Project title:	The Bedding and Pot Plant Centre – new product opportunities for bedding and pot plant growers. ***Objective 1****. To evaluate plant growth regulators for use on bedding plants pre- and post-transplant*
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Project leader:	Dr Jill England, ADAS Boxworth
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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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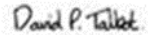
Signature  Date 30 April 2020

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Headline

- Effective pre- and post-transplant plant growth regulator spray programmes were identified for *Cosmos* 'Sonata' carmine, *Dianthus* 'Festival' violet, Geranium 'Horizon' red and *Osteospermum* 'Akila' purple.
- Primo Maxx II (trinexapac-ethyl) is not recommended for use on Cosmos. Moddus (trinexapac-ethyl) is not recommended for use on Geranium.

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 are also included in the programme.

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

This is the Bedding and Pot Plant Centre report for:

***Objective 1**. To evaluate plant growth regulators for use on bedding plants pre- and post-transplant*

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 label restrictions and loss of approval for the use of chlormequat based products in protected ornamental plant production. Growers apply PGRs as drenches, sometimes during propagation, and have developed application rates specific to the crops they grow under the specific growing conditions on their nurseries. This trial re-examines PGRs previously tested at the BPPC as spray programmes for use from plug stage to marketing.

A range of plant growth regulators with or without the adjuvant (Stena) was trialled on four seed-raised bedding plant species (*Cosmos* 'Sonata' carmine, *Dianthus* 'Festival' violet, Geranium 'Horizon' red and *Osteospermum* 'Akila' purple). All species were treated with PGRs in the plug tray two days prior to transplant using either a spray, sprench (5% of plug tray volume) or drench (10% of plug tray volume) at a water rate of 300 L/ha. Plants were then

transplanted in week 21 (*Dianthus* and Geranium), week 29 (*Cosmos*) and week 31 (*Osteospermum*) at Baginton Nurseries, using standard 6-packs for the *Dianthus* and Geranium, and jumbo 6-packs for the *Cosmos* and *Osteospermum*.

Products tested are listed in **Table 1**. Sprays (pre- and post-transplant) 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). Pre-transplant sprenches (5% of plug tray volume) were applied using a hand-held mister and pre-transplant drenches (10% of plug tray volume) were applied using a syringe. Post-transplant sprenches (5% of pack volume) were applied by hand using a backpack and single nozzle lance, with a 02f110 nozzle. All treatments were applied during early morning or late afternoon with shade screens over the crop prior to treatment. Treatments were applied as a foliar spray or sprench at one week post-transplant, and then after a further 10 days minimum if deemed necessary, up to a maximum of two applications post-transplant. An overspray of Bonzi (2.0 ml/L) was applied on 21 August 2019 to prevent plants from becoming stretched before flowering.

Table 1. Approval status of PGR products tested in 2019

Product	Active ingredient	Approval status
Bonzi	paclobutrazol	On-label approval
Canopy (MAPP 16314)*	mepiquat (as chloride) and prohexadione calcium	EAMU 4484/19
Dazide Enhance (MAPP 16092)	daminozide	On-label approval
Moddus (MAPP 15151)	trinexapac-ethyl	EAMU 3062/10
Pirouette (MAPP 17203)	paclobutrazol	On-label approval (spray application) and EAMU 1269/17 (drench application)
Primo Maxx II (MAPP 17509)	trinexapac-ethyl	EAMU 0621/18
Regalis Plus (MAPP 16485)	prohexadione	EAMU 2153/19
Stena (ADJ 0895)+	polyglycerol	Adjuvant
Terpal (MAPP 16463)	ethephon + mepiquat chloride	EAMU 0151/18

*Canopy applied under experimental permit in 2019 and coded as HDC P005 in previous reports. Note that rates used in the trial may be higher than permitted in EAMU 4484/19 (issued 18 December 2019).
+Stena applied under experimental permit in 2019 and coded as HDC P006; authorisation issued October 2019.

A number of PGRs, either alone or in combination provided effective growth control on the species included in this trial, when applied pre- and post-transplant, although some treatments

also caused paling of the foliage / flowers. All of the products tested, except for Primo Maxx II, featured in spray programmes that had a significant effect on plant growth compared with the water only control without adversely affecting plant quality.

***Cosmos* 'Sonata' carmine**

The *Cosmos* trial received two post-transplant PGR applications. A number of PGR programmes proved effective, producing plants within or close to a height specification of 15-20 cm, and these are presented in **Table 2**.

Most effective treatments. The most effective treatments were T4 (Pirouette plug sprench, two sprays of Dazide Enhance), T5 (Pirouette plug sprench, two sprays of Canopy), T8 (Pirouette plug sprench, one spray of Regalis Plus, one spray of Pirouette) and T9 (Pirouette plug sprench, two sprays of Terpal) compared with the water only control.

Also effective. Treatments T6 (Pirouette plug sprench, one spray of Terpal, one spray of Pirouette). Treatment T3 (Pirouette plug, one spray of Pirouette, one spray of Pirouette) did control plant growth compared with the water control, but plants were marginally outside the height specification at 20.5 cm. These treatments would achieve greater height control with a slight adjustment to treatment rates.

Not effective. Treatment T2 (Pirouette plug sprench, 0.6 L/ha; two sprays of Pirouette, 0.75 L/ha) was not effective on Cosmos.

Flowering. None of the treatments significantly delayed flowering.

Phytotoxicity. Primo Maxx II is not recommended for use on Cosmos as it caused slight petal bleach when applied at 2.0 L/ha (**Figure 4**).

Figure 1. Cosmos with slight petal bleaching seen in plants treated with T7 Pirouette and Primo Maxx II (right) compared to the water control (left), week 41 2019

Table 2. *Cosmos 'Sonata' carmine* - effective PGR programmes

Trt.	Pre-transplant Sprench+		Post-transplant 1 Spray++		Post-transplant 2 Spray++	
	Product	**Dose**	**Product**	**Dose**	**Product**	**Dose**
T3	Pirouette	2.0 ml/L (0.6 L/ha)	Pirouette	4.0 ml/L (1.2 L/ha)	Pirouette	5.0 ml/L (1.5 L/ha)
T4			Dazide Enhance	6.0 g/L (1.8 kg/ha)	Dazide Enhance	6.0 g/L 1.8 kg/ha)
T5			Canopy*	2.25 g/L (0.675 kg/ha)	Canopy*	2.25 g/L (0.675 kg/ha)
T6			Terpal	6.67 ml/L (2.0 L/ha)	Pirouette	3.0 ml/L (0.9 L/ha)
T8			Regalis Plus	4.17 g/L (1.25 kg/ha)	Pirouette	2.0 ml/L (0.6 L/ha)
T9			Terpal	6.67 ml/L (2.0 L/ha)	Terpal	6.67 ml/L (2.0 L/ha)

*Treatments applied under experimental permit. Canopy applied under experimental permit in 2019 and coded as HDC P005 in previous reports. Note that rates used in the trial may be higher than permitted in EAMU 4484/19 (issued 18 December 2019). +Sprench applied at 5% of the plug tray volume, using a water rate of 300 L/ha. ++Foliar sprays applied in 300 L water/ha.

Dianthus 'Festival' violet

The *Dianthus* trial received two post-transplant PGR applications. A number of PGR programmes proved effective, producing plants within or close to a height specification of 8-10 cm and these are presented in **Table 3.**

Most effective treatments. Treatment T2 (Pirouette plug spray, two sprays of Pirouette) was the most effective on *Dianthus*.

Also effective. Plants in treatments T3 (Pirouette plug drench, two sprays of Pirouette) and T4 (Terpal plug drench, two sprays of Terpal) were effective, but just outside of specification, with heights of 7.8 cm and 10.4 cm respectively. These treatments would achieve greater height control with a slight adjustment to application rates.

Not effective. Treatment T5, a Terpal plug drench (0.5 L/ha) followed by one spray of Terpal + Stena (0.5 L/ha + 0.75 L/ha) was not effective on *Dianthus.*

Flowering. Treatment T3 (Pirouette plug drench, two sprays of Pirouette) produced the fewest plants in flower, recorded at 83% by the end of the trial.

Phytotoxicity. There was no evidence of phytotoxicity as a result of any of the treatments.

Table 3. *Dianthus* 'Festival' violet - effective PGR programmes

Trt.	Plug treatment Spray (S)+ / Drench (D)++		Post-transplant 1 Spray+		Post-transplant 2 Spray+	
	Product	**Rate**	**Product**	**Rate**	**Product**	**Rate**
T2	Pirouette (S)	1.5 ml/L (0.45 L/ha)	Pirouette	1.5 ml/L (0.45 L/ha)	Pirouette	1.5 ml/L (0.45 L/ha)
T3	Pirouette (D)	1.0 ml/L (0.3 L/ha)	Pirouette	1.5 ml/L (0.45 L/ha)	Pirouette	1.5 ml/L (0.45 L/ha)
T4	Terpal (D)	3.33 ml/L (1.0 L/ha)	Terpal	3.33 ml/L (1.0 L/ha)	Terpal	3.33 ml/L (1.0 L/ha)

+Foliar sprays applied in 300 L water/ha. ++Drenches applied by hand with a syringe at 10% of the plug tray volume, using a water rate of 300 L/ha.

Geranium 'Horizon' red

The Geranium trial received one PGR post-transplant application. A number of the PGR programmes tested were effective, producing plants within the height specification of 8 -10 cm (**Table 4**).

Most effective treatments. The most effective treatments without impact on plant quality were T3 (Terpal plug drench, one spray of Terpal + Stena), T4 (Terpal plug drench, one spray of Terpal) and T6 (Pirouette plug drench, one spray of Terpal).

Not effective. Treatment T2 (Terpal plug spray 0.225 L/ha, one spray of Terpal 0.5 /ha + Stena 0.75 L/ha) was not effective.

Flowering. Flowering was poor in the water only control, with only 2.8% of plants in flower by 65 days after treatments. There were no flowers produced in treatments T3, T4 and T5, but treatment T6 (Pirouette plug drench 0.3 L/ha, one spray of Terpal 0.75 L/ha) promoted flowering (12.5%) compared with the water control.

Phytotoxicity. Treatments T3 (Terpal plug drench 0.5 L/ha, one spray of Terpal + Stena 0.5 L/ha + 0.75 L/ha) and T4 (Terpal plug drench 0.45 L/ha, one spray of Terpal 0.75 L/ha) caused some leaf chlorosis early on in the trial, but the plants grew away from this. The foliage and flowers in T5 (Moddus plug drench 0.15 L/ha, one spray of Terpal + Stena 0.5 L/ha + 0.75 L/ha) were pale and the zoning was less pronounced than in other treatments, therefore this treatment is not recommended on Geranium (**Figure 7**).

Figure 2. Plants treated with T5 (Moddus plug drench and one spray of Terpal + Stena), showing paler foliage and zoning, and slightly pale flowers (right) compared to the water control (left), week 32 2019

Table 4. Geranium 'Horizon' red - effective PGR programmes

Trt No.	Plug treatment Spray (S)+ / Drench (D)++		Post-transplant 1 Spray+	
	Product	**Rate**	**Product**	**Rate**
T3	Terpal (D)	1.67 ml/L (0.5 L/ha)	Terpal + Stena *	1.67 ml/L (0.5 L/ha) + 2.5 ml/L (0.75 L/ha)
T4	Terpal (D)	1.5 ml/L (0.45 L/ha)	Terpal	2.5 ml/L (0.75 L/ha)
T6	Pirouette (D)	1.0 ml/L (0.3 L/ha)	Terpal	2.5 ml/L (0.75 L/ha)

*Treatments applied *under experimental permit.* Stena applied under experimental permit in 2019 and coded as HDC P006 in previous reports. ADJ 0895 (issued 30 October 2019). +Foliar sprays applied in 300 L water/ha. ++Drenches applied by hand with a syringe at 10% of the plug tray volume, using a water rate of 300 L/ha.

Osteospermum 'Akila' purple

The *Osteospermum* trial received two post-transplant PGR applications, with plants in a number of treatments achieving the height specification of 8 -10 cm (**Table 5)**. Plant quality may have been impacted by the timing of this trial, under decreasing temperatures and shortening day length, therefore the results should be treated with caution.

Effective treatments. Treatments T2 (Regalis Plus plug spray, one sprench of Canopy + Stena, one sprench of Regalis Plus), T3 (Terpal plug drench, one sprench of Regalis Plus, one sprench of Canopy), and T5 (Terpal plug drench, two sprenches of Terpal + Stena) were the most effective, producing plants of marketable quality and within the height specification.

The dose rate used in treatment T4 (Terpal plug drench 2.0 L/ha, two sprenches of Terpal 2.0 L/ha) proved too high, and impacted on plant quality (score 2.0), plant height (average 4.8 cm) and plants did not flower. With an adjustment to the dose rate, this may prove a useful spray programme.

Not effective. Treatments T6 (Pirouette plug drench, one sprench of Pirouette) and T7 (Pirouette plug drench; one sprench of Pirouette) were not effective.

Flowering. Flowers were produced in the water only control and treatments T6 and T7. All other treatments produced buds, but did not flower within the trial period.

Phytotoxicity. After one post-transplant sprench, T7 (Pirouette plug drench, one sprench of Pirouette) showed some yellow leaf spotting, but the plants grew away from this. There was no evidence of chlorosis, bleaching or distortion at the end of the trial.

Table 5. *Osteospermum* 'Akila' purple - effective PGR programmes

Trt.	Plug treatment Spray (S)+ / Drench (D)++		Post-transplant 1 Sprench+++		Post-transplant 2 Sprench+++	
	Product	**Rate**	**Product**	**Rate**	**Product**	**Rate**
T2	Regalis Plus (S)	4.17 g/L (1.25 kg/ha)	Canopy + Stena *	1.12 g/L (0.337 kg/ha) + 2.5 ml/L (0.75 L/ha)	Regalis Plus	4.17 g/L (1.25 kg/ha)
T3	Terpal (D)	1.67 ml/L (0.5 L/ha)	Regalis Plus	4.17 g/L (1.25 kg/ha)	Canopy*	2.25 g/L (0.675 kg/ha)
T5	Terpal (D)	3.33 ml/L (1.0 L/ha)	Terpal + Stena *	3.33 ml/L (1.0 L/ha) + 2.5 ml/L (0.75 L/ha)	Terpal + Stena *	3.33 ml/L (1.0 L/ha) + 2.5 ml/L (0.75 L/ha)

*Treatments applied under experimental permit. **Stena** applied under experimental permit in 2019 and coded as HDC P006 in previous reports. ADJ 0895 (issued 30 October 2019). **Canopy** applied under experimental permit in 2019 and coded as HDC P005 in previous reports. Note that rates used in the trial may be higher than permitted in EAMU 4484/19 (issued 18 December 2019). +Foliar sprays applied in 300 L water/ha. ++Drenches applied by hand with a syringe at 10% of the plug tray volume, using a water rate of 300 L/ha. +++Sprenches applied at 5% of the pack volume, using a water rate of 300 L/ha.

