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 and pot plants*
Project number:	PO 019a
Project leader:	Dr Jill England, ADAS Boxworth
Report:	Annual report, 31 March 2018
Previous report:	None
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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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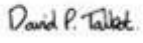
Signature  Date 31 March 2018

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Grower Summary

Headline

- Terpal + Activator 90 spray and drench applications reduced growth of *Begonia, Dianthus,* Geranium, Pansy, New Guinea *Impatiens* and *Zantedeschia* compared with the untreated control.
- Spray applications of the remaining products all controlled the growth of some species to varying degrees, in particular the spray application of HDC P005 showed promise in controlling growth of *Dianthus*.
- Drench applications of HDC P005, Moddus, Primo Maxx II, Terpal + Activator 90 and Regalis Plus reduced growth in all species, but were too strong; further trials in 2018 will refine application rates.
- EAMU 0151/18 has been issued for Terpal and 0621/18 for Primo Max II, an application has been submitted to CRD for an EAMU for HDC P005.

Background

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

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

This is the Bedding and Pot Plant Centre report for:

***Objective 1**. To evaluate plant growth regulators for use on bedding and pot plants*

Summary

The evaluation of new plant growth regulators (PGRs) for use on bedding and pot plants was prompted by label changes to the plant growth regulator Bonzi (paclobutrazol), including removal of the option for drench application, and the potential loss of approval for the use of chlormequat in protected ornamental plant production. Many growers apply PGRs as sprays and drenches and have developed application rates specific to the crops they grow under the specific growing conditions on their nurseries. The PGRs included in this trial have either been trialled in Denmark with promising results on bedding and pot plants, are new to the market or

have recently received CRD approval for use on related crops in the UK. However, any phytotoxic effects and efficacy of these chemicals on bedding and pot plants grown under UK conditions are currently unknown.

The active ingredients of the products included in this trial were predominately anti-gibberellins, which prevent production of gibberellin at various points in its biosynthesis. The three PGR groupings are: 1) Quaternary Ammonium Compounds (QAC) e.g. chlormequat chloride (Stabilan 750) and mepiquat chloride (a component of Terpal) which prevent gibberellin production early in its biosynthesis; 2) triazoles e.g. myclobutanil (Systhane 20 EW), paclobutrazol (Bonzi, Pirouette) and propiconazole (Bumper 250 EC); and 3) a group which prevents gibberellin production late in its biosynthesis: prohexadione calcium (Regalis), trinexapac-ethyl (Cutaway, Moddus and Primo Maxx II) 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.

A range of plant growth regulators was trialled on four bedding plant species (*Begonia semperflorens* 'Heaven' mixed, seed; *Dianthus* 'Festival' mixed, seed; Geranium 'Horizon' mixed, seed; Pansy 'Matrix' mixed, seed and two pot plant species (New Guinea *Impatiens* 'Divine Cherry Red', seed; and *Zantedeschia*, twelve varieties – 'Captain Series', 18-20mm corms). The bedding plants and New Guinea *Impatiens* were transplanted in weeks 21 (23 May 2017) and 22 (31 May 2017) respectively at Baginton Nurseries. The *Zantedeschia* were planted in week 18 (02 May 2017) by Lovania Nurseries (Preston, Lancs) and transported to Baginton Nurseries in week 20 (17 May 2017). The bedding and pot plants (New Guinea *Impatiens* and *Zantedeschia*) were transplanted into six-packs and 1L pots respectively.

Products tested are listed in **Table 1**. Sprays were applied by hand using a backpack and single nozzle lance, with an 02f110 nozzle, to achieve a fine spray quality, in a water volume of 300L/ha. All treatments were applied during late afternoon/early evening with shade screens over the crop prior to treatment.

For the New Guinea *Impatiens* and *Zantedeschia* in 1L pots, 75ml was applied as the drench, followed by 25ml as plain water to wash plant growth regulators off the foliage and into the growing media. For the six-pack bedding, 101.25ml was applied to each pack as the drench, followed by 33.75ml of plain water.

Treatments were applied as a foliar spray or drench from one week post-transplant, except for the *Zantedeschia,* where drench treatments were applied from two weeks after planting, when the new shoots were 1-2cm tall; spray treatments were applied from four weeks after planting.

