Pirouette (paclobutrazol) was also too strong when applied as a drench, highlighting the importance of not applying high rates when using PGRs as drenches.
- *Osteospermum* were somewhat responsive to foliar sprays, with no phytotoxicity caused; however drenches are likely to be more effective on this crop – further work is required to determine which PGRs deliver the best and safest results.
- Growers should note that that the spray rate used in the trials (300 litres water per hectare) may be lower than the rate they currently use and as such application rates or volumes may need to be adjusted to maintain the same application rate of active ingredient. Test new or unfamiliar products on a small number of plants before large scale use.
- Growers should familiarise themselves with and adhere to product labels, approvals and Extensions of Approval for Minor Use (EAMUs) prior to use. Note that a number of the treatments included in this trial were carried out under experimental permit and are not currently authorised for nursery use.

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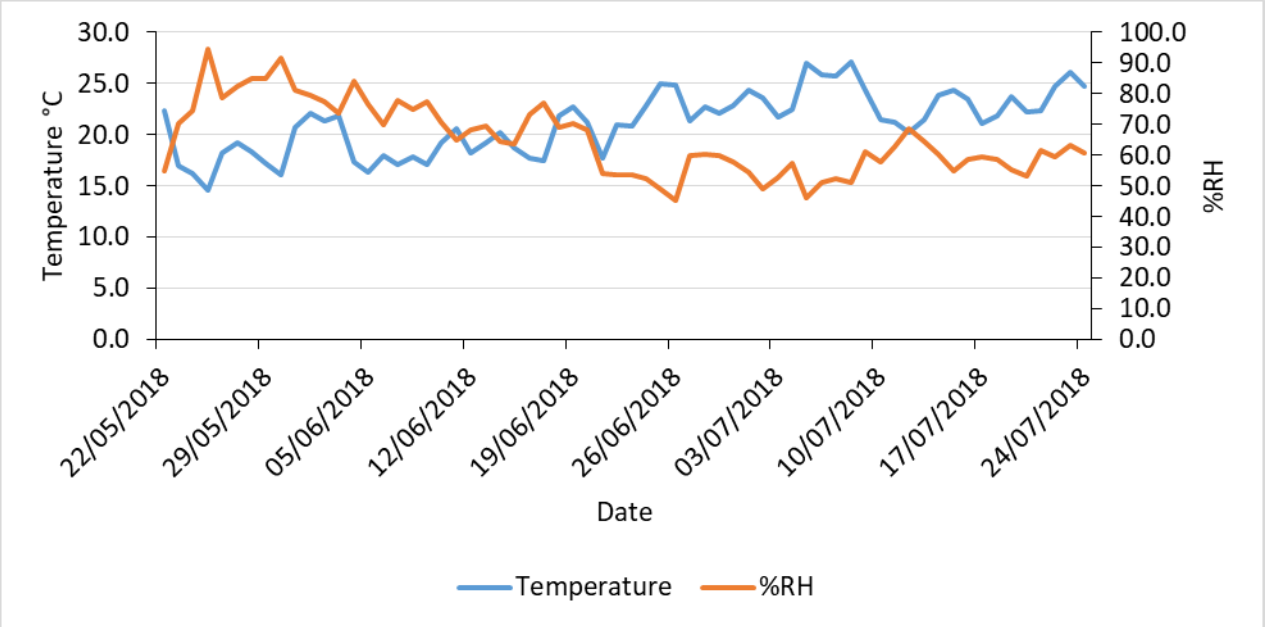
Appendices