Financial benefits

The evaluation of PGRs either approved in the UK or in other European Countries for use on bedding plants, followed by appropriate AHDB EAMU applications, will expand the range of active ingredients available to growers' for controlling plant growth. Whilst growers do use a range of cultural methods (e.g. reductions in growing temperatures, deficit irrigation and minimising the nutrient supply) to control plant growth where possible, lack of cost-effective PGRs, approved for use on protected ornamentals, would likely reduce the range of plants that can be produced profitably within client specifications.

PGR applications are required from germination onwards for many plant species to keep growth in check, and a lack of control at any point can lead to downgrading or losses quite quickly, or the need to undertake expensive cultural corrective measures, such as pinching or trimming.

PGRs are also important when used to hold mature crops at the specified height during any period of low demand, where other physical methods may lead to unacceptable impacts on quality such as leaf yellowing or flower bud drop.

The cost per litre of spray solution of each treatment (excluding application) included in this trial at the specified rates, ranged from 2p to 88.2p (**Table 6**). All (including the other 'standard' products) are more expensive than the chlormequat based product, Stabilan 750, as chlormequat based products are primarily used on cereal crops to control growth and prevent stem lodging, and therefore there is a much larger market for their use. However, all the products examined still provide greater opportunity to increase business profit through reduced input cost.

The use of the adjuvant Stena could be used to reduce the cost per litre of some of the treatments further, if its addition permits a reduction in the rate used while generating the same effect. For some of the less expensive PGR products however, the use of the adjuvant would provide no financial saving due to its relative 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 (2.0 ml/L)	9.5/ml	19
Canopy (1.12 g/L)	2.2/g	2.5
Dazide Enhance (6.0 g/L)	14.7/g	88.2
Moddus (0.5 ml/L)	3.9/ml	2.0
Pirouette (1.0 ml/L)	9.5/ml	9.5
Primo Maxx II (6.67 ml/L)	5.0/ml	33.4
Regalis Plus (4.17 g/L)	12.3/g	51.3
Terpal (2.5 ml/L)	1.8/ml	4.3
Stena, adjuvant (2.5 ml/L)	2.0/ml	5.0

Action points

Effective spray programmes were identified for all four species and growers may wish to trial these further on small batches of plants to identify suitable commercial treatments:

- ***Cosmos* 'Sonata' carmine.** Pirouette as a pre-transplant sprench (2.0 ml/L) applied at 5% of plug volume), followed by applications of Pirouette, Dazide Enhance, Canopy, Terpal, or Regalis Plus. Refer to **Table 2** for PGR programmes.
- ***Dianthus* 'Festival' violet.** Pirouette treatments (pre- and post-transplant) were effective on Dianthus. A PGR programme using Terpal (also pre- and post-transplant) produced plants slightly outside the height specification, but would be more effective with an adjustment to dose rates. Refer to **Table 3** for PGR programmes.

- **Geranium 'Horizon' red.** Effective PGR programmes included pre-transplant drenches of Terpal or Pirouette, followed by Terpal with or without Stena. Refer to **Table 4** for PGR programmes.
- ***Osteospermum* 'Akila' purple.** Useful PGR programmes included a pre-transplant Regalis Plus spray or a Terpal drench, followed by application of Canopy, Regalis Plus or Terpal + Stena. Refer to **Table 5** for PGR programmes.

- Growers should note that that the spray rate used in these trials (300 litres 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.

- Growers should familiarise themselves with and adhere to product labels, approvals and Extensions of Approval for Minor Use (EAMUs) prior to use. PGRs applied under EAMU authorisation are made at the grower's own risk. (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).

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 British Protected Ornamental Association (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, 2019-20 were:

Objective 1: 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 Stena (adjuvant) on bedding plants pre- and post-transplant (spray, sprench and drench application).

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 plant plugs at cotyledon stage (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 and Stena (adjuvant) on Poinsettia, and their effect on marketability.

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

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 loss of approval for many products containing chlormequat in protected ornamental plant production. Many growers apply PGRs as drenches and have developed application rates specific to the crops they grow under the specific growing conditions on their nurseries. 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. A number of PGRs were considered for inclusion in this trial.

Canopy (300 g/L mepiquat chloride + 50 g/L prohexadione-calcium, BASF) was developed for use on cereals and grass seed, and has label approval for use on cereals in the UK. 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%. Canopy did not reduce the number of *Bacopa* flowers produced although they were slightly smaller (Paaske, 2015). Canopy was used in PGRs trials pre- and post-transplanting at the Bedding and Pot Plant Centre in 2017 and 2018, and although drenches were too strong, growth control was promising when applied as foliar sprays, particularly on *Osteospermum*. Canopy was authorised for use on protected and outdoor ornamental plant production – container grown crops under EAMU 4484/19 in December 2019.

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, Terpal was authorised for use in ornamental plant production on container grown plants under EAMU 0151/18 in January 2018.

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, we are informed that Cutaway's authorisation for use is likely to be lost in the near future as some of its co-formulants are likely to be banned. 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 EAMUs for Cutaway and Primo Maxx II. 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). In the Danish work, Regalis produced compact Marguerites (*Argyranthemum frutescens* Dana) at 0.1% (Paaske,

2010). Regalis Plus is the new formulation which includes a built-in water conditioner which reduces the time required for rain fastness from 6 hrs to 2 hrs. The new formulation has superseded Regalis.

PGR modes of action

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 (Canopy and 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, Canopy), 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 specify plant height in the range 4-8 cm, up to 10 cm for *Dianthus*, and 15-20 cm for *Cosmos*, while independent garden centres may have a wider height range tolerance for selected marketable products.

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 Canopy 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 refined for the 2018 trial and tailored to each species used. Again, treatments were applied as sprays and drenches to a range of species post transplanting into packs. Pirouette was the most promising product on *Dianthus,* although further work was required to determine the most effective spray rate for this species. Terpal applied as a spray was the most promising PGR on Geranium and showed potential for use at rates between 1 – 1.5 L/ha. Terpal, Pirouette and Canopy applied as sprays had some potential on Pansy, however further work may be required to find the most appropriate rates.

All of the new products produced too strong an effect when applied as drenches at the rates tested. Pirouette was also too strong when applied as a drench, highlighting the importance of applying lower rates for drench application, and testing new products and application methods on a limited number of plants before widespread use.

For the 2019 trial, rates were further refined, and a range of programmes were developed for each species, applying different PGR products at different crop stages. *Cosmos* was introduced into the trial programme for the first time, as it can be difficult to control growth in this species.

A range of PGRs (**Table 7**) was tested on pot and bedding plant subjects via spray and / or sprench / drench application under UK conditions. Products and treatment rates varied for each plant species. Treatments were applied to plugs two days prior to transplant, seven days post-transplant, and then a minimum of 10 days later.

Table 7. Approval status of PGR products tested in 2019 (Unauthorised or off-label treatments applied under experimental permit)

Product	Active ingredient	Approval status
Dazide Enhance (MAPP 16092)	daminozide	On-label approval
Canopy* (MAPP 16314)	mepiquat (as chloride) and prohexadione calcium	EAMU 4484/19. 2 applications permitted per year
Stena+ (ADJ 0895)	polyglycerol	Adjuvant
Moddus (MAPP 15151)	trinexapac-ethyl	EAMU 3062/10. 1 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
Regalis Plus (MAPP 16485)	prohexadione	EAMU 2153/19
Terpal (MAPP 16463)	ethephon + mepiquat chloride	EAMU 0151/18

*Canopy applied under experimental permit in 2019 and coded as HDC P005 in previous reports. Note that rates used in the trial may be higher than permitted in EAMU 4484/19 (issued 18 December 2019). +Stena applied under experimental permit in 2019 and coded as HDC P006. Authorisation issued October 2019.

Project objectives

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 plants pre- and post-transplant (via spray, sprench and / or drench application).

Specific objective 1: To evaluate efficacy of up to seven PGRs plus an adjuvant for spray, sprench and/or drench application over seed-raised bedding plants.

Specific objective 2. To evaluate any phytotoxic effects of up to seven PGRs plus an adjuvant due to spray, sprench and/or drench application over seed-raised bedding 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 (*Cosmos* 'Sonata' carmine, *Dianthus* 'Festival' violet, Geranium 'Horizon' red and *Osteospermum* 'Akila' purple) were used for this trial. All species were treated with PGRs in the plug tray two days prior to transplant using either a spray, sprench (5% of plug tray volume) or drench (10% of plug tray volume) at a rate of 300 L/ha. Plants were transplanted in week 21 (*Dianthus* and Geranium), week 29 (*Cosmos*) and week 31 (*Osteospermum*) at Baginton Nurseries, into standard 6-packs (*Dianthus* and Geranium), and jumbo 6-packs (*Cosmos* and *Osteospermum*). The late transplant date for *Osteospermum* was due to poor seed germination. Seeds were sown on three separate occasions to ensure there were sufficient plants at the correct growth stage for the trial. Plants were set out on mypex under glass in a randomised plot design (**Figure 3**). All species were transplanted into ICL growing media (60% peat, 40% woodfibre, plus Osmocote Protect 5 to 6 months 14-8-11+2MgO+TE).

Sprays (pre- and post-transplant) 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). Pre-transplant sprenches (5% of plug tray volume) were applied using a hand-held mister and pre-transplant drenches (10% of plug tray volume) were applied using a syringe. Post-transplant sprenches (5% of pack volume) were applied by hand using a backpack and single nozzle lance, with an 02f110 nozzle. All treatments were applied during early morning or late afternoon with shade screens over the crop prior to treatment. Plots were de-randomised at each sprench / spray application, to avoid any overspray of treatment onto neighbouring plots.

Treatments were applied as a foliar spray or sprench at one week post-transplant, and then after a further 10 days minimum if deemed necessary, up to a maximum of two applications post-transplant (**Table 8**). Treatments applied in this trial were informed by the results of the 2018 trial, treatments were tailored to each species (**Table 9 - Table 12**). Products not currently authorised for use on protected ornamentals or for drench application were applied under experimental permit (2017/01098, 2019/01194 and 2019/00967).

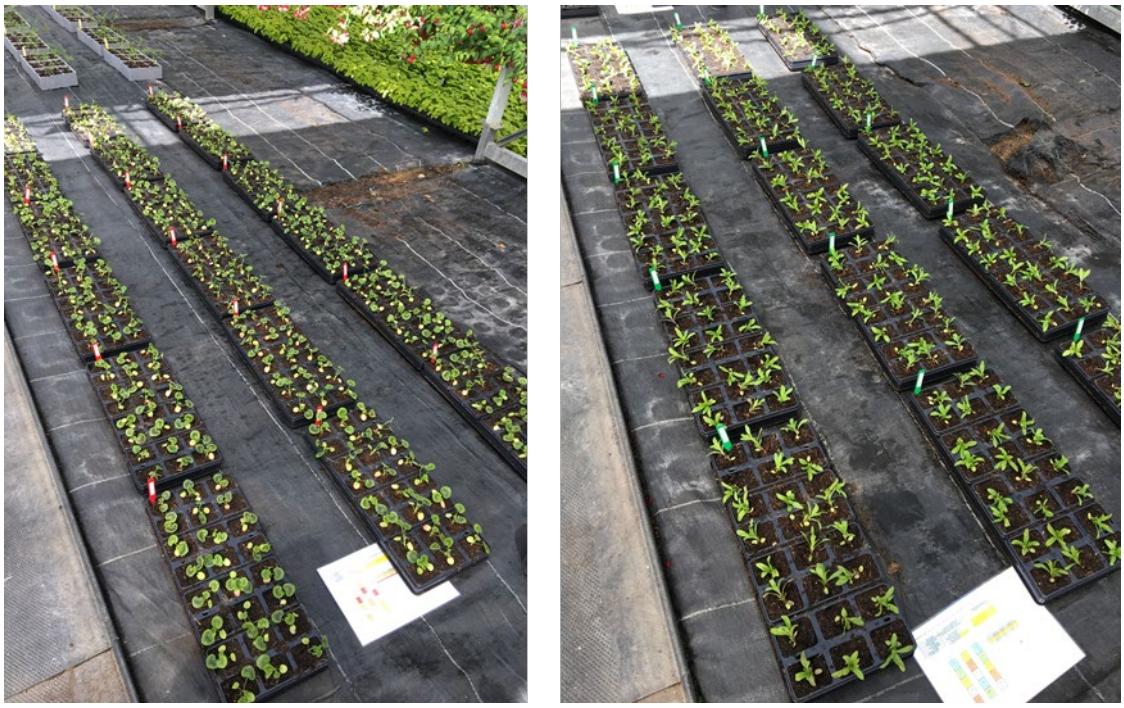

Figure 3. PGR trials set-up under glass at Baginton Nurseries, 2019

Table 8. Treatment application dates for the four species used in the PGR bedding trial 2019

Species	Plug treatment	Transplant date	Post-transplant #1	Post-transplant #2
*Cosmos**	Week 29	Week 29	Week 30	Week 32
	(16.07.19)	(18.07.19)	(25.07.19)	(08.08.19)
Dianthus	Week 21	Week 21	Week 22	Week 26

	(21.05.19)	(23.05.19)	(30.05.19)	(28.06.19)
Geranium	Week 21	Week 21	Week 22	Not needed
	(21.05.19)	(23.05.19)	(30.05.19)	
Osteospermum	Week 31	Week 31	Week 32	Week 34
	(30.07.19)	(01.08.19)	(08.08.19)	(22.08.19)

*Overspray of Bonzi applied at 2.0 ml/L on 21 August 2019 to prevent stretch prior to flowering.

Table 9. PGR product and treatment list 2019 – *Cosmos*

Trt No.	Plug treatment Sprench[+]		Post-transplant #1 Spray[++]		Post-transplant #2 Spray[++]	
	Product	**Rate**	**Product**	**Rate**	**Product**	**Rate**
1	Water control	N/A	Water control	N/A	Water control	N/A
2	Pirouette	2.0 ml/L (0.6 L/ha)	Pirouette	2.5 ml/L (0.75 L/ha)	Pirouette	2.5 ml/L (0.75 L/ha)
3	Pirouette	2.0 ml/L (0.6 L/ha)	Pirouette	4.0 ml/L (1.2 L/ha)	Pirouette	5.0 ml/L (1.5 L/ha)
4	Pirouette	2.0 ml/L (0.6 L/ha)	Dazide Enhance	6.0 g/L (1.8 Kg/ha)	Dazide Enhance	6.0 g/L (1.8 Kg/ha)
5	Pirouette	2.0 ml/L (0.6 L/ha)	Canopy*	2.25 g/L (0.675 kg/ha)	Canopy*	2.25 g/L (0.675 kg/ha)
6	Pirouette	2.0 ml/L (0.6 L/ha)	Terpal*	6.67 ml/L (2.0 L/ha)	Pirouette	3.0 ml/L (0.9 L/ha)
7	Pirouette	2.0 ml/L (0.6 L/ha)	Primo Maxx II	6.67 ml/L (2.0 L/ha)	Primo Maxx II	6.67 ml/L (2.0 L/ha)
8	Pirouette	2.0 ml/L (0.6 L/ha)	Regalis Plus	4.17 g/L (1.25 kg/ha)	Pirouette	2.0 ml/L (0.6 L/ha)
9	Pirouette	2.0 ml/L (0.6 L/ha)	Terpal*	6.67 ml/L (2.0 L/ha)	Terpal*	6.67 ml/L (2.0 L/ha)

[+]Sprench applied at 5% of the plug tray volume, using a water volume of 300 L/ha. [++]Foliar sprays applied in 300 L water/ha. *Treatments applied under experimental permit.