The number of applications varied depending upon plant species and PGR product. All the bedding plant varieties and New Guinea *Impatiens* received two spray or drench applications (with the exception of Moddus and Regalis Plus, which were applied once only), the *Zantedeschia* received two spray or three drench treatments (Moddus and Regalis Plus were applied only once as sprays and Moddus once as a drench, but two Regalis Plus drenches were applied as they were made three weeks apart).

Table 1. Approval status of PGR products and treatments applied - 2017

	Product	**Active ingredient**	**Application method**	**Dose rate**	**Approval status**
1	HDC P005		Spray*	2.25ml/L (0.675L/ha)	Not approved on protected ornamentals in UK
2			Drench*		
3	Terpal (MAPP 16463) + Activator 90 (ADJ 0547)	Ethephon + mepiquat chloride	Spray*	6.67ml/L (2.0L/ha) +40ml/100L spray solution	EAMU 0151/18 issued 30.01.18
4			Drench*		
5	Regalis Plus (MAPP 16485)	Prohexadione	Spray	4.17g/L (1.25kg/ha)	EAMU 0181/15. Three weeks must be allowed between applications
6			Drench*		
7	Dazide Enhance (MAPP 16092)	Daminozide	Spray	6.0g/L (1.8kg/ha)	Full approval
8			Drench*		
9	Primo Maxx II (MAPP 17509)	Trinexapac-ethyl	Spray*	6.67ml/L (2.0L/ha)	Not approved on protected ornamentals in UK (EAMU issued after the trial)
10			Drench*		
11	Moddus (MAPP 15151)	Trinexapac-ethyl	Spray	2ml/L (0.6L/ha)	EAMU 3062/10. One application only permitted per crop
12			Drench*		
13	Untreated	-	-	-	-

* Treatments applied under experimental permit.

Plant height and growth

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

Spray applications

Terpal + Activator 90 showed most promise out of the new products, controlling growth of all plant species compared with the untreated control. Dazide Enhance sprays provided some growth control of *Begonia* and Pansy under the conditions of this trial, 20 days after treatment (DAT). The remaining products all controlled the growth of some species to varying degrees. Moddus did reduce growth of New Guinea *Impatiens* (41 DAT) with the single application permitted by the approval. Similarly, a single application of Regalis Plus was made as the approval requires three weeks between treatments, and this reduced growth of Pansy (20 DAT) and *Zantedeschia* (20 and 33 DAT).

Spray application of HDC P005 showed promise, controlling growth in the *Dianthus,* Pansy, New Guinea *Impatiens* and *Zantedeschia*; while Primo Maxx II controlled the growth of Geranium, New Guinea *Impatiens* and *Zantedeschia*.

Drench applications

Drench applications of HDC P005, Moddus, Primo Maxx II, Regalis Plus and Terpal + Activator 90 all had a strong effect at the rates used in this trial, controlling the height of all species to varying degrees. For some species the effect was too strong, resulting in plants that were too small.

Flowering

None of the treatments had a significant effect on flowering of Geranium. Significantly fewer flowers were produced by the Pansy (20 DAT) due to the Terpal + Activator 90 spray and drench treatments compared with the untreated control, indicating delayed flowering. The New Guinea *Impatiens* was more sensitive than other species, producing significantly fewer flowers than the untreated control in the majority of treatments throughout the trial; the exceptions were the Dazide Enhance and Regalis Plus sprays.

Flowering was delayed by the Terpal + Activator 90 drench treatments, with significantly fewer flowers produced compared with the untreated control on the *Begonia, Dianthus,* and Pansy at 20 DAT, and on the New Guinea *Impatiens* at all assessments; no flowers were produced in the Geranium or New Guinea *Impatiens.* Within the timescale of this trial, the *Zantedeschia* did not produce any flowers in the untreated control, and few flowers in the treatments.

Phytotoxicity

Spray treatments

Minimal or no phytotoxicity was recorded in the Dazide Enhance and HDC P005 spray treatments on all plant species. Similarly little phytotoxicity was recorded for the Moddus spray treatments, with the exception of treatments on *Dianthus*, which showed significant phytotoxicity 10 DAT; this was not evident by 20 DAT.

Strong phytotoxicity was recorded in treatments of Primo Maxx II and Terpal + Activator 90 treatment on *Dianthus* (10 DAT); and slight phytotoxicity found on *Dianthus* and Pansy (20 DAT). Primo Maxx II also caused slight phytotoxicity on *Begonia* (20 DAT).