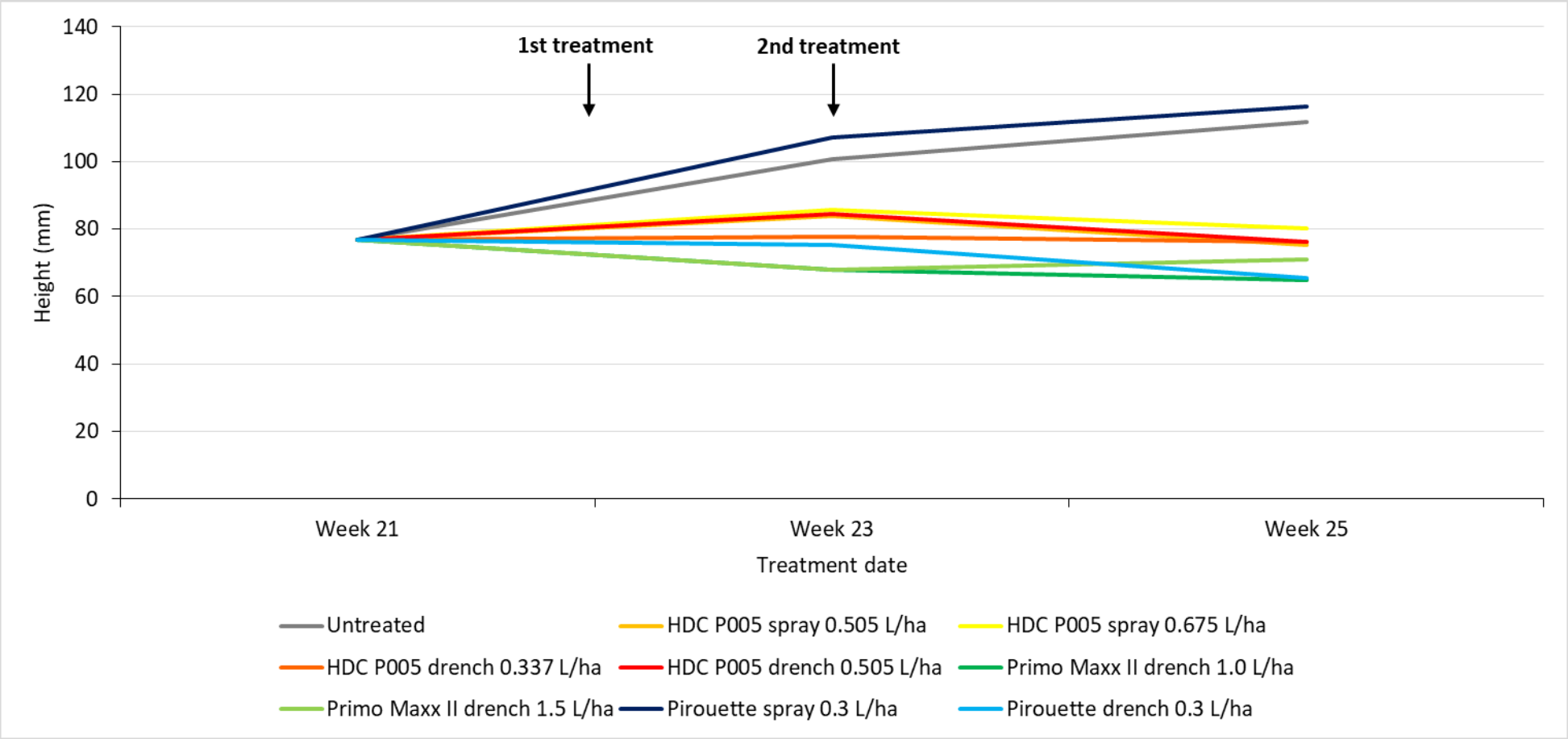
Appendix 1

Glasshouse temperature and humidity during the PGR bedding plants trial.