Table 10. PGR product and treatment list 2019 – *Dianthus*

Trt No.	Plug treatment Spray (S)[+] / Drench (D)[++]		Post-transplant #1 Spray[+]		Post-transplant #2 Spray[+]	
	Product	**Rate**	**Product**	**Rate**	**Product**	**Rate**
1	Water control (D)	N/A	Water control	N/A	Water control	N/A
2	Pirouette (S)	1.5 ml/L (0.45 L/ha)	Pirouette	1.5 ml/L (0.45 L/ha)	Pirouette	1.5 ml/L (0.45 L/ha)
3	Pirouette (D)	1.0 ml/L (0.3 L/ha)	Pirouette	1.5 ml/L (0.45 L/ha)	Pirouette	1.5 ml/L (0.45 L/ha)
4	Terpal (D)	3.33 ml/L (1.0 L/ha)	Terpal*	3.33 ml/L (1.0 L/ha)	Terpal*	3.33 ml/L (1.0 L/ha)

5	Terpal (D)	1.67 ml/L (0.5 L/ha)	Terpal + Stena*	1.67 ml/L (0.5 L/ha) + 2.5 ml/L (0.75 L/ha)	Terpal + Stena*	1.67 ml/L (0.5 L/ha) + 2.5 ml/L (0.75 L/ha)

[+]Foliar sprays applied in 300 L water/ha. [++]Drenches applied by hand with a syringe at 10% of the plug tray volume, using a water volume of 300 L/ha. *Treatments applied under experimental permit.

Table 11. PGR product and treatment list 2019 – Geranium

Trt No.	Plug treatment Spray (S)[+] / Drench (D)[++]		Post-transplant #1 Spray[+]	
	Product	**Rate**	**Product**	**Rate**
1	Water control (D)	N/A	Water control	N/A
2	Terpal (S)*	0.75 ml/L (0.225 L/ha)	Terpal + Stena*	1.67 ml/L (0.5 L/ha) + 2.5 ml/L (0.75 L/ha)
3	Terpal (D)	1.67 ml/L (0.5 L/ha)	Terpal + Stena *	1.67 ml/L (0.5 L/ha) + 2.5 ml/L (0.75 L/ha)
4	Terpal (D)	1.5 ml/L (0.45 L/ha)	Terpal*	2.5 ml/L (0.75 L/ha)
5	Moddus (D)*	0.5 ml/L (0.15 L/ha)	Terpal + Stena *	1.67 ml/L (0.5 L/ha) + 2.5 ml/L (0.75 L/ha)
6	Pirouette (D)	2.0 ml/L (0.3 L/ha)	Terpal*	2.5 ml/L (0.75 L/ha)

[+]Foliar sprays applied in 300 L water/ha. [++]Drenches applied by hand with a syringe at 10% of the plug tray volume, using a water volume of 300 L/ha. *Treatments applied under experimental permit.

Table 12. PGR product and treatment list 2019 – *Osteospermum*

Trt No.	Plug treatment Spray (S)[+] / Drench (D)[++]		Post-transplant #1 Sprench[+++]		Post-transplant #2 Sprench[+++]	
	Product	**Rate**	**Product**	**Rate**	**Product**	**Rate**
1	Water control (D)	N/A	Water control	N/A	Water control	N/A
2	Regalis Plus (S)	4.17 g/L (1.25 kg/ha)	Canopy + Stena *	1.12 g/L (0.337 L/ha) + 2.5 ml/L (0.75 L/ha)	Regalis Plus	4.17 g/L (1.25 kg/ha)
3	Terpal (D)	1.67 ml/L (0.5 L/ha)	Regalis Plus	4.17 g/L (1.25 kg/ha)	Canopy*	2.25 g/L (0.675 kg/ha)
4	Terpal (D)	6.66 ml/L (2.0 L/ha)	Terpal*	6.66 ml/L (2.0 L/ha)	Terpal*	6.66 ml/L (2.0 L/ha)
5	Terpal (D)	3.33 ml/L (1.0 L/ha)	Terpal + Stena *	3.33 ml/L (1.0 L/ha) + 2.5 ml/L (0.75 L/ha)	Terpal + Stena *	3.33 ml/L (1.0 L/ha) + 2.5 ml/L (0.75 L/ha)
6	Pirouette (D)	1.0 ml/L (0.3 L/ha)	Pirouette	2.5 ml/L (0.75 L/ha)	Pirouette	2.5 ml/L (0.75 L/ha)
7	Pirouette (D)	0.75 ml/L (0.225 L/ha)	Pirouette	1.25 ml/L (0.375 L/ha)	Pirouette	1.25 ml/L (0.375 L/ha)

[+]Foliar sprays applied in 300 L water/ha. [++]Drenches applied by hand with a syringe at 10% of the plug tray volume, using a water rate of 300 L/ha. [+++]Sprenches applied at 5% of the pack volume, using a water volume of 300 L/ha. *Treatments applied under experimental permit.

No PGRs were applied to the plants prior to dispatch. 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 as a distinct trial, arranged in a randomised plot design with either nine treatments (*Cosmos*), five treatments (*Dianthus*), six treatments (Geranium) or seven treatments (*Osteospermum*). Plots consisted of four 6-packs (24 plants) for *Dianthus* and Geranium, three 6-packs (18 plants) for *Cosmos* and two 6-packs (12 plants) for *Osteospermum*. Within each trial there were three replicate blocks, with an overall total of 1530 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 13**), plant quality (**Table 14**), and height were assessed. Further assessments on plant height, quality and number of plants in flower were made throughout the trials. Phytotoxicity was assessed from the first treatment application onwards (**Table 15**). For plant height, the same plants per plot were assessed each time, and the average height calculated. Inspections and assessments are summarised in **Table 16** and below.

Table 13. 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 14. 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 15. 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 16. Summary of bedding and pot plant trial inspections and assessments, 2019

Date	Week no.	Action	Plant species	Assessment
21 May	21	Pre-treatment assessment completed. Plugs treated in plug tray	*Dianthus*, Geranium	Root development, plant quality, plant height (cm)
23 May	21	Plants transplanted and trials set out	*Dianthus*, Geranium	N/A

30 May	22	Post-transplant treatment #1 and assessment.	*Dianthus*, Geranium	Plant height (cm), plant quality, phytotoxicity
07 June	23	Assessment	*Dianthus*, Geranium	Plant height (cm), plant quality, phytotoxicity
17 June	25	Assessment	*Dianthus*, Geranium	Plant height (cm), plant quality, phytotoxicity, no. of plants in flower
28 June	26	Post-transplant treatment #2 (*Dianthus*) and assessment	*Dianthus*, Geranium (no treatment)	Plant height (cm), plant quality, phytotoxicity, no. of plants in flower
11 July	28	Assessment	*Dianthus*, Geranium	Plant height (cm), plant quality, phytotoxicity, no. of plants in flower
16 July	29	Pre-treatment assessment completed. Plugs treated in plug tray	*Cosmos*	Root development, plant quality, plant height (cm)
18 July	29	Plants transplanted and trial set out	*Cosmos*	N/A
25 July	30	Post-transplant treatment #1 (*Cosmos*) and assessment	*Cosmos*, Geranium (no treatment)	Plant height (cm), plant quality, phytotoxicity, no. of plants in flower (Geranium)
30 July	31	Pre-treatment assessment completed. Plugs treated in plug tray	*Osteospermum*	Root development, plant quality, plant height (cm)
01 Aug	31	Plants transplanted and trial set out	*Osteospermum*	N/A
08 Aug	32	Post-transplant treatments #1 (*Osteospermum*) and #2 (*Cosmos*) treatment and assessment	*Cosmos*, *Osteospermum*	Plant height (cm), plant quality, phytotoxicity

15 Aug	33	Assessment	*Cosmos*, *Osteospermum*	Plant height (cm), plant quality, phytotoxicity
22 Aug	34	Post-transplant treatment #2 (*Osteospermum)* treatment and assessment	*Cosmos* (no treatment), *Osteospermum*	Plant height (cm), plant quality, phytotoxicity
04 Sept	36	Assessment	*Cosmos*, *Osteospermum*	Plant height (cm), plant quality, phytotoxicity
23 Sept	39	Assessment	*Cosmos*, *Osteospermum*	Phytotoxicity, no. of plants in flower, no. of plants in bud (*Osteospermum*)
10 Oct	41	Assessment	*Cosmos*, *Osteospermum*	Plant quality, phytotoxicity, no. of plants in flower, no. of plants in bud and plant height (*Osteospermum*)
01 Nov	44	Assessment	*Osteospermum*	Plant height (cm), plant quality, phytotoxicity, no. of plants in flower, no. of plants in bud

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 water 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**). Plant height graphs are presented in **Appendix 2**. Images of treatment effects compared with the water control are presented in **Appendix 3**.

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

Plant height and growth

Plant growth between transplant and the final assessment, with a calculation of the percentage height difference compared with the water control are presented in **Table 17** - **Table 20**. It should be noted that for growers the focus is on products that will control plants sufficiently to keep them within the required height specification.

Cosmos

There were significant differences between treatments for all height assessments, with some treatment programmes controlling growth better than others. After the first post-transplant treatment (week 30), only plants submitted to treatment T8 (Pirouette plug sprench, one spray of Regalis Plus) were significantly shorter than the water control (p=0.050). By week 32, these plants were still significantly shorter. Plants from T2 (Pirouette plug sprench, one spray of Pirouette 2.5 ml/L) had already reached the height specification of 15 cm, with the water control measuring 14.5 cm. The second post-transplant treatment was applied in week 32, with the final height assessment completed in week 33, when plants in the water control had surpassed the specified height range of 15 – 20 cm.

Height differences were more pronounced at the final height assessment (week 33), with plants treated with T8 (Pirouette plug sprench, one spray of Regalis Plus, one spray of Pirouette), T9 (Pirouette plug sprench, two sprays of Terpal), T4 (Pirouette plug sprench, two sprays of Dazide Enhance) and T5 (Pirouette plug sprench, two sprays of Canopy) all significantly shorter than the water control (p =0.001). Plants from T2 (Pirouette plug sprench, two sprays of Pirouette 2.5 ml/L) and T3 (Pirouette plug sprench, one spray of Pirouette 4.0 ml/L, one spray of Pirouette 5.0 ml/L) were just over specification, with an average plant height of 22.9 cm and 20.5 cm respectively. An overspray of Bonzi (2.0 ml/L) was applied to the whole trial in week 34 to prevent stretch, so that plant quality and flowering could be assessed.

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

	Plug Sprench	Post-transplant Spray #1	Post-transplant Spray #2	Ave. height (cm)	Ave. growth (cm)	Height change (%)
1	Water control	Water control	Water control	22.5	16.1	-
2	Pirouette 0.6 L/ha	Pirouette 0.75 L/ha	Pirouette 0.75 L/ha	22.9	16.6	+3%
3	Pirouette 0.6 L/ha	Pirouette 1.2 L/ha	Pirouette 1.5 L/ha	20.5	14.6	-9%
4	Pirouette 0.6 L/ha	Dazide Enhance 1.8 kg/ha	Dazide Enhance 1.8 kg/ha	17.2	11.4	-30%
5	Pirouette 0.6 L/ha	Canopy 0.675 Kg/ha	Canopy 0.675 Kg/ha	17.8	12.5	-22%
6	Pirouette 0.6 L/ha	Terpal 2.0 L/ha	Pirouette 0.9 L/ha	18.8	13.8	-14%
7	Pirouette 0.6 L/ha	Primo Maxx II 2.0 L/ha	Primo Maxx II 2.0 L/ha	19.0	13.3	-18%
8	Pirouette 0.6 L/ha	Regalis Plus 1.25 kg/ha	Pirouette 0.6 L/ha	17.1	12.0	-26%
9	Pirouette 0.6 L/ha	Terpal 2.0 L/ha	Terpal 2.0 L/ha	16.2	11.1	-31%
	s.e.d. l.s.d. F pr			1.309 2.790 0.001	n/a	n/a
	Values highlighted red are significantly different to the water control.					

Final assessment date for height was 15 August 2019, week 33, 30 DAT (days after first treatment). Height specification for Cosmos is 15 cm – 20 cm.

Dianthus

All treatments controlled plant height throughout the trial compared to the water control, although some treatment programmes were more effective than others. One week after the first post-transplant treatment, all plants were significantly shorter than the water control (p =0.004). Plants continued to grow, particularly in T2 (Pirouette plug spray, one spray of Pirouette) and T5 (Terpal plug drench, one spray of Terpal + Stena), so the second post-transplant treatment was applied in week 26. By the time of the final height assessment in week 28, the most effective treatments were T2 (Pirouette plug spray, two sprays of Pirouette) and T3 (Pirouette plug drench, two sprays of Pirouette), with plants significantly shorter than the water control (**Table 18**; p=0.021). Plants in treatment T2 (Pirouette plug spray, two sprays of Pirouette) were within the height specification for pack bedding (between 8 and 10 cm), whereas those in T5 (Terpal plug drench, two sprays of Terpal + Stena) were outside of this range, with an average final height of 12 cm. Treatment T3 (Pirouette plug drench, two sprays

of Pirouette) was effective, although plants were slightly shorter than the specification, with an average plant height of 7.8 cm.

Table 18. *Dianthus*: average plant height, growth (height increase from transplant) and average height reduction relative to the water control

	Plug Treatment	Post-transplant Spray #1	Post-transplant Spray #2	Ave. height (cm)	Ave. growth (cm)	Height change (%)
1	Water control	Water control	Water control	12.5	10.4	-
2	Pirouette (S) 0.45 L/ha	Pirouette 0.45 L/ha	Pirouette 0.45 L/ha	9.6	7.9	-24%
3	Pirouette (D) 0.3 L/ha	Pirouette 0.45 L/ha	Pirouette 0.45 L/ha	7.8	6.4	-39%
4	Terpal (D) 1.0 L/ha	Terpal 1.0 L/ha	Terpal 1.0 L/ha	10.4	8.6	-18%
5	Terpal (D) 0.5 L/ha	Terpal + Stena 0.5 L/ha + 0.75 L/ha	Terpal + Stena 0.5 L/ha + 0.75 L/ha	12.0	10.4	0%
	s.e.d. l.s.d. F pr			1.156 2.666 0.021	n/a	n/a
	Values highlighted red are significantly different to the water control.					