Drench treatments

The Dazide Enhance did not cause significant phytotoxicity, with the exception of some leaf yellowing present in Pansy, 10 DAT, but these symptoms were no longer evident by 20 DAT. None of the drench treatments caused phytotoxicity symptoms on *Zantedeschia.*

Regarding the HDC P005 drench, no phytotoxicity symptoms were apparent 10 DAT, but were present by 20 DAT in all the bedding species and New Guinea *Impatiens;* no phytotoxicity was present on the *Zantedeschia.*

In the case of the Moddus drench, phytotoxicity symptoms appeared by 10 DAT in Pansy and New Guinea *Impatiens*; and by 20 DAT in *Begonia,* Geranium, Pansy and New Guinea *Impatiens.* No phytotoxicity was present in the *Zantedeschia.*

Regalis Plus caused phytotoxicity in the *Begonia,* Geranium and New Guinea *Impatiens* by 20 DAT.

The Terpal + Activator 90 drench treatment was too strong, resulting in phytotoxicity to all plant species with the exception of *Zantedeschia.*

Summary of results by plant species

- *Begonia semperflorens* 'Heaven'
    - Spray treatments generally did not effectively control growth; the exception was the Terpal spray which had a strong effect.
    - Drench treatments were generally too strong, producing plants that were too small, except for Dazide Enhance which had a slight effect on plant growth.
    - Phytotoxicity ranged from slight (HDC P005, Dazide Enhance, Moddus and Primo Maxx II) to severe (Regalis Plus and Terpal + Activator 90).

    - Flowering time was significantly delayed by the drench treatments (HDC P005, Moddus, Primo Maxx II, Regalis Plus and Terpal + Activator 90) at the final assessment. Spray treatments did not delay flowering.
- *Dianthus* 'Festival'
    - Spray treatments of HDC P005 were effective on *Dianthus* growth compared with the untreated control, but Dazide Enhance, Moddus, Primo Maxx II, and Regalis Plus were not effective. Terpal + Activator 90 had a slight effect.
    - Drench treatments of HDC P005, Moddus, Primo Maxx II and Terpal + Activator 90 all had a strong effect. Dazide Enhance and Regalis Plus (single application) were ineffective and had a slight effect respectively.
    - Slight phytotoxicity was caused by the Terpal + Activator 90 drench treatment.
    - Significantly fewer flowers were produced in the HDC P005 and Terpal + Activator 90 drench treatments at the final assessment.
- Geranium 'Horizon'
    - Spray applications of Primo Maxx II and Terpal + Activator 90 were effective in controlling growth, HDC P005, Dazide Enhance, Moddus and Regalis Plus did not control growth.
    - Terpal + Activator 90 treatment caused slight chlorosis at the rate used when applied as a spray.
    - Drench treatments of HDC P005, Moddus, Primo Maxx II, Regalis Plus and Terpal + Activator 90 were too strong at the rates used, controlling growth but also causing slight to severe phytotoxicity.
- Pansy 'Matrix'
    - The Pansy in all treatments including the untreated control were below 80mm in height.
    - Spray treatments of HDC P005, Dazide Enhance, Regalis Plus and Terpal + Activator 90 were all effective in controlling growth compared with the untreated control; Moddus and Primo Maxx II were not effective.
    - Drench treatments of HDC P005, Moddus and Regalis Plus were effective on Pansy with no or minimal phytotoxicity. Dazide Enhance was not effective. Primo Maxx II and Terpal + Activator 90 were too strong and caused severe phytotoxicity.
    - Fewer flowers were produced in both the spray and drench treatments of Terpal + Activator 90; no other treatments affected flowering.

- New Guinea *Impatiens* Divine 'Cherry Red'
    - All products except for Regalis Plus (single spray) reduced plant growth when applied as sprays.
    - Drench treatments were all too strong and with varying degrees of phytotoxicity ranging from slight (HDC P005, Dazide Enhance and Moddus) to severe (Primo Maxx II, Regalis Plus and Terpal + Activator 90).
    - Fewer flowers were produced in the spray and drench treatments of HDC P005 and Terpal + Activator 90; and drench treatments of Moddus, Primo Maxx II and Regalis Plus.
- *Zantedeschia* 'Captain' Series
    - No phytotoxicity was observed in either spray or drench treatments.
    - Spray treatments of Terpal + Activator 90 effectively controlled plant growth; HDC P005 and Regalis Plus had some effect on plant growth; other products had no effect.
    - Drench treatment of Terpal + Activator 90 had the strongest effect on plant growth; all other treatments had a slight effect except for Dazide Enhance which had no effect.
    - Few flowers were produced on the *Zantedeschia* within the timeframe of this trial.