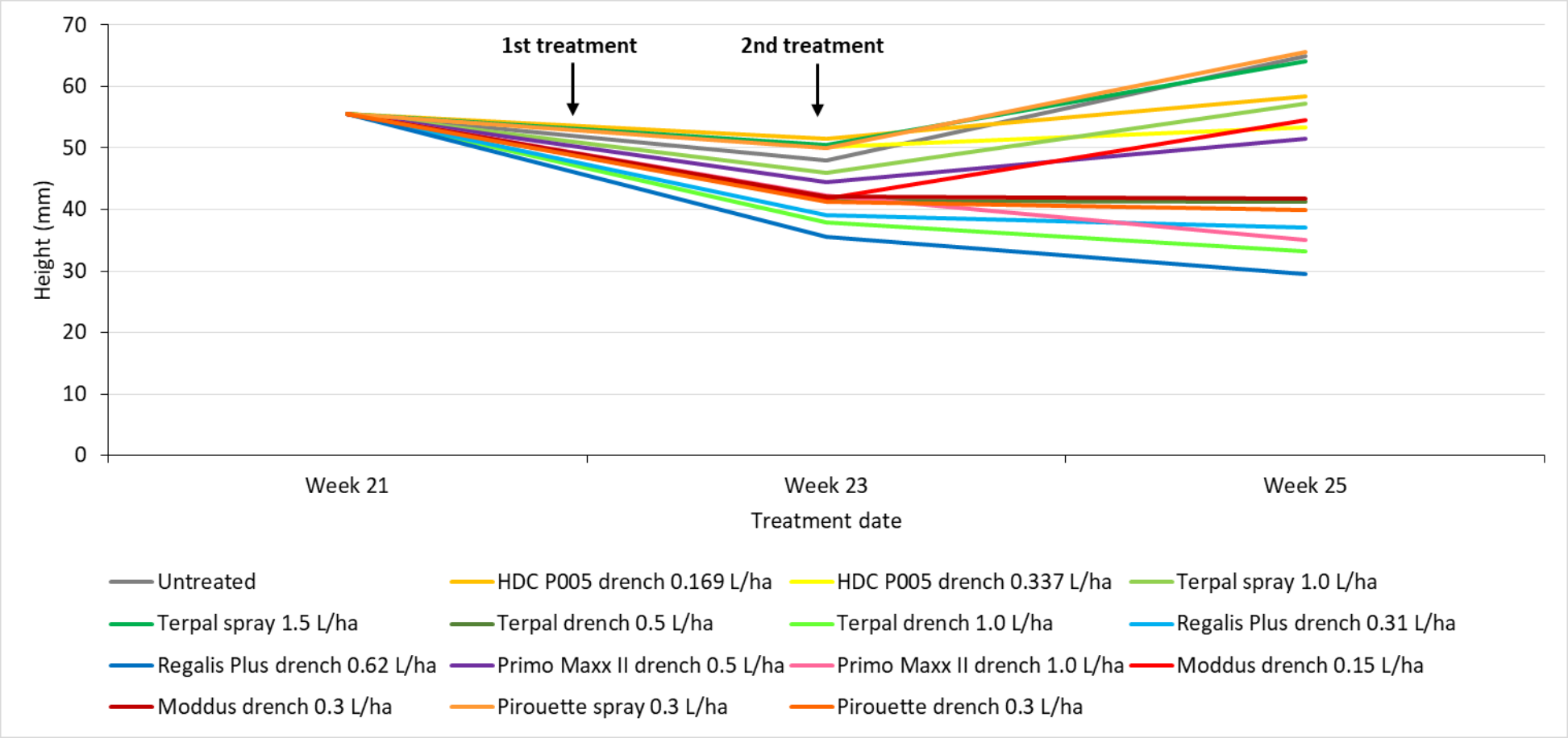
Appendix 2

Plant height - *Dianthus*



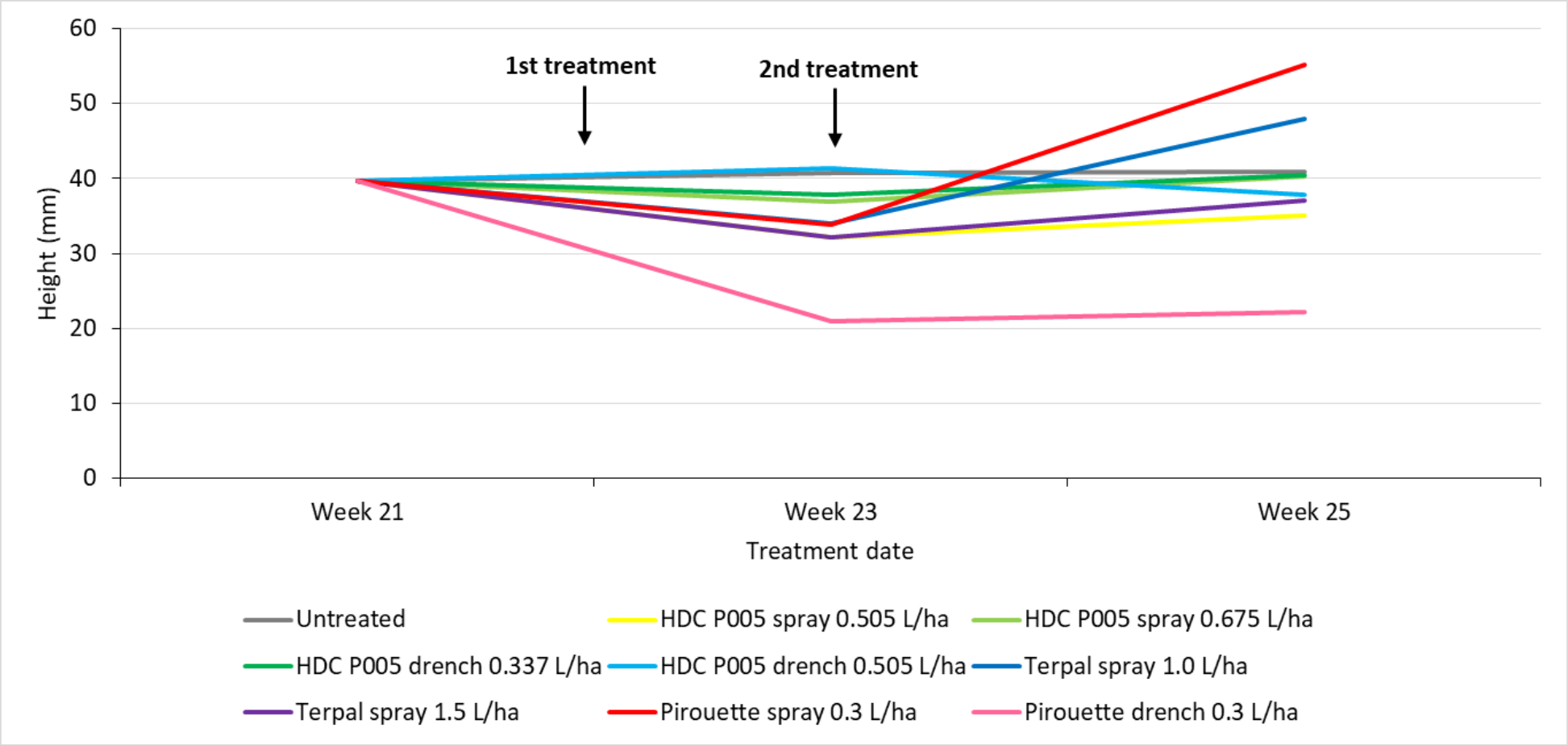
A. *Dianthus* 'Festival' violet height (mm). Height was assessed at transplant (22 May 2018, week 21), prior to the second treatment on 08 June 2018 (week 23, 10 DAT) and on 18 June 2018 (week 25, 20 DAT). Plants were treated with two sprays and two drenches of all treatments. Apparent decreases in plant height are the effect of using mean heights of multiple plants.