(S) = spray, (D) = Drench. Final assessment date was 11 July 2019, week 28, 51 DAT (days after first treatment). Height specification for pack bedding is 8 cm – 10 cm.

Geranium

All treatments controlled Geranium growth to some degree and there were significant differences between treatments at the final assessment (week 26, **Table 19**, p=0.012); only one post-transplant application was applied across all treatments.

Treatments T4 (Terpal plug drench, one spray of Terpal), T5 (Moddus plug drench, one spray of Terpal + Stena) and T6 (Pirouette plug drench, one spray of Terpal) controlled growth most effectively, with plants within specification. Terpal was less effective when applied at lower rates in the plug, either as a spray (T2) or drench (T3), and followed by reduced rates of Terpal with Stena. In fact, plants from T2 (Terpal plug spray, one spray of Terpal + Stena) were very slightly taller than the water control at the final height assessment in week 26.

Comparing treatments T2 and T3. T3 provided greater height control than T2, but this was due to the higher rate of Terpal at plug stage (0.5 L/ha in T3, and 0.225 L/ha in T2) rather than the post-transplant application (Terpal, 0.5 L/ha + Stena, 0.75 L/ha). This suggests that the combination of a lower rate of Terpal with Stena was not beneficial in this instance on Geranium as a post-transplant treatment. More effective control was achieved by treatment T4 (Terpal plug drench 0.45 L/ha followed by one spray of Terpal at 0.75 L/ha).

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

	Plug Treatment	Post-transplant Spray #1	Ave. height (cm)	Ave. growth (cm)	Height change (%)
1	Water control	Water control	11.5	7.5	-
2	Terpal (S) 0.225 L/ha	Terpal + Stena 0.5 L/ha + 0.75 L/ha	11.8	7.8	+4.69%
3	Terpal (D) 0.5 L/ha	Terpal + Stena 0.5 L/ha + 0.75 L/ha	9.8	5.8	-22.32%
4	Terpal (D) 0.45 L/ha	Terpal 0.75 L/ha	8.5	4.5	-40.18%
5	Moddus (D) 0.15 L/ha	Terpal + Stena 0.5 L/ha + 0.75 L/ha	8.6	4.6	-37.95%
6	Pirouette (D) 0.3 L/ha	Terpal 0.75 L/ha	8.1	4.1	-44.87%
	s.e.d. l.s.d. F pr		0.983 2.191 0.012	n/a	n/a
	Values highlighted red are significantly different to the water control.				

(S) = spray, (D) = Drench. Final assessment date was 28 June 2019, week 26, 38 DAT (days after first treatment). Height specification for pack bedding is 8 cm – 10 cm.

Osteospermum

There were no significant differences between treatments for plant height following the first post-transplant sprench in week 32. However, by week 34, plants in both treatments T6 (Pirouette plug drench, one sprench of Pirouette) and T7 (Pirouette plug drench, one sprench of Pirouette at lower rate) were significantly taller than the water control ($p < 0.001$), prompting the second post-transplant treatment. Plants submitted to treatments T4 (Terpal plug drench, one sprench of Terpal) and T5 (Terpal plug drench, one sprench of Terpal + Stena) were significantly shorter than the water control.

These differences between treatments remained significant for the duration of the trial, and by the final assessment in week 44, the differences were extreme (**Table 20**; $p < 0.001$). The most effective treatments for controlling plant growth compared to the water control were T2 (Regalis Plus plug spray, one sprench of Canopy + Stena, one sprench of Regalis Plus), T3 (Terpal plug drench, one sprench of Regalis Plus, one sprench of Canopy) and T5 (Terpal plug drench, two sprenches of Terpal + Stena). The smallest plants were produced in T4 (Terpal plug drench, two sprenches of Terpal). These plants were extremely compact and would not have been suitable for marketing. Whilst not significantly different to the water

control, T6 (Pirouette plug drench, two sprenches of Pirouette) gave good growth control. Treatment T7 (Pirouette plug drench, two sprenches of Pirouette at lower rate) was not effective.

Table 20. *Osteospermum*: average plant height, growth (height increase from transplant) and average height reduction relative to the water control

	Plug Treatment	**Post-transplant Sprench #1**	**Post-transplant Sprench #2**	**Ave. height (cm)**	**Ave. growth (cm)**	**Height change (%)**
1	Water control	Water control	Water control	16.1	13.0	-
2	Regalis Plus (S) 1.25 kg/ha	Canopy + Stena 0.337 L/ha + 0.75 L/ha	Regalis Plus 1.25 kg/ha	7.8	4.8	-62.92%
3	Terpal (D) 0.5 L/ha	Regalis Plus 1.25 kg/ha	Canopy 0.675 kg/ha	7.0	4.0	-69.57%
4	Terpal (D) 2.0 L/ha	Terpal 2.0 L/ha	Terpal 2.0 L/ha	4.8	1.7	-86.96%
5	Terpal (D) 1.0 L/ha	Terpal + Stena 1.0 L/ha + 0.75 L/ha	Terpal + Stena 1.0 L/ha + 0.75 L/ha	9.4	6.7	-48.85%
6	Pirouette (D) 0.3 L/ha	Pirouette 0.75 L/ha	Pirouette 0.75 L/ha	15.8	12.9	-0.77%
7	Pirouette (D) 0.225 L/ha	Pirouette 0.375 L/ha	Pirouette 0.375 L/ha	16.1	13.1	+0.13%
	s.e.d. l.s.d. F pr			1.634 3.561 <0.001	n/a	n/a
	Values highlighted red are significantly different to the water control.					

(S) = spray, (D) = Drench. Final assessment date was 01 November 2019, week 44, 94 DAT (days after first treatment). Height specification for pack bedding is 8 cm – 10 cm.

Phytotoxicity

Cosmos

Phytotoxicity was assessed throughout the trial period (**Table 21**). No phytotoxic effects were observed on the plant foliage on any of the assessment dates. All foliage was similar in colour to the water control, and there was no evidence of crinkling, distortion or chlorosis. When the flowers emerged, there was evidence of phytotoxicity in week 39, when plants in T7 (Pirouette plug sprench, two sprays of Primo Maxx II) showed paler flowers in comparison to the other treatments; these plants scored 6.0, as the pale flower colour would have made them unmarketable (**Figure 4**). All other treatments scored 9.0. Differences remained the same at the final phytotoxicity assessment in week 41.

Table 21. *Cosmos*: phytotoxicity scores (scored 0-9) throughout the trial period

	Plug Sprench	**Post-transplant Spray #1**	**Post-transplant Spray #2**	**Phyto Wk 30**	**Phyto Wk 32**	**Phyto Wk 33**	**Phyto Wk 34**	**Phyto Wk 36**	**Phyto Wk 39**	**Phyto Wk 41**
1	Water control	Water control	Water control	9.0	9.0	9.0	9.0	9.0	9.0	9.0
2	Pirouette 0.6 L/ha	Pirouette 0.75 L/ha	Pirouette 0.75 L/ha	9.0	9.0	9.0	9.0	9.0	9.0	9.0
3	Pirouette 0.6 L/ha	Pirouette 1.2 L/ha	Pirouette 1.5 L/ha	9.0	9.0	9.0	9.0	9.0	9.0	9.0
4	Pirouette 0.6 L/ha	Dazide Enhance 1.8 kg/ha	Dazide Enhance 1.8 kg/ha	9.0	9.0	9.0	9.0	9.0	9.0	9.0
5	Pirouette 0.6 L/ha	Canopy 0.675 kg/ha	Canopy 0.675 kg/ha	9.0	9.0	9.0	9.0	9.0	9.0	8.7
6	Pirouette 0.6 L/ha	Terpal 2.0 L/ha	Pirouette 0.9 L/ha	9.0	9.0	9.0	9.0	9.0	9.0	9.0
7	Pirouette 0.6 L/ha	Primo Maxx II 2.0 L/ha	Primo Maxx II 2.0 L/ha	9.0	9.0	9.0	9.0	9.0	6.0	6.3
8	Pirouette 0.6 L/ha	Regalis Plus 1.25 kg/ha	Pirouette 0.6 L/ha	9.0	9.0	9.0	9.0	9.0	9.0	9.0
9	Pirouette 0.6 L/ha	Terpal 2.0 L/ha	Terpal 2.0 L/ha	9.0	9.0	9.0	9.0	9.0	9.0	9.0
	s.e.d. l.s.d. F pr			n/a	n/a	n/a	n/a	n/a	n/a	0.2515 0.5361 <.001
	Values highlighted red are significantly different to the water control.									

Final assessment date was 10 October 2019, week 41, 86 DAT (days after first treatment).

Figure 4. *Cosmos* with slight petal bleaching seen in plants treated with T7 Pirouette and Primo Maxx II (right) compared to the water control (left), week 41 2019

Dianthus

There were no signs of phytotoxicity due to any of the treatments on the first three assessment dates. By the fourth assessment in week 26, there were significant differences between treatments (p =0.003; **Table 22**), with plants in both T2 (Pirouette plug spray, one spray of Pirouette) and T3 (Pirouette plug drench, one spray of Pirouette) showing paler foliage, although insufficient to make them unmarketable (scores of 8.3 and 8.0 respectively).

A second PGR application was applied in week 26, and at the final assessment in week 28, only plants in T3 (Pirouette plug drench, two sprays of Pirouette) and T5 (Terpal plug drench, two sprays of Terpal + Stena) scored lower than the water control (both scored 7.0), meaning they were marketable. Both T3 and T5 had paler foliage than the water control (**Figure 5**), but there was no evidence of bleaching or spotting on the flowers. All other treatments scored 9.0.

Figure 5. *Dianthus* with some foliage bleaching seen in plants treated with T3 Pirouette plug drench and two sprays of Pirouette (right) compared to the water control (left), week 28 2019

Table 22. *Dianthus*: phytotoxicity scores (scored 0-9) throughout the trial period

	Plug Treatment	**Post-transplant Spray #1**	**Post-transplant Spray #2**	**Phyto Wk 22**	**Phyto Wk 23**	**Phyto Wk 25**	**Phyto Wk 26**	**Phyto Wk 28**
1	Water control	Water control	Water control	9.0	9.0	9.0	9.0	9.0
2	Pirouette (S) 0.45 L/ha	Pirouette 0.45 L/ha	Pirouette 0.45 L/ha	9.0	9.0	9.0	8.3	9.0
3	Pirouette (D) 0.3 L/ha	Pirouette 0.45 L/ha	Pirouette 0.45 L/ha	9.0	9.0	9.0	8.0	7.0
4	Terpal (D) 1.0 L/ha	Terpal 1.0 L/ha	Terpal 1.0 L/ha	9.0	9.0	9.0	9.0	9.0
5	Terpal (D) 0.5 L/ha	Terpal + Stena 0.5 L/ha + 0.75 L/ha	Terpal + Stena 0.5 L/ha + 0.75 L/ha	9.0	9.0	9.0	9.0	7.0
	s.e.d. l.s.d. F pr			n/a	n/a	n/a	0.2108 0.4861 0.003	n/a
	Values highlighted red are significantly different to the water control.							

Final assessment date was 11 July 2019, week 28, 51 DAT (days after first treatment).

Geranium

The Geranium plants were only treated with one PGR application post-transplant, in week 22. At the first assessment, one week later, all of the plants in T3 (Terpal plug drench, one spray of Terpal + Stena) and T4 (Terpal plug drench, one spray of Terpal) scored 6.0, due to discolouration and marginal chlorosis (**Figure 6**). There were no signs of phytotoxicity in any other treatments.

Figure 6. Example of leaf chlorosis seen in plants treated with T3 Terpal plug drench and one spray of Terpal + Stena, week 23 2019

By the next assessment in week 25, the leaf chlorosis seen in T3 and T4 was less evident, but the foliage appeared to be paler in all treatments apart from T2 (Terpal plug spray, one spray of Terpal + Stena). However, the plants did grow out of the chlorosis by the final assessment in week 30, and at the end of the trial, all plants were marketable (**Table 23**). T5 (Moddus plug drench, one spray of Terpal + Stena) scored 7.0 as the foliage was still slightly paler than the water control, and the zoning was less pronounced. All other treatments scored 9.0. The trial was monitored until week 32 when a final phytotoxicity assessment was made on the flowers. Apart from T5 (Moddus plug drench, one spray of Terpal + Stena), where the flowers were slightly paler (**Figure 7**), all treatments scored the same as the water control, with no evidence of bleaching.

Table 23. Geranium: phytotoxicity scores (scored 0-9) throughout the trial period

	Plug Treatment	**Post-transplant Spray #1**	**Phyto Wk 23**	**Phyto Wk 25**	**Phyto Wk 26**	**Phyto Wk 28**	**Phyto Wk 30**
1	Water control	Water control	9.0	9.0	9.0	9.0	9.0
2	Terpal (S) 0.225 L/ha	Terpal + Stena 0.5 L/ha + 0.75 L/ha	9.0	9.0	9.0	9.0	9.0

3	Terpal (D) 0.5 L/ha	Terpal + Stena 0.5 L/ha + 0.75 L/ha	6.0	8.0	9.0	9.0	9.0
4	Terpal (D) 0.45 L/ha	Terpal 0.75 L/ha	6.0	7.0	8.0	9.0	9.0
5	Moddus (D) 0.15 L/ha	Terpal + Stena 0.5 L/ha + 0.75 L/ha	9.0	8.0	7.0	7.0	7.0
6	Pirouette (D) 0.3 L/ha	Terpal 0.75 L/ha	9.0	7.3	9.0	9.0	9.0
	s.e.d. l.s.d. F pr		n/a	0.385 0.858 0.002	n/a	n/a	n/a
	Values highlighted red are significantly different to the water control.						

Final assessment date was 25 July 2019, week 30, 65 DAT (days after first treatment).

Figure 7. Plants treated with T5 (Moddus plug drench and one spray of Terpal + Stena), showing paler foliage and zoning, and slightly pale flowers (right) compared to the water control (left), week 32 2019

Osteospermum

When the plants were assessed in week 33, one week after the first post-transplant sprench, there was some evidence of phytotoxicity in T7 (Pirouette plug drench, one sprench of Pirouette), with plants scoring 6.0 due to yellow spotting on the leaves (**Figure 8**). All other treatments scored 9.0.