Terpal + Activator 90 was perhaps the most promising product of those tested, controlling growth of all subjects when applied both as a spray and drench. However, the drench rate used was too strong, producing plants that were too small, delaying flowering and causing phytotoxicity. The spray treatment delayed flowering in New Guinea *Impatiens* and Pansy but not the other species.

Growers find it particularly difficult to control the growth of *Dianthus*, therefore it was promising that HDC P005 had an effect in this trial.

While spray applications of Moddus and Regalis Plus did not control growth as effectively as some other products, only one application was made to all species. No phytotoxicity was recorded by either of these treatments at the final assessment, therefore these products may prove useful as part of a spray programme, particularly for plant species with a longer production time.

While the drench treatments of most of the products tended to be too strong, this does provide the opportunity to test lower application rates to achieve good growth control without phytotoxicity and delayed flowering.

Financial benefits

The evaluation of plant growth regulators (PGRs) either approved in the UK or in other European Countries for use on bedding plants (spray and drench application), followed by appropriate AHDB EAMU applications will expand the range of active ingredients in the growers' armoury for controlling plant growth. Whilst growers do use cultural methods (e.g. temperature, diff/drop, controlling irrigation and nutrient supply) to control plant growth where possible, lack of cost-effective PGRs approved for use on protected ornamentals would reduce the range of plants that can be produced profitably within client specifications. PGRs are particularly important when used to hold mature crops at a specified height during periods of low demand where other methods would lead to unacceptable effects e.g. leaf yellowing. The cost per litre of spray solution to apply the products included in this trial at the specified rates ranges from 0.5p to 88.4p (**Table 2**) and provides greater opportunity to increase profit through reduced input cost.

Table 2. PGR costs (non-discounted, excluding VAT and labour costs for application)

Product	Cost of active ingredient (p/ml)	Cost of spray at rate used** (p/L)
Bonzi	9.5	11.9
Dazide Enhance	14.7	88.4
HDC P005	XX	XX
Moddus	3.9	7.8
Primo Maxx II	5.0	33.3
Regalis Plus	12.3	51.3
Terpal + Activator 90	2.4	11.6
Terpal*	1.7	11.3
Activator 90*	0.6	0.3

*Individual cost of adjuvant and PGR. Regalis Plus and Moddus applied as a single treatment; all other products applied as two treatments due to label requirements. **Refers to full approval/EAMU rate.

Action points

- Test new or unfamiliar products on a small number of plants before large scale use.
- Growers should familiarise themselves with and adhere to product labels, approvals and Extensions of Approval for Minor Use (EAMUs) prior to use. Note that a number of the treatments included in this trial have been carried out under experimental permit and are not currently authorised for nursery use in the UK.
- Growers should note that that the spray rate used in the trials (300 litres per hectare) may be lower than the rate they currently use and as such application rates or volumes may need to be adjusted to maintain the same application rate of active ingredient.

- Of the products currently with approved uses on protected ornamentals in the UK, useful effects were achieved with spray treatments of Terpal + Activator 90 on Geranium 'Horizon', Pansy 'Matrix' and New Guinea *Impatiens*; Regalis Plus on Pansy 'Matrix'; and Moddus on New Guinea *Impatiens.*
- Although their use is not currently permitted on protected ornamentals, useful effects were achieved with spray treatments of HDC P005 on *Dianthus* 'Festival', Pansy 'Matrix' and New Guinea *Impatiens*; Primo Maxx II on Geranium 'Horizon' and New Guinea *Impatiens*. EAMU applications have been submitted for Primo Maxx II and HDC P005.
- Useful effects were achieved with drench treatments of Terpal + Activator 90 on Pansy 'Matrix' and *Zantedeschia*; Moddus on Pansy 'Matrix'; and Regalis Plus on Pansy 'Matrix'.

Science Section

Introduction

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

The work programme is guided by a grower-led Management Group that includes members of the BPOA Technical Committee and representatives from Baginton Nurseries, Coventry the central host nursery for the BPPC. The agreed objectives for the Bedding and Pot Plant Centre, 2017-18 were:

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

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

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

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

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

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

This is the Bedding and Pot Plant Centre report for Objective 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 potential loss of approval for the use of chlormequat in protected ornamental plant production. Many growers apply PGRs as sprays

or 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 CRD approval for use on related crops in the UK; any phytotoxic effects and efficacy of these chemicals under UK conditions are unknown. A number of PGRs were considered for inclusion in this trial.