Plant height - Geranium



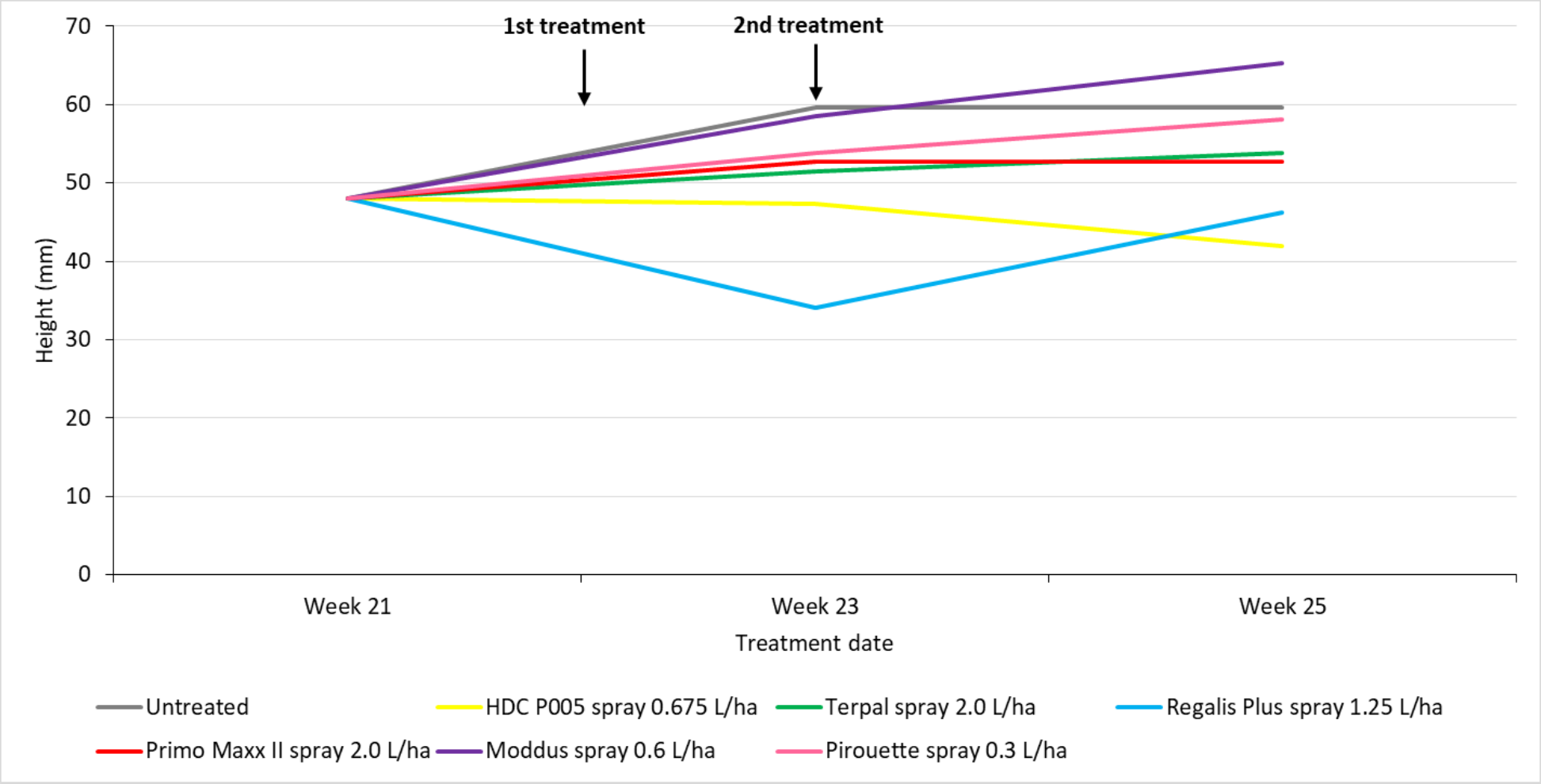
B. Geranium 'Horizon' red height (mm). Height was assessed at transplant (22 May 2018, week 21), prior to the second treatment on 08 June 2018 (week 23, 10 DAT) and on 18 June 2018 (week 25, 20 DAT). Plants were treated with one drench of Moddus and Regalis Plus (week 22); two sprays and two drenches of all other treatments. Apparent decreases in plant height are the effect of using mean heights of multiple plants.

Plant height - Pansy



C. Pansy 'Matrix' red blotch height (mm). Height was assessed at transplant (22 May 2018, week 21), prior to the second treatment on 08 June 2018 (week 23, 10 DAT) and on 18 June 2018 (week 25, 20 DAT). Plants were treated with two sprays and two drenches of all treatments. Apparent decreases in plant height are the effect of using mean heights of multiple plants.