Figure 8. Evidence of leaf spotting in *Osteospermum* plants treated with T7 (Pirouette plug drench and one sprench of Pirouette) week 33 2019

The second PGR application was made in week 34 and there was no further evidence of phytotoxicity in any of the treatments, including T7. The plants had grown away from the yellow spotting (**Table 24**).

However, there was an adverse effect on plant quality. When the second PGR application was applied in week 34, not only was T4 (Terpal plug drench, one sprench of Terpal) much smaller than the other treatments, there was evidence of leaf distortion as well. This was exacerbated by the second Terpal sprench treatment. Plants quality continued to decline throughout the trial period, and by the end of the trial, plant quality was significantly poorer in all treatments than the water control (P<.001) (**Table 24** and **Figure 9**). However, T6 (Pirouette plug drench, 0.3 L/ha; two sprenches of Pirouette, 0.75 L/ha) and T7 (Pirouette plug drench, 0.225 L/ha; two sprenches of Pirouette, 0.375 L/ha) were of good quality, achieving quality scores of 4.0 scale of 0-5, where 5 = good quality with little damage) were still good quality. Plants in treatment T4 (Terpal plug drench 2.0 L/ha, two sprenches of Terpal 2.0 L/ha) were of poor quality scoring 2.3.

Table 24. *Osteospermum*: phytotoxicity scores (scored 0-9) throughout the trial period and average plant quality (scored 0-5) compared to the water control

	Plug Treatment	**Post-transplant Sprench #1**	**Post-transplant Sprench #2**	**Phyto Wk 32**	**Phyto Wk 33**	**Phyto Wk 34**	**Phyto Wk 36**	**Phyto Wk 41**	**Phyto Wk 44**	**Plant quality Wk 44**
1	Water control	Water control	Water control	9.0	9.0	9.0	9.0	9.0	9.0	4.7
2	Regalis Plus (S) 1.25 kg/ha	Canopy + Stena 0.337 L/ha + 0.75 L/ha	Regalis Plus 1.25 kg/ha	9.0	9.0	9.0	9.0	9.0	9.0	3.0
3	Terpal (D) 0.5 L/ha	Regalis Plus 1.25 kg/ha	Canopy 0.675 kg/ha	9.0	9.0	9.0	9.0	9.0	9.0	3.0
4	Terpal (D) 2.0 L/ha	Terpal 2.0 L/ha	Terpal 2.0 L/ha	9.0	9.0	9.0	9.0	9.0	9.0	2.3
5	Terpal (D) 1.0 L/ha	Terpal + Stena 1.0 L/ha + 0.75 L/ha	Terpal + Stena 1.0 L/ha + 0.75 L/ha	9.0	9.0	9.0	9.0	9.0	9.0	3.0
6	Pirouette (D) 0.3 L/ha	Pirouette 0.75 L/ha	Pirouette 0.75 L/ha	9.0	9.0	9.0	9.0	9.0	9.0	4.0
7	Pirouette (D) 0.225 L/ha	Pirouette 0.375 L/ha	Pirouette 0.375 L/ha	9.0	6.0	6.0	9.0	9.0	9.0	4.0
	s.e.d. l.s.d. F pr			n/a	n/a	n/a	n/a	n/a	n/a	0.2412 0.5256 <.001
	Values highlighted red are significantly different to the water control.									

Final assessment date was 01 November 2019, week 44, 94 DAT (days after first treatment).

Figure 9. Treatment effects on plant quality seen in T4 (Terpal plug drench and two sprenches of Terpal, right) and T7 (Pirouette plug drench and two sprenches of Pirouette at lower rate, centre) compared to the water control (left), week 44 2019

Flowering

A full assessment of flowering was completed at the end of each trial and the results are presented in **Table 25** - **Table 28**. For the *Osteospermum* trial, not all of the treatments had come into flower by week 44, so an assessment of the percentage of plants in bud was also completed.

Cosmos

In the *Cosmos* trial, flowers were emerging in all treatments by week 39, and there was no significant difference between treatments for flowering at the end of the trial. Whilst the percentage of plants in flower was highest in the water control, plants in treatments T2 (Pirouette plug sprench, two sprays of Pirouette), T3 (Pirouette plug sprench, two sprays of Pirouette at a higher rate), T7 (Pirouette plug sprench, two sprays of Primo Maxx II) and T8 (Pirouette plug sprench, one spray of Regalis Plus and one spray of Pirouette) were also very floriferous, with 87% of plants in flower by week 41.

Table 25. *Cosmos*: average percentage of plants in flower compared to the water control

	Plug Sprench	**Post-transplant Spray #1**	**Post-transplant Spray #2**	**% of plants in flower**
1	Water control	Water control	Water control	91.4
2	Pirouette 0.6 L/ha	Pirouette 0.75 L/ha	Pirouette 0.75 L/ha	87.2
3	Pirouette 0.6 L/ha	Pirouette 1.2 L/ha	Pirouette 1.5 L/ha	87.0
4	Pirouette 0.6 L/ha	Dazide Enhance 1.8 kg/ha	Dazide Enhance 1.8 kg/ha	65.3
5	Pirouette 0.6 L/ha	Canopy 0.675 kg/ha	Canopy 0.675 kg/ha	79.5
6	Pirouette	Terpal*	Pirouette	75.5

	0.6 L/ha	2.0 L/ha	0.9 L/ha	
7	Pirouette 0.6 L/ha	Primo Maxx II 2.0 L/ha	Primo Maxx II 2.0 L/ha	87.0
8	Pirouette 0.6 L/ha	Regalis Plus 1.25 kg/ha	Pirouette 0.6 L/ha	87.0
9	Pirouette 0.6 L/ha	Terpal 2.0 L/ha	Terpal 2.0 L/ha	74.3
	s.e.d. l.s.d. F pr			9.60 20.46 0.215

Final assessment date for flowering was 10 October 2019, week 41, 86 DAT (days after first treatment).

Dianthus

Flowering was greatest in the water control (97.2%) by week 28, although the majority of treatments were almost fully in flower by this point, with more than 90% of plants in flower. The only treatment where flowering was significantly delayed (p =0.052) was T3 (Pirouette plug drench, two sprays of Pirouette), with 83.3% of plants in flower.

Table 26. *Dianthus*: average percentage of plants in flower compared to the water control

	Plug Treatment	**Post-transplant Spray #1**	**Post-transplant Spray #2**	**% of plants in flower**
1	Water control	Water control	Water control	97.2
2	Pirouette (S) 0.45 L/ha	Pirouette 0.45 L/ha	Pirouette 0.45 L/ha	94.4
3	Pirouette (D) 0.3 L/ha	Pirouette 0.45 L/ha	Pirouette 0.45 L/ha	83.3
4	Terpal (D) 1.0 L/ha	Terpal 1.0 L/ha	Terpal 1.0 L/ha	93.1
5	Terpal (D) 0.5 L/ha	Terpal + Stena 0.5 L/ha + 0.75 L/ha	Terpal + Stena 0.5 L/ha + 0.75 L/ha	95.8
	s.e.d. l.s.d. F pr			4.00 9.23 0.052
	Values highlighted red are significantly different to the water control.			

Final assessment date was 11 July 2019, week 28, 51 DAT (days after first treatment).

Geranium

By the final assessment in week 30, 65 days post-transplant, there were no flowers in T3 (Terpal plug drench, one spray of Terpal + Stena), T4 (Terpal plug drench, one spray of Terpal) or T5 (Moddus plug drench, one spray of Terpal + Stena). A small percentage of plants in the

water control were in flower (2.8%), however the highest level of flowering was seen in T6 (Pirouette plug drench, one spray of Terpal) with 12.5% of plants in flower.

Table 27. Geranium: average percentage of plants in flower compared to the water control

	Plug Treatment	**Post-transplant Spray #1**	**% of plants in flower**
1	Water control	Water control	2.8
2	Terpal (S) 0.225 L/ha	Terpal + Stena 0.5 L/ha + 0.75 L/ha	1.4
3	Terpal (D) 0.5 L/ha	Terpal + Stena 0.5 L/ha + 0.75 L/ha	0.0
4	Terpal (D) 0.45 L/ha	Terpal 0.75 L/ha	0.0
5	Moddus (D) 0.15 L/ha	Terpal + Stena 0.5 L/ha + 0.75 L/ha	0.0
6	Pirouette (D) 0.3 L/ha	Terpal 0.75 L/ha	12.5
	s.e.d. l.s.d. F pr		4.85 10.81 0.159

Final assessment date for flowering was 25 July 2019, week 30, 65 DAT (days after first treatment).

Osteospermum

By week 44, 94 days post-transplant, there were significant differences between treatments for both the percentage of plants in flower ($p < 0.001$) and the percentage of plants in bud ($p < 0.001$). Whilst the water control had 19.2% of plants in flower, plants from T6 (Pirouette plug drench, two sprenches of Pirouette) had significantly more, with 49.9% of plants in flower. T7 (Pirouette plug drench, two sprenches of Pirouette at a lower rate) had 29.7% of plants in flower. None of the other treatments were flowering by this stage.

There were buds in all treatments apart from T4 (Terpal plug drench, two sprenches of Terpal). This was the only treatment with no buds or flowers. All other treatments which were not yet flowering were in bud, although there were significantly fewer buds in T5 (Terpal plug drench, two sprenches of Terpal + Stena). T7 (Pirouette plug drench, two sprenches of Pirouette at a lower rate) had a good number of both flowers and buds, and was the only treatment comparable to the water control.

Table 28. *Osteospermum*: average percentage of plants in flower or in bud compared to the water control

	Plug Treatment	Post-transplant Sprench #1	Post-transplant Sprench #2	% of plants in flower	% of plants in bud
1	Water control	Water control	Water control	19.2	80.8
2	Regalis Plus (S) 1.25 kg/ha	Canopy + Stena 0.337 L/ha + 0.75 L/ha	Regalis Plus 1.25 kg/ha	0.0	81.0
3	Terpal (D) 0.5 L/ha	Regalis Plus 1.25 kg/ha	Canopy 0.675 kg/ha	0.0	63.7
4	Terpal (D) 2.0 L/ha	Terpal 2.0 L/ha	Terpal 2.0 L/ha	0.0	0.0
5	Terpal (D) 1.0 L/ha	Terpal + Stena 1.0 L/ha + 0.75 L/ha	Terpal + Stena 1.0 L/ha + 0.75 L/ha	0.0	11.1
6	Pirouette (D) 0.3 L/ha	Pirouette 0.75 L/ha	Pirouette 0.75 L/ha	49.9	44.3
7	Pirouette (D) 0.225 L/ha	Pirouette 0.375 L/ha	Pirouette 0.375 L/ha	29.7	61.5
	s.e.d. l.s.d. F pr			9.37 20.41 <.001	15.60 33.98 <.001
	Values highlighted red are significantly different to the water control.				

Final assessment date was 01 November 2019, week 44, 94 DAT (days after first treatment).

Summary of results by plant species

Cosmos 'Sonata' carmine

- The *Cosmos* trial received two post-transplant applications. Plant height specification was 15-20 cm.
- Treatments T4 (Pirouette plug sprench 0.6 L/ha, two sprays of Dazide Enhance 1.8 kg/ha), T5 (Pirouette plug sprench 0.6 L/ha, two sprays of Canopy 0.675 kg/ha), T8 (Pirouette plug sprench 0.6 L/ha, one spray of Regalis Plus 1.25 kg/ha, one spray of Pirouette 0.6 L/ha) and T9 (Pirouette plug sprench 0.6 L/ha, two sprays of Terpal 2.0 L/ha) were the most effective, providing significant height control compared with the water control.
- Treatments T6 (Pirouette plug sprench 0.6 L/ha, one spray of Terpal 2.0 L/ha, one spray of Pirouette 0.9 L/ha) and T7 (Pirouette plug sprench 0.6 L/ha, two sprays of Primo Maxx II 2.0 L/ha) also controlled growth, with plant height within specification although not significantly different to applying water only. Treatment T3 (Pirouette plug sprench 0.6 L/ha, one spray of Pirouette 1.2 L/ha, one spray of Pirouette 1.5 L/ha) did control plant growth compared with the water control, but plants were marginally outside height specification at 20.5 cm.

- Treatments T2 (Pirouette plug sprench 0.6 L/ha, two sprays of Pirouette 0.75 L/ha) was the least effective of the treatments.
- There was no evidence of phytotoxicity due to any of the treatments until the flowers emerged, when plants in treatment T7 (Pirouette plug sprench 0.6 L/ha, two sprays of Primo Maxx II 2.0 L/ha) produced paler flowers than the water control.
- There was no significant effect of any treatment on flowering time, with flowers emerging in all treatments by week 39. The lowest percentage of plants in flower was in T4 (Pirouette plug sprench 0.6 L/ha, two sprays of Dazide Enhance 1.8 kg/ha).

Dianthus 'Festival' violet

- The *Dianthus* trial received two post-transplant applications. Plant height specification was 8-10 cm.
- By the end of the trial, T2 (Pirouette plug spray 0.45 L/ha, two sprays of Pirouette 0.45 L/ha) and T3 (Pirouette plug drench 0.3 L/ha, two sprays of Pirouette 0.45 L/ha) were the most effective treatments on *Dianthus.* However, plants in T3 were just below specification (7.5 cm). Treatments T4 (Terpal plug drench 1.0 L/ha, two sprays of Terpal 1.0 L/ha) did control plant growth compared with the water control, but plants were marginally outside height specification at 10.4 cm.
- Treatment T5 (Terpal plug drench 0.5 L/ha, one spray of Terpal + Stena 0.5 L/ha + 0.75 L/ha) was the least effective on *Dianthus.*
- The foliage of plants in treatments T2 (Pirouette plug spray 0.45 L/ha, two sprays of Pirouette 0.45 L/ha), and T3 (Pirouette plug drench 0.3 L/ha, two sprays of Pirouette 0.45 L/ha) and T5 (Terpal plug drench 0.5 L/ha, two sprays of Terpal + Stena 0.5 L/ha + 0.75 L/ha) appeared slightly pale at various stages of the trial, but were not considered to be unmarketable. There was no evidence of petal bleach or spotting.
- There were no delays in flowering, with flowers emerging in all treatments by week 26. T3 (Pirouette plug drench 0.3 L/ha, two sprays of Pirouette 0.45 L/ha) had significantly fewer plants in flower at the end of the trial (83%).

Geranium 'Horizon' red

- The Geranium trial received one PGR post-transplant application. The plant height specification was 8 -10 cm.
- Treatments T4 (Terpal plug drench 0.45 L/ha, one spray of Terpal 0.75 L/ha), T5 (Moddus plug drench 0.15 L/ha, one spray of Terpal + Stena 0.5 L/ha + 0.75 L/ha) and T6 (Pirouette plug drench 0.3 L/ha, one spray of Terpal 0.75 L/ha) were effective, providing significantly greater growth control than water only.