Caryx (210g/L mepiquat (as chloride) and 30g/L metconazole, BASF), is currently used on Poinsettia in Germany and was included in Danish trials (Hartvig and Hjelmroth, 2016; Paaske, 2015). However, any EAMU application was likely to fail worker exposure assessments and therefore was not being pursued.

Configure (20g/L 6-benzyladenine, Fine Agrochemicals Ltd / Fargro) is new to the UK and has approval for use on *Phalaenopsis, Schlumbergera, Sempervivum* and *Kalanchoe.* The expected effect is increased bud growth and branching to produce height restrictions. Consideration is being given to an application to increase the range of species included in the EAMU, but restrictive handling restrictions (currently a species-dependent 30-60 day re-entry period) would make this less useful to bedding plant producers.

Cutaway (121g/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 projects HNS 187 and HNS 187a on tree species, 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. This product has now been replaced in the trial with **Primo Maxx II** (116.4g/L trinexapac-ethyl), as this is the most similar formulation.

Medax Top (300g/L mepiquat chloride + 50g/L prohexadione-calcium, BASF) was developed for use on cereals and grass seed, and is approved for use on cereals in the UK. It was found to be less effective at controlling the growth of *Pelargonium '*Dronning Ingrid' than Caryx, 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%. Medax Top did not reduce the number of *Bacopa* flowers produced although they were slightly smaller (Paaske, 2015).

Moddus (250g/L trinexapac-ethyl, Syngenta Crop Protection UK Ltd) is approved for use on cereals in the UK and has approval (EAMU 3062/10) for use on ornamentals. However, the formulation and application rates differ from the EAMU for Cutaway. Danish work has indicated that Moddus was too strong for *Osteospermum* 'Naomi', with dose rates of 0.5% to 1.0%,

causing plant death (Paaske, 2013). However, it was not effective on Marguerites at the rates tested (Paaske, 2010).

Regalis Plus (100g/kg prohexadione, BASF) is approved for use on protected ornamentals in the UK (EAMU 1868/15). It is in the same chemical group as daminozide, although with greater activity. Previous trials have indicated that Regalis, applied either as a drench or spray, is effective in controlling plant growth within some bedding plant species. However, its use can also result in flower petal bleaching in some plant species (Brough, 2011). Regalis Plus is the new formulation which includes a built-in water conditioner which will reduce the time required for rain fastness from 6 hrs to 2 hrs. The new formulation will supersede Regalis once existing stocks have been sold. In the Danish work, Regalis produced compact Marguerites (*Argyranthemum frutescens* 'Dana') at 0.1% (Paaske, 2010).

Terpal (155g/L ethephon + 305g/L mepiquat chloride, BASF) is a new product that is approved for use on protected ornamentals in Denmark, where results were promising on *Osteospermum* 'Naomi' (Paaske, 2013). In the UK, Terpal is approved for use in outdoor forest nurseries (EAMU 2725/14). At the time of the trial, the manufacturer recommended that Terpal should be applied with an authorised non-ionic wetter (e.g. Activator 90) which must be added to the spray tank at a rate of 40ml per 100L of spray solution.

The active ingredients of the products included in this trial are predominately anti-gibberellins, which prevent production of gibberellin at various points in its biosynthesis. The three PGR groupings are: 1) Quaternary Ammonium Compounds (QAC) e.g. chlormequat chloride (Stabilan 750) and mepiquat chloride (a component of Terpal) which prevent gibberellin production early in its biosynthesis; 2) triazoles e.g. myclobutanil (Systhane 20 EW), paclobutrazol (Bonzi, Pirouette) and propiconazole (Bumper 250 EC); and 3) a group which prevents gibberellin production late in its biosynthesis: prohexadione calcium (Regalis Plus), trinexapac-ethyl (Cutaway, Moddus and Primo Maxx II) and daminozide (B-nine). The exception is ethephon (a component of Terpal) which breaks down within the plant to produce the plant hormone, ethylene. Of the three groups the triazoles are the most active, although levels of activity varies within this group.