Plant height - *Osteospermum*



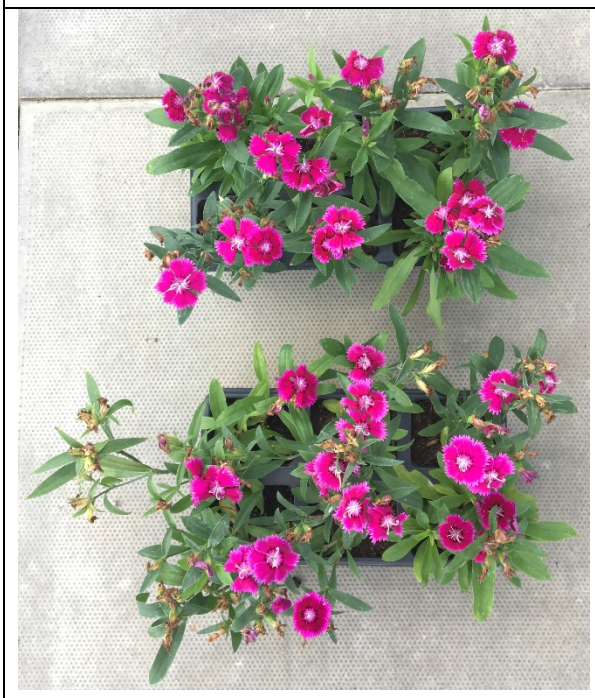
D. *Osteospermum* 'Akila' purple height (mm). Height was assessed at transplant (22 May 2018, week 21), prior to the second treatment on 08 June 2018 (week 23, 10 DAT) and on 18 June 2018 (week 25, 20 DAT). Plants were treated with one spray of Moddus and Regalis Plus (week 22); two sprays of all other treatments. Apparent decreases in plant height are the effect of using mean heights of multiple plants.

Appendix 3

Photographic records of treatment effects.

A. *Dianthus* ‘Festival’ violet. Effects of treatments compared with the untreated control, week 30 2018

	
Untreated (top) vs. HDC P005 0.505 L/ha Spray	Untreated (top) vs. HDC P005 0.675 L/ha Spray
	
Untreated (top) vs. HDC P005 0.337 L/ha Drench	Untreated (top) vs. HDC P005 0.505 L/ha Drench

	
Untreated (top) vs. Primo Maxx II 1.0 L/ha Drench	Untreated (top) vs. Primo Maxx II 1.5 L/ha Drench
	
Untreated (top) vs. Pirouette 0.3 L/ha Spray	Untreated (top) vs. Pirouette 0.3 L/ha Drench

B. Geranium ‘Horizon’ red. Effects of treatments compared with the untreated control, week 30 2018

	
Untreated (top) vs. HDC P005 0.169 L/ha Drench	Untreated (top) vs. HDC P005 0.337 L/ha Drench
	
Untreated (top) vs. Terpal 1.0 L/ha Spray	Untreated (top) vs. Terpal 1.5 L/ha Spray

	
Untreated (top) vs. Terpal 0.5 L/ha Drench	Untreated (top) vs. Terpal 1.0 L/ha Drench
	
Untreated (top) vs. Regalis Plus 0.31 L/ha Drench	Untreated (top) vs. Regalis Plus 0.62 L/ha Drench

	
Untreated (top) vs. Primo Maxx II 0.5 L/ha Drench	Untreated (top) vs. Primo Maxx II 1.0 L/ha Drench
	
Untreated (top) vs. Moddus 0.15 L/ha Drench	Untreated (top) vs. Moddus 0.3 L/ha Drench

	
Untreated (top) vs. Pirouette 0.3 L/ha Spray	Untreated (top) vs. Pirouette 0.3 L/ha Drench

C. Pansy ‘Matrix’ red blotch. Effects of treatments compared with the untreated control, week 25 2018

	
Untreated (top) vs. HDC P005 0.505 L/ha Spray	Untreated (top) vs. HDC P005 0.675 L/ha Spray
	
Untreated (top) vs. HDC P005 0.337 L/ha Drench	Untreated (top) vs. HDC P005 0.505 L/ha Drench

	
Untreated (top) vs. Terpal 1.0 L/ha Spray	Untreated (top) vs. Terpal 1.5 L/ha Spray
	
Untreated (top) vs. Pirouette 0.3 L/ha Spray	Untreated (top) vs. Pirouette 0.3 L/ha Drench

D. *Osteospermum* ‘Akila’ purple. Effects of treatments compared with the untreated control, week 30 2018

	
Untreated (top) vs. HDC P005 0.675 L/ha Spray	Untreated (top) vs. Terpal 2.0 L/ha Spray
	
Untreated (top) vs. Regalis Plus 1.25 L/ha Spray	Untreated (top) vs. Primo Maxx II 2.0 L/ha Spray

	
Untreated (top) vs. Moddus 0.6 L/ha Spray	Untreated (top) vs. Pirouette 0.3 L/ha Spray