- Treatment T3 (Terpal plug drench 0.5 L/ha, one spray of Terpal + Stena 0.5 L/ha + 0.75 L/ha) was not effective; plants were within height specification in week 26.
- Treatment T2 (Terpal plug spray 0.225 L/ha, one spray of Terpal + Stena 0.5 L/ha + 0.75 L/ha) was not effective.
- Trials of treatments of Terpal + Stena on other plant species have indicated that the addition of Stena can allow the PGR dose rate to be halved while having the same growth control effect. However, there appears to be little advantage in using Terpal with Stena over Geranium as plants in treatments T2 and T3 were taller than T4 (Terpal plug drench 0.45 L/ha, one spray of Terpal 0.75 L/ha).
- Treatment at plug stage was more important than the post-transplant treatments when comparing treatments T6 and T4. The low rate plug drench of Pirouette (T6, 0.3 L/h) was more effective than the Terpal plug drench (T4, 0.45 L/ha) when both treatments were followed by Terpal (0.75 L/ha).
- Treatment at plug stage was similarly important when comparing the effectiveness of treatments T2, T3 and T5, all of which were a plug treatment followed by a post-transplant treatment of Terpal (0.5 L/ha) + Stena (0.75 L/ha). The most effective plug treatment was the Moddus drench (T5, 0.15 L/ha), while the low rate Terpal spray (T2, 0.225 L/ha) and drench (T3, 0.5 L/ha) treatments were less effective.
- Treatments T3 (Terpal plug drench 0.5 L/ha, one spray of Terpal + Stena 0.5 L/ha + 0.75 L/ha) and T4 (Terpal plug drench 0.45 L/ha, one spray of Terpal 0.75 L/ha) caused some leaf chlorosis early on in the trial, but the plants grew away from this.
- All plants were marketable at the end of the trial, except for T5 (Moddus plug drench 0.15 L/ha, one spray of Terpal + Stena 0.5 L/ha + 0.75 L/ha) where the foliage and flowers were pale and the zoning was less pronounced than in other treatments. This treatment is not recommended.
- T6 (Pirouette plug drench 0.3 L/ha, one spray of Terpal 0.75 L/ha) appeared to promote flowering, with more flowers produced in this treatment compared to the water control.

Osteospermum ‘Akila’ purple

- The *Osteospermum* trial received two post-transplant applications. Plant height specification was 8-10 cm.
- There were extreme height differences by the end of the trial. Treatments T2 (Regalis Plus plug spray, 1.25 kg/ha; one sprench of Canopy + Stena, 0.337 kg/ha + 0.75 L/ha; and one sprench of Regalis Plus 1.25 kg/ha), T3 (Terpal plug drench, 0.5 L/ha; one sprench of Regalis Plus,1.25 kg/ha; and one sprench of Canopy 0.675 kg/ha), T4 (Terpal plug drench, 2.0 L/ha; two sprenches of Terpal, 2.0 L/ha) and T5 (Terpal plug drench, 1.0 L/ha; two

sprenches of Terpal + Stena, 1.0 L/ha + 0.75 L/ha) were effective, with plants significantly shorter than the water control.

- Treatments T6 (Pirouette plug drench, 0.3 L/ha; two sprenches of Pirouette, 0.75 L/ha) and T7 (Pirouette plug drench, 0.225 L/ha; two sprenches of Pirouette, 0.375 L/ha) were not effective.
- After one post-transplant sprench, T7 (after application of:Pirouette plug drench, 0.225 L/ha; one sprench of Pirouette, 0.375 L/ha) showed some yellow leaf spotting, but the plants grew away from this. There was no evidence of chlorosis, bleaching or distortion at the end of the trial.
- Plant quality was impacted during this trial. Scores ranged from 3 and 4 (good quality, some damage visible and good quality, very little damage) to 2 (poor quality). The dose rate used in T4 (Terpal plug drench 2.0 L/ha, two sprenches of Terpal 2.0 L/ha) proved too high, and impacted on plant quality (score 2.0), plant height (average 4.8 cm) and plants did not flower.
- Plant quality may have been impacted by the timing of this trial, under decreasing temperatures and shortening day length, therefore the results must be treated with caution.

Discussion

Dazide Enhance

Dazide Enhance was only used in the *Cosmos* trial as a post-transplant spray at 1.8 kg/ha. The product gave good growth control, and there was no evidence of phytotoxicity, although this treatment did produce the fewest open flowers at the end of the trial and appears to delay flowering with this species.

Canopy

Canopy gave reasonable growth control when it was used post-transplant at a rate of 0.675 kg/ha in the *Cosmos* trial. There was no phytotoxicity and no adverse effect on flowering due to Canopy. Canopy was also used post-transplant at 0.337 kg/ha in a tank-mix with Stena at 0.75 L/ha in the *Osteospermum* trial, followed by Regalis Plus 1.25 kg/ha; plant height was significantly shorter than the water control and there was no phytotoxicity but the time of year may have impacted the results in this trial.

Moddus

Moddus was used pre-transplant as a plug drench at 0.15 L/ha in the Geranium trial, followed post-transplant by Terpal tank-mixed with Stena (0.5 L/ha + 0.75 L/ha). This treatment gave good growth control, although the foliage and flowers were paler and the zoning was less

pronounced than in other treatments, which is likely to be a result of the Moddus drench, rather than the Terpal + Stena mix.

Pirouette

Pirouette was used pre-transplant as a plug sprench at 0.6 L/ha in the *Cosmos* trial followed by a range of treatments post-transplant. When Pirouette was followed by Dazide Enhance 1.8 kg/ha or Terpal 2.0 L/ha post-transplant it gave good growth control. The low rate of post-transplant Pirouette sprays at 0.75 L/ha did not provide sufficient control on *Cosmos*. Post-transplant sprays of Pirouette at 1.2 L/ha and 1.5 L/ha were more effective. There was no phytotoxicity or delay in flowering in the *Cosmos* trial due to any of the Pirouette treatments.

In the *Dianthus* trial, Pirouette was most effective when used as either a pre-transplant spray at 0.45 L/ha (T2) or drench at 0.3 L/ha (T3), followed by post-transplant sprays of Pirouette at 0.45 L/ha. When Pirouette was used as a drench pre-transplant, foliage was slightly pale but still acceptable. There were also fewer flowers produced by plants in this treatment.

Pirouette also gave good growth control and plants were good quality in the *Osteospermum* trial. Using Pirouette pre-transplant as a plug drench at 0.225 L/ha followed by one post-transplant sprench at 0.375 L/ha produced some yellow spotting on the leaves, but the plants recovered. Pirouette used at both 0.75 L/ha and 0.375 L/ha as post-transplant treatments resulted in more open flowers at the end of the trial compared with the water control.

Primo Maxx II

Primo Maxx II was only used in the *Cosmos* trial as a post-transplant treatment at 2.0 L/ha, when it provided limited height control and the flowers were pale in this treatment.

Regalis Plus

Regalis Plus was used post-transplant in the *Cosmos* trial at 1.25 kg/ha followed by Pirouette 0.6 L/ha. The Regalis Plus treatment gave good growth control for a short period, but after 14 days a further PGR application was required, hence an application of Pirouette 0.6 L/ha. There was no phytotoxicity in the *Cosmos* trial.

Regalis Plus was used pre-transplant as a drench at 1.25 kg/ha and post-transplant as a sprench at 1.25 kg/ha in the *Osteospermum* trial, when it was effective in controlling plant growth and there was no phytotoxicity.

Terpal

Terpal was used at 2.0 L/ha in the *Cosmos* trial. When there were two applications post-transplant, plant growth was significantly controlled, and there was no evidence of phytotoxicity or any adverse effect on flowering.

Terpal was used at a range of rates in the *Dianthus* trial. When used pre-transplant as a drench at 0.5 L/ha followed by two spray applications post-transplant at 0.5 L/ha + Stena 0.75 L/ha, the treatment was less effective, and plant height was similar to the water control. This treatment also resulted in slightly paler foliage. When Terpal was used at a higher dose rate pre-transplant as a drench at 1.0 L/h, followed by two spray applications post-transplant at 1.0 L/ha, plants were just within the height specification. There was no phytotoxicity or adverse effect on flowering.

In the Geranium trial, a post-transplant application of Terpal 0.5 L/ha + Stena 0.75 L/ha gave good growth control when Moddus 0.15 L/ha was used pre-transplant as a drench (T5). Height was also well controlled when Terpal was used alone post-transplant at 0.75 L/ha (T6, with a Pirouette 0.3 L/ha pre-transplant drench). There was no difference in growth control when Terpal was used either pre-transplant as a spray (T2, 0.225 L/ha) or pre-transplant as a drench (T3, 0.5 L/ha) and followed post-transplant by Terpal 0.5 L/ha + Stena 0.75 L/ha. When Terpal was used pre-transplant as a drench and followed post-transplant by Terpal, there was some chlorosis but the plants grew away from this.

Terpal was also used pre-transplant as a drench and post-transplant as a sprench in the *Osteospermum* trial. Growth was severely restricted when Terpal was used pre-transplant at 2.0 L/ha as a drench followed by two post-transplant sprench applications at 2.0 L/ha (T4). When Terpal was used post-transplant as a sprench at 1.0 L/ha + Stena 0.75 L/ha (T5), height was within specification. At the end of the trial, there were no open flowers in any of the Terpal treatments.

Stena

The adjuvant Stena was used post-transplant at 0.75 L/ha (label rate), with the PGR generally applied at half rate, although there was not always a directly comparable treatment without Stena due to limitations in trial size.

When used with Terpal at 0.5 L/ha (T5, with Stena) in the *Dianthus* trial, growth was less well controlled than Terpal applied at 1.0 L/ha (T4, without Stena), and the foliage was slightly pale; there was no adverse effect on flowering. However, this would also have been influenced by the pre-transplant Terpal treatments, which were applied at 0.5 L/ha (T5) and 1.0 L/ha (T4). Results were similar in the Geranium trial, when Stena was again applied with Terpal at 0.5

L/ha (T2 and T3) and plant height was very similar to the water control. However, more effective height control may be achieved by applying Terpal at a higher dose rate at plug (without Stena) or post-transplant stage.

Stena was used with Canopy at 0.337 L/ha in the *Osteospermum* trial followed by Regalis Plus 1.25 Kg/ha (T2). Growth control was effective, with the plants just below the height specification. There were no open flowers at the end of the trial, but many plants were showing buds. Treatment T5 (two post-transplant applications of Stena + Terpal, 1.0 L/ha). Was effective on *Osteospermum*, producing plants within specification, however there were no open flowers and significantly fewer buds in this treatment.

Conclusions

A number of PGRs, either alone or in combination, provided effective growth control on the species included in this trial, when applied pre- and post-transplant, although some treatments also caused pale foliage / flowers. All of the products tested except for Primo Maxx II featured in spray programmes that had a significant effect on plant growth compared with the water only control.

Pre-transplant treatments

Pirouette was effective when applied as the pre-transplant element at plug stage in programmes as a sprench (0.6 L/ha, *Cosmos*), spray (0.45 L/ha, *Dianthus*) and drench (0.3 L/ha, Geranium), without causing phytotoxicity. Similarly effective pre-transplant treatments were Regalis Plus (1.25 kg/ha drench, *Osteospermum*) and Terpal (0.5 L/ha, *Osteospermum, Dianthus,* Geranium or 1.0 L/ha drench, *Osteospermum;* 0.45 L/ha drench, Geranium).

In 2018, Moddus was used on Geranium post-transplant as a drench at 0.15 L/ha and 0.3 L/ha. Both treatments controlled height, but caused phytotoxicity. In 2019, Moddus was used pre-transplant as a drench at 0.15 L/ha, and caused some bleaching to flowers along with less pronounced zoning in the leaves. Even at low rates, Moddus is not recommended for use on Geranium.

Effective growth control at plug stage is important to ensure that control is achieved by the spray programme as a whole. Using the Geranium trial as an example, comparing treatments T4 (Terpal plug drench, 0.45 ml//L) and T6 (Pirouette plug drench, 0.3 ml/L), where the treatments at plug stage were followed with Terpal at 0.75 ml/L. Treatment T6 was more effective than T4. In this case, there is the potential to increase the dose rate of the Terpal pre-transplant treatment to improve efficacy.

Post-transplant treatments

In the 2018 post-transplant trial, the most promising product on *Dianthus* was Pirouette at 0.3 L/ha, however, further work was required to determine the most effective spray rate. The 2019 trial showed that *Dianthus* height was effectively controlled when Pirouette was used either pre-transplant as a spray (0.3 - 0.45 L/ha) or post-transplant as a spray at 0.45 L/ha.

Terpal applied at 1.0 L/ha – 1.5 L/ha showed promise on Geranium in the 2018 work. In 2019, Terpal was effective post-transplant either as a spray (0.75 L/ha), or as a spray with Stena (Terpal 0.5 L/ha + Stena 0.75 L/ha); in either case with a suitable pre-transplant treatment such as Pirouette drench (0.3 L/ha) or Terpal (0.5 L/ha).

During the 2018 *Osteospermum* trial, products were only applied as sprays at the full label or EAMU rate. Treatments were somewhat effective, but drench applications were likely to improve efficacy. In 2019, treatments were applied post-transplant as sprenches (5% of pack volume). The results however need to be viewed with caution, as the trial was carried out later in the year, with lower temperatures and decreasing day lengths.

Terpal sprenches at 2.0 L/ha post-transplant on *Osteospermum* appear to be too strong, severely restricting plant growth. However, Terpal sprenches at 1.0 L/ha + Stena 0.75 L/ha show promise. Height was reasonably well controlled, with no phytotoxicity, although flowering was delayed. A reduced rate of 0.5 L/ha + Stena 0.75 L/ha may prove suitable. Pirouette sprenches at 0.375 L/ha and 0.75 L/ha did not provide adequate control of *Osteospermum* growth.

A number of treatments showed promise on *Cosmos*. Effective post-transplant treatments were spray applications of Pirouette (1.2 L/ha and 1.5 L/ha), Canopy (0.675 Kg/ha), Terpal (2.0 L/ha) and Dazide Enhance (1.8 Kg/ha), which have potential on *Cosmos*.

Primo Maxx II sprays (2.0 L/ha) post-transplant are not recommended for use on *Cosmos* due to the risk of petal bleach. A lower rate is unlikely to provide sufficient growth control.

The use of the adjuvant Stena in some cases may allow rate reductions for the PGR in question, without impacting performance. However, the relative cost of adding Stena needs to be compared with the cost savings achieved using less PGR.