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

DIY stores and multiple retailers generally specify plant height of 80-120mm (excluding 'flower stems') and 100% pack cover for pack bedding. Garden centres can have a less rigid approach and accept product with less pack cover, while reject primarily 'stretched' or 'floppy' plants. The distance between Danish trolley shelves (typically 8 shelves plus base) presents a practical limitation on plant height of around 160mm.

A range of PGRs were tested on pot and bedding plant subjects via spray and / or drench application as appropriate under UK conditions.

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 and pot plants (spray and drench application) **(To evaluate plant growth regulators for use on bedding and pot plants).**

Methods and materials

Site and crop production details

Four bedding plant species (*Begonia semperflorens* 'Heaven' mixed, seed; *Dianthus* 'Festival' mixed, seed; Geranium 'Horizon' mixed, seed; Pansy 'Matrix' mixed, seed) and two pot plant species (New Guinea *Impatiens* 'Divine Cherry Red', seed; and *Zantedeschia*, twelve varieties – 'Captain Brunello', 'Captain Cheerio', 'Captain Fargo', 'Captain Fresco', 'Captain Fuego', 'Captain Lido', 'Captain Lovely', 'Captain Marrero', 'Captain Morelli', 'Captain Marrero', and 'Captain Samba', 'Mercedes' and 'Red Alert', 18-20mm corms) were used for this trial.

The bedding plants and New Guinea *Impatiens* were transplanted in weeks 21 (23 May 2017) and 22 (31 May 2017) respectively at Baginton Nurseries (**Figure 1**). The *Zantedeschia* corms were planted in week 18 (02 May 2017) by Lovania Nurseries (Preston, Lancs) and transported to Baginton Nurseries in week 20 (17 May 2017). The bedding and pot plants (New Guinea *Impatiens* and *Zantedeschia*) were transplanted into six-packs and 1 L pots respectively.

Everris growing media (60% peat, 40% woodfibre, plus Osmocote Protect 5 to 6 months 14-8-11+2MgO+TE) was used for the bedding varieties and New Guinea *Impatiens* (Bagintons standard mix); Sinclair growing media (100% medium peat, plus PG Mix 12-14-24) was used for the *Zantedeschia.* No liquid feeding was required for any of the varieties.

Spray treatments were applied by hand using a backpack and single nozzle lance, with an 02f110 nozzle, to achieve a fine spray quality, in a water volume of 300L/ha. Spray boards were used to prevent drift onto neighbouring plots.

Drenches were applied at 10% of pot/pack volume of which 75% was applied as the drench followed by 25% as plain water to wash plant growth regulators off the foliage and into the growing media. For the New Guinea *Impatiens* and *Zantedeschia* in 1 L pots, 75% (75ml) was applied as the drench, followed by 25% (25ml) as plain water to wash plant growth regulators off the foliage and into the growing media. For the six-pack bedding, 101.25ml was applied to each pack as the drench, followed by 33.75ml of plain water.

For both the drenches and the sprays, treatments were applied during late afternoon/early evening with shade screens over the crop prior to treatment. Plants were moist when treatments were applied, and were not watered for 24 hours after treatment.

Products not currently authorised for use on protected ornamentals or for drench application were applied under experimental permit (2017/01098/17 and 2017/02964).

For the bedding varieties and New Guinea *Impatiens*, treatments (**Table 3**) were applied as a foliar spray or drench from one week post-transplant. For the *Zantedeschia,* drench treatments were applied from two weeks after planting, when the new shoots were 1-2cm tall; spray treatments were applied from four weeks after planting.

On 20 July, two Geranium plants from each treatment (one pink, one white) were potted on into 1 L pots and placed under glass to assess the longer term effect of the PGR treatments.