Growers should note 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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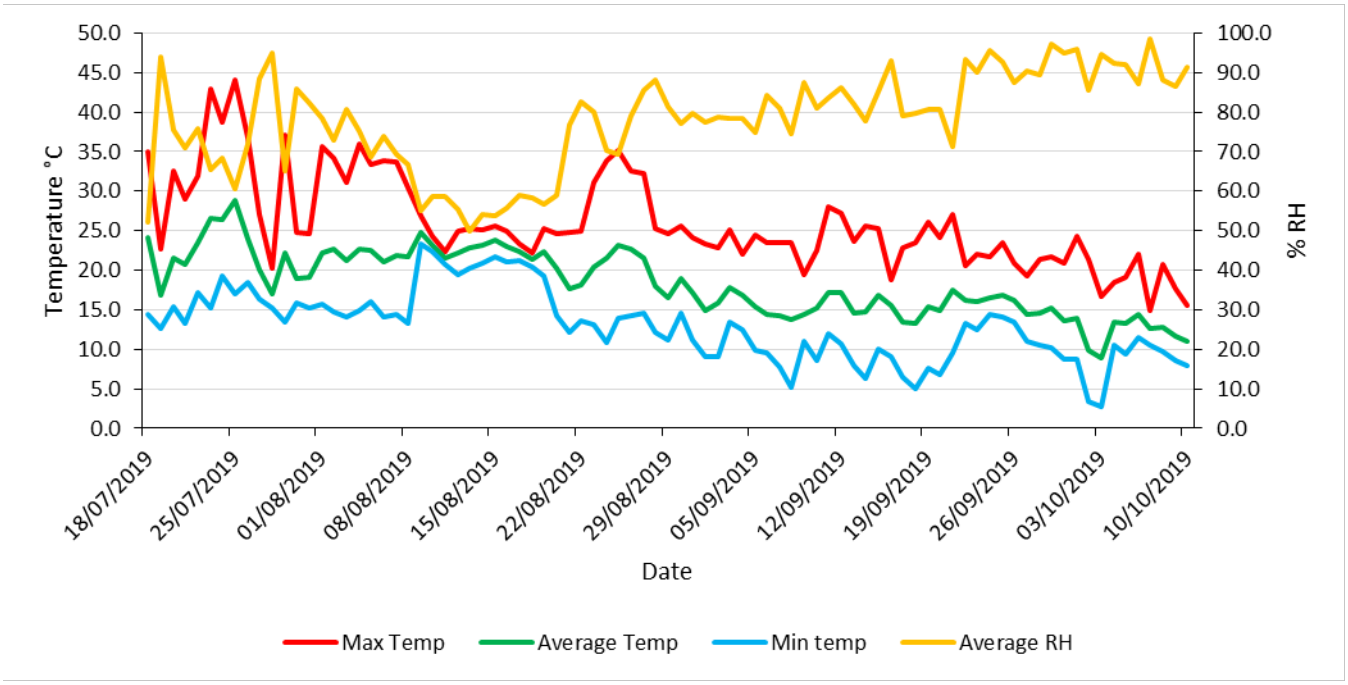
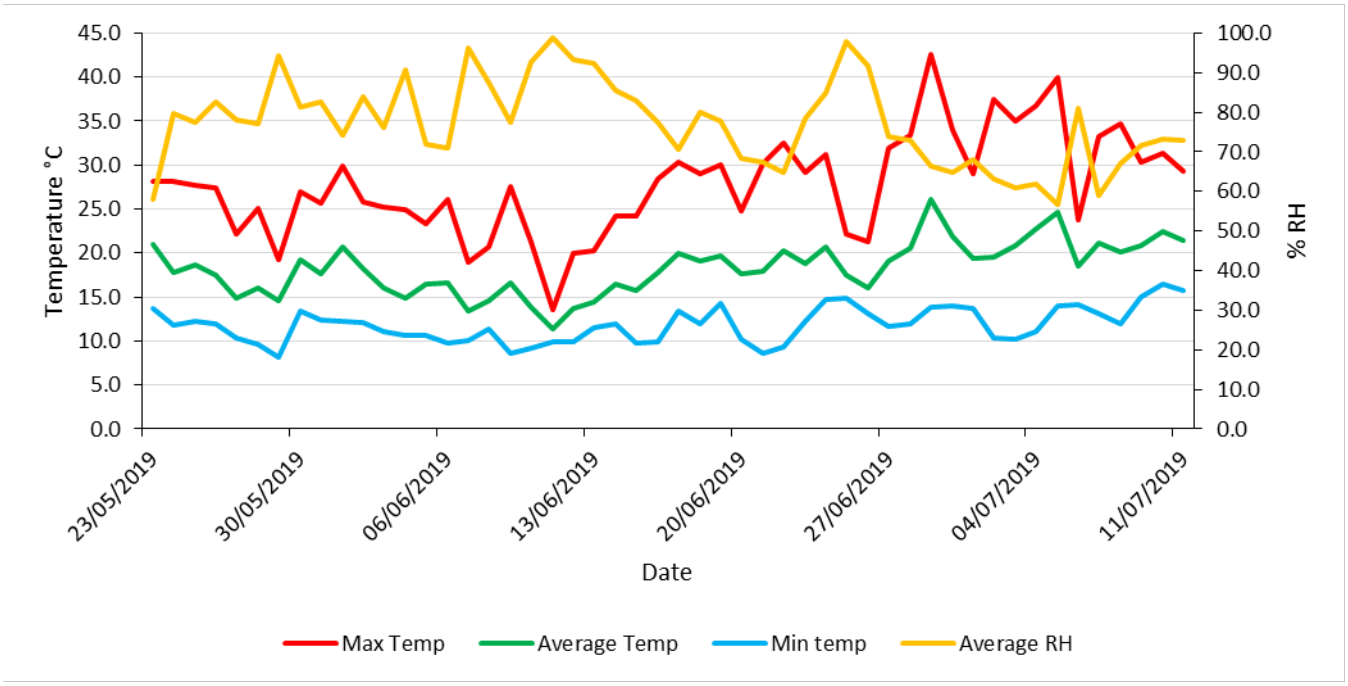
Appendix 1

Glasshouse temperature and humidity during the PGR bedding plants trial

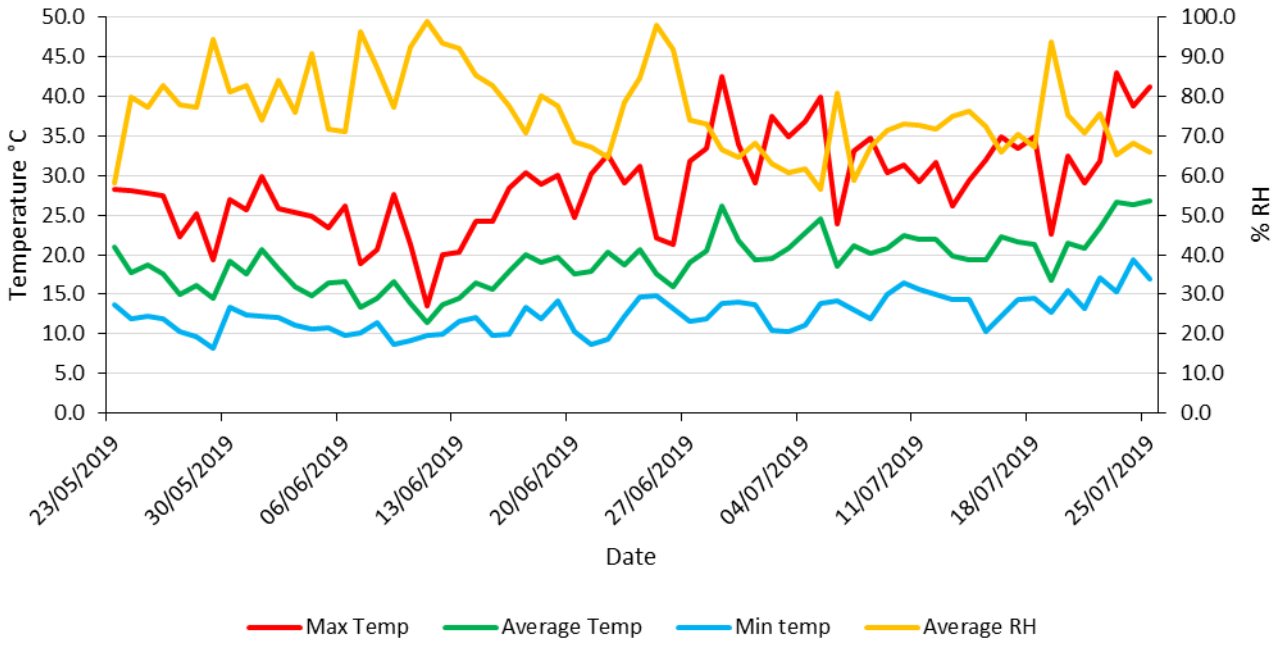
Cosmos



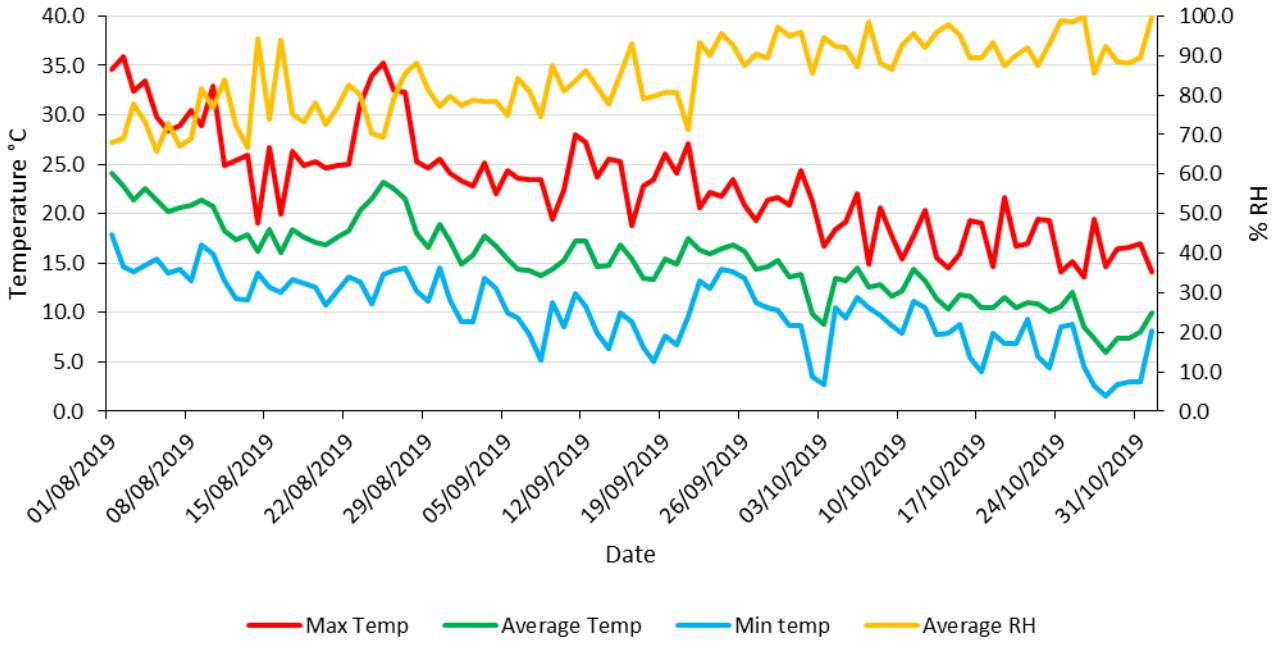
Dianthus



Geranium

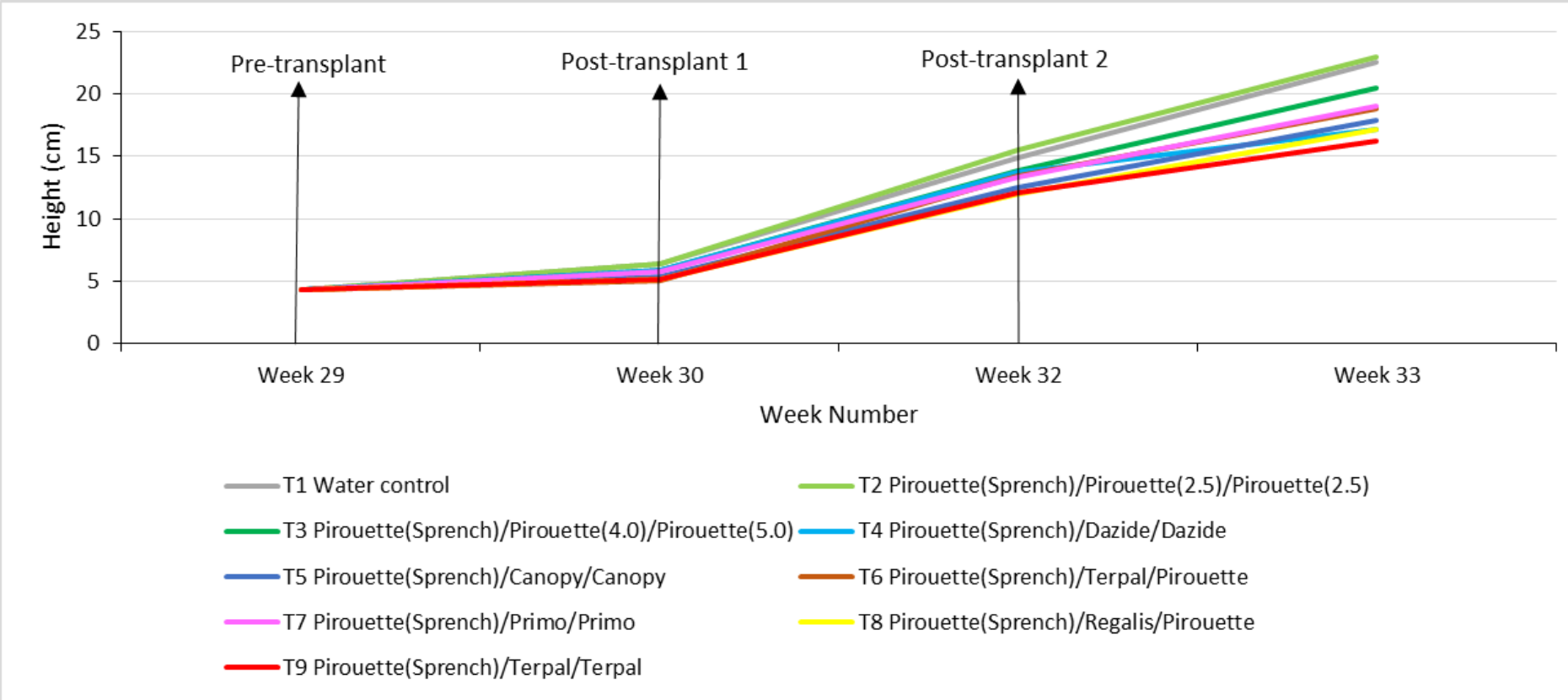


Osteospermum



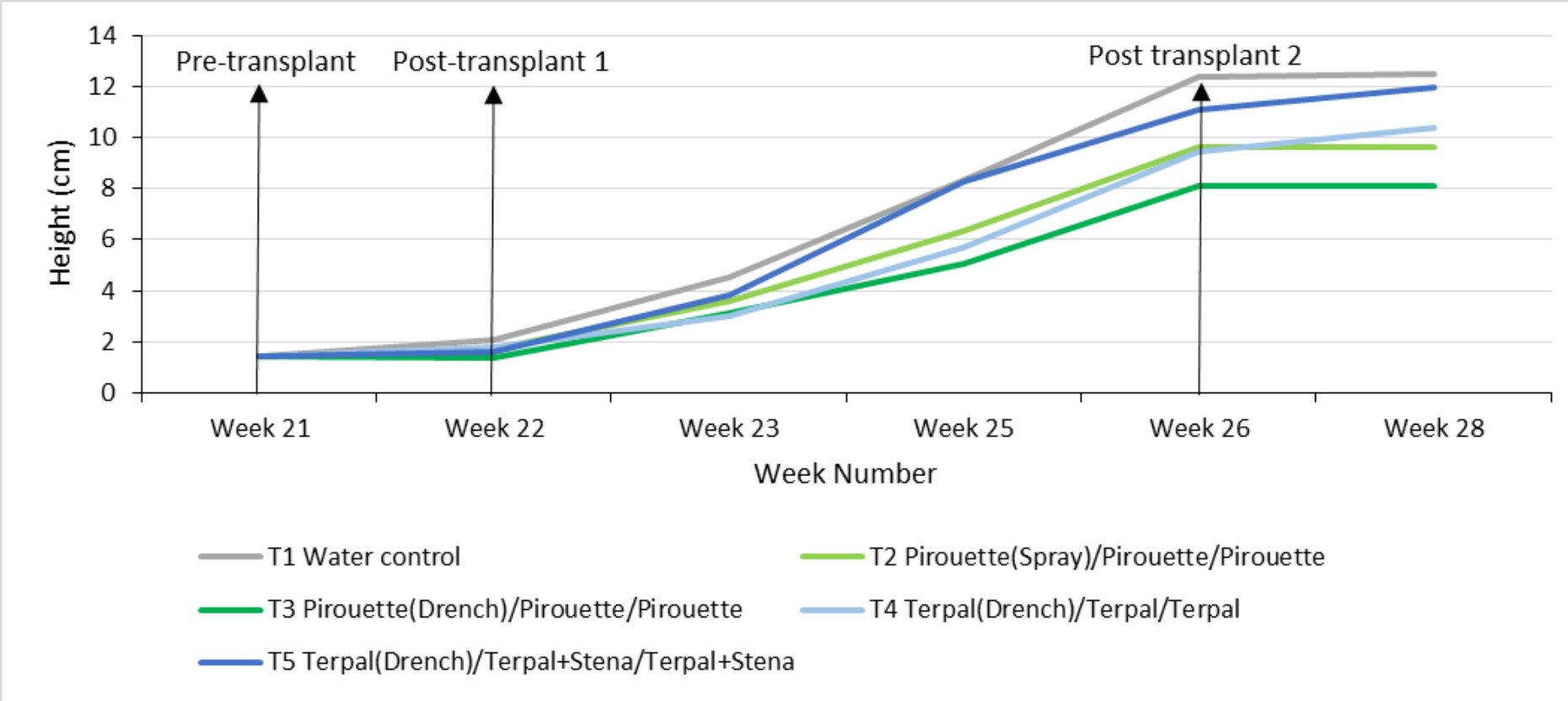
Appendix 2

Plant height - *Cosmos*



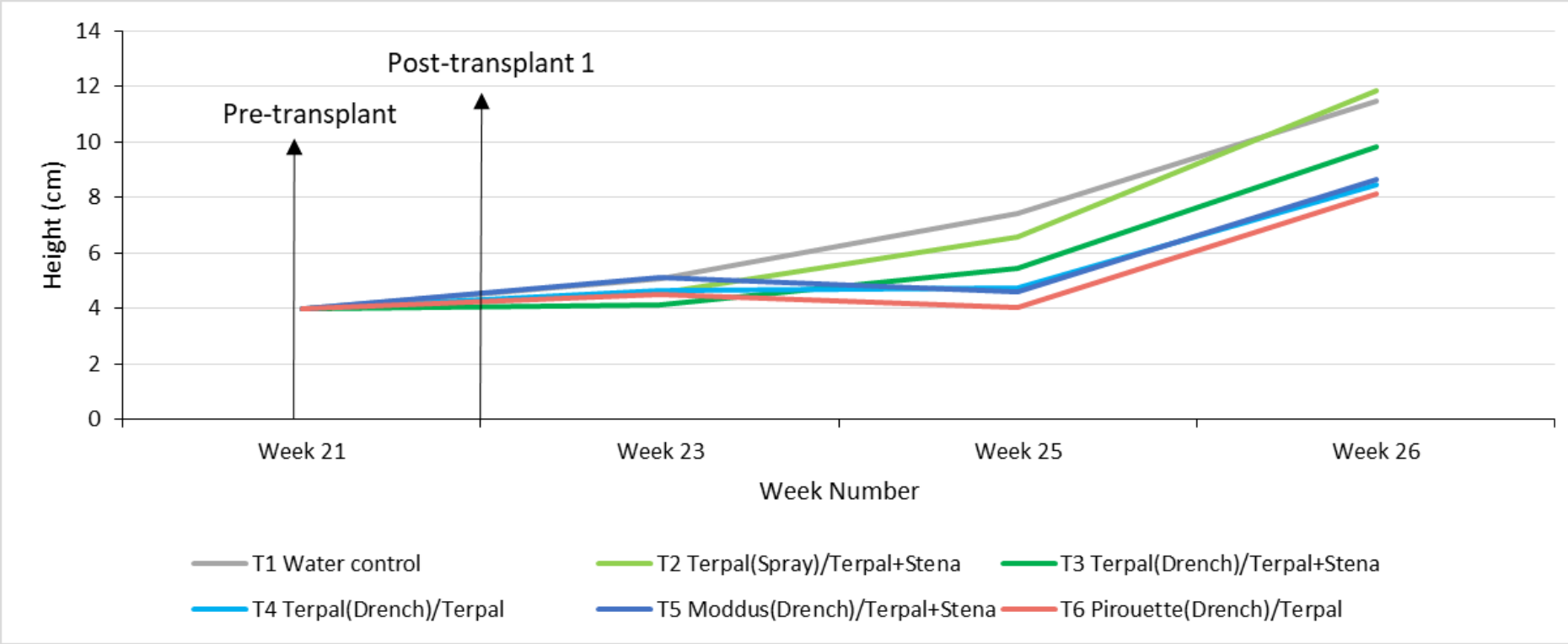
A. *Cosmos* 'Sonata' carmine height (cm). Height was assessed in weeks 29 (pre-transplant), 30 (prior to first post-transplant treatment), 32 (prior to second post-transplant treatment) and 33. Plants were treated in the plug tray two days prior to transplant, then twice post-transplant. An overspray of Bonzi at 2.0 ml/L was applied to the whole trial in week 34

Plant height - *Dianthus*



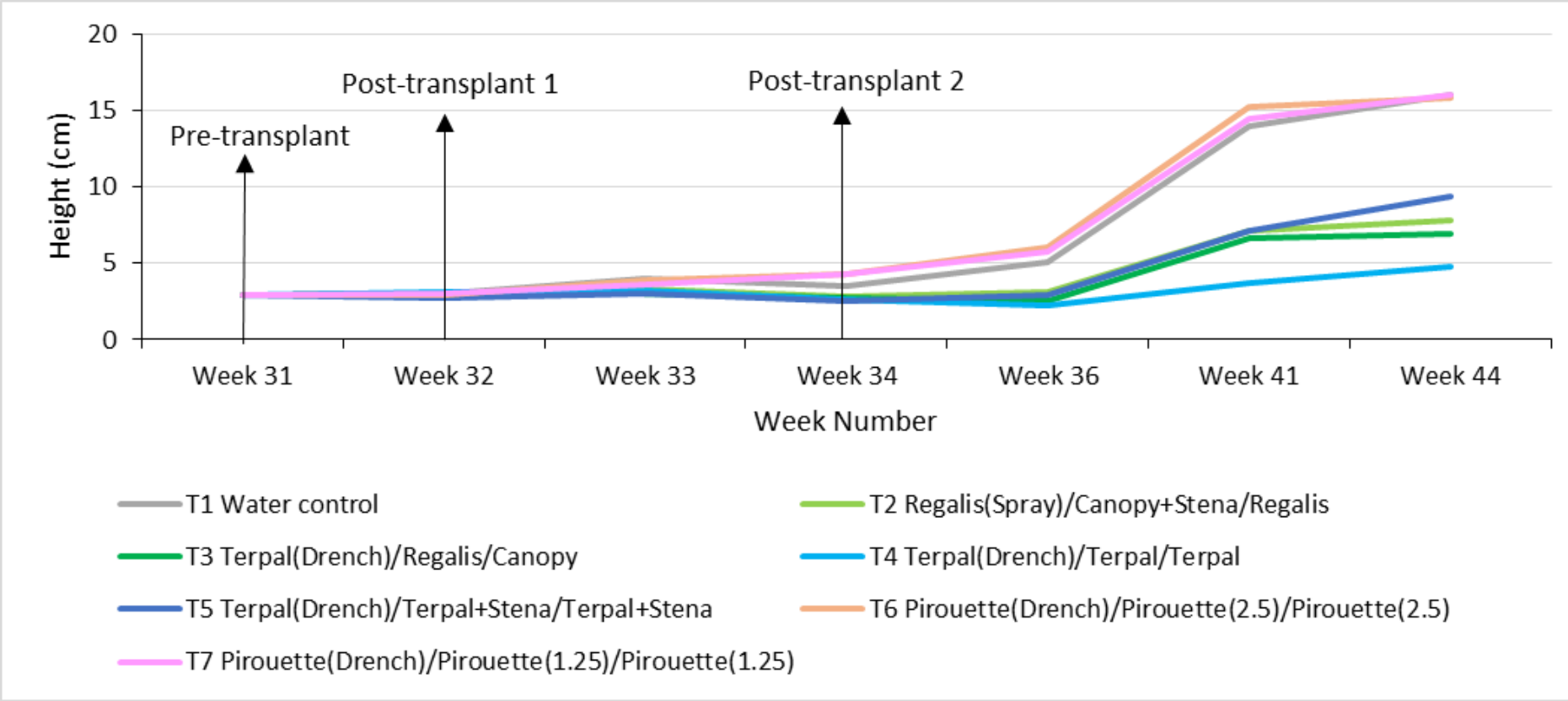
B. *Dianthus* 'Festival' violet height (cm). Height was assessed in weeks 21 (pre-transplant), 22 (prior to first post-transplant treatment), 23, 25, 26 (prior to second post-transplant treatment) and 28. Plants were treated in the plug tray two days prior to transplant, then twice post-transplant

Plant height - Geranium



C. Geranium 'Horizon' red height (cm). Height was assessed in weeks 21 (pre-transplant), 23, 25 and 26. Plants were treated in the plug tray two days prior to transplant, then once post-transplant in week 22

Plant height - *Osteospermum*



D. *Osteospermum* 'Akila' purple height (cm). Height was assessed in weeks 31 (pre-transplant) 32 (prior to first post-transplant treatment), 33, 34 (prior to second post-transplant treatment), 36, 41 and 44. Plants were treated in the plug tray two days prior to transplant, then twice post-transplant

Appendix 3

A. *Cosmos* 'Sonata' carmine - effects of treatments compared with the water control, week 41 2019. (Pre-transplant sprench of Pirouette 0.6 L/ha was used for T2 – T9)

	
T1 Water (left) vs. T2 Pirouette 0.75 L/ha (x2)	T1 Water (left) vs. T3 Pirouette 1.2 L/ha / Pirouette 1.5 L/ha
	
T1 Water (left) vs. T4 Dazide Enhance 1.8 kg/ha (x2)	T1 Water (left) vs. T5 Canopy 0.675 kg/ha (x2)
	
T1 Water (left) vs. T6 Terpal 2.0 L/ha / Pirouette 0.9 L/ha	T1 Water (left) vs. T7 Primo Maxx II 2.0 L/ha (x2)
	
T1 Water (left) vs. T8 Regalis Plus 1.25 kg/ha / Pirouette 0.6 L/ha	T1 Water (left) vs. T9 Terpal 2.0 L/ha (x2)

B. *Dianthus* ‘Festival’ violet - effects of treatments compared with the water control, week 28 2019

	
T1 Water (left) vs. T2 Pirouette plug spray 0.45 L/ha / Pirouette 0.45 L/ha (x2)	T1 Water (left) vs. T3 Pirouette plug drench 0.3 L/ha / Pirouette 0.45 L/ha (x2)
	
T1 Water (left) vs. T4 Terpal plug drench 1.0 L/ha / Terpal 1.0 L/ha (x2)	T1 Water (left) vs. T5 Terpal plug drench 0.5 L/ha / Terpal 0.5 L/ha + Stena 0.75 L/ha (x2)

C. Geranium ‘Horizon’ red - effects of treatments compared with the water control, week 32 2019

	
T1 Water (left) vs. T2 Terpal plug spray 0.225 L/ha / Terpal 0.5 L/ha + Stena 0.75 L/ha	T1 Water (left) vs. T3 Terpal plug drench 0.5 L/ha / Terpal 0.5 L/ha + Stena 0.75 L/ha
	
T1 Water (left) vs. T4 Terpal plug drench 0.45 L/ha / Terpal 0.75 L/ha	T1 Water (left) vs. T5 Moddus plug drench 0.15 L/ha / Terpal 0.5 L/ha + Stena 0.75 L/ha
	
T1 Water (left) vs. T6 Pirouette plug drench 0.3 L/ha / Terpal 0.75 L/ha	

D. *Osteospermum* ‘Akila’ purple - effects of treatments compared with the water control, week 44 2019

	
T1 Water (left) vs. T2 Regalis plug spray 1.25 kg/ha / Canopy 0.337 Kg/ha + Stena 0.75 L/ha / Regalis 1.25 kg/ha	T1 Water (left) vs. T3 Terpal plug drench 0.5 L/ha / Regalis 1.25 kg/ha / Canopy 0.675 kg/ha
	
T1 Water (left) vs. T4 Terpal plug drench 2.0 L/ha / Terpal 2.0 L/ha (x2)	T1 Water (left) vs. T5 Terpal plug drench 1.0 L/ha / Terpal 1.0 L/ha + Stena 0.75 L/ha (x2)
	
T1 Water (left) vs. T6 Pirouette plug drench 0.3 L/ha / Pirouette 0.75 L/ha (x2)	T1 Water (left) vs. T7 Pirouette plug drench 0.225 L/ha / Pirouette 0.375 L/ha (x2)