Table 3. PGR product and treatment list 2017

	Product	Active ingredient	Marketing company	Application method*	Dose rate	Approval status
1	HDC P005			Spray**	2.25ml/L (0.675L/ha)	EAMU application submitted; dose rate based on EAMU application.
2				Drench**		
3	Terpal (MAPP 16463) + Activator 90 (ADJ 0547)	Ethephon + mepiquat chloride	BASF	Spray**	6.67ml/L (2.0L/ha)	EAMU 0151/18 issued 30.01.18. Activator 90 applied at 40 ml/100 L spray solution.
4				Drench**		
5	Regalis Plus (MAPP 16485)	Prohexadione	BASF	Spray	4.17g/L (1.25kg/ha)	EAMU 0181/15. Three weeks must be allowed between applications.
6				Drench**		
7	Dazide Enhance (MAPP 16092)	Daminozide	Fargro Ltd	Spray	6.0g/L (1.8kg/ha)	Full approval. Maximum of 5 treatments per crop permitted.
8				Drench**		
9	Primo Maxx II (MAPP 17509)	Trinexapac-ethyl	Syngenta UK Ltd	Spray**	6.67ml/L (2.0L/ha)	Primo Maxx II substituted for Cutaway; dosed rate based on Cutaway EAMU 2140/16.
10				Drench**		
11	Moddus (MAPP 15151)	Trinexapac-ethyl	Syngenta UK Ltd	Spray	2ml/L (0.6L/ha)	EAMU 3062/10. One application only permitted per crop.
12				Drench**		
13	Untreated	-	-	-	-	-

*Foliar sprays applied in approximately 300 L water/ha. Drenches were applied at 10% of pot / pack volume of which 75% was applied as the drench followed by 25% as plain water to wash plant growth regulators off the foliage and into the growing media, i.e. drenches were applied to 1 L pot as 75 ml followed by 25 ml plain water. ** Treatments applied under experimental permit

Figure 1. PGR trials at set up**:** Bedding varieties (left), New Guinea *Impatiens* 'Divine Cherry Red' (centre) and *Zantedeschia* varieties (right)

PGRs* applied to plants by the supplier prior to dispatch were as follows:

- *Dianthus*: paclobutrazol (as Bonzi, 2 applications, 25/04/17 and 05/05/17)
- *Pelargonium:* daminozide (as B-Nine) + chlormequat (as Stabilan 750, 1 application, 27/04/17)
- Pansy: chlormequat (as Stabilan 750, 1 application, 01/05/17) and paclobutrazol (as Bonzi, 1 application, 12/05/17)
- *Begonia*, New Guinea *Impatiens* 'Divine Cherry' and *Zantedeschia* (all varieties): no PGRs applied prior to delivery.

(*note: rates not included as commercial in confidence)

Plants were monitored for pests and diseases throughout the trial. No insecticides or fungicides were applied.

Table 4. Summary of PGR applications, 2017

Date	Week no.	Application method	Plant
17 May	20	1st drench	*Zantedeschia*
30 May	22	1st spray and drench	Bedding varieties
30 May	22	1st spray	*Zantedeschia*
30 May	22	2nd drench	*Zantedeschia*, excluding Moddus and Regalis Plus
09 June	23	2nd spray and drench	Bedding varieties excluding Moddus and Regalis Plus
09 June	23	1st spray and drench	New Guinea *Impatiens*
09 June	23	2nd spray	*Zantedeschia*, excluding Moddus and Regalis Plus
09 June	23	3rd drench	*Zantedeschia*, excluding Moddus. A second Regalis Plus drench treatment was applied as 3 weeks had passed since the first drench treatment
19 June	25	2nd spray and drench	New Guinea *Impatiens*, excluding Moddus and Regalis Plus

Trial design and statistical analysis

Treatments were arranged in a randomised split plot design with 13 treatments (product x application method), with three replicate blocks and a total of 2808 plants (36 per variety, per treatment). The *Zantedeschia* and New Guinea *Impatiens* were set out separately to the bedding plants and each other as they were planted or transplanted on different dates. For the bedding plants, plots consisted of two 6-packs (12 plants); for the *Zantedeschia* and New Guinea *Impatiens,* plots consisted of 12 plants in 1 L pots.

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

Assessments

Prior to transplant, plug root development (**Table 5**), plant quality (**Table 6**), and height were assessed. Phytotoxicity was assessed from the first treatment application onwards (**Table 7**).

Inspections and assessments are summarised in **Table 8** and below.

Table 5. 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 6. 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 7. 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 8. Summary of bedding and pot plant trial inspections and assessments, 2017

Date	Week no.	Action	Assessment
02 May	18	*Zantedeschia* corms planted	-
23 May	21	Bedding transplanted	Root development score, plant quality score, plant height (mm)
30 May	22	Pre-treatment assessment (*Zantedeschia*)	Plant height (mm), phytotoxicity score
30 May	22	Pre-treatment assessment (bedding)	Plant quality score, plant height (mm)
31 May	22	New Guinea *Impatiens* transplanted	
09 June	23	Pre-treatment assessment (New Guinea *Impatiens*)	Plant quality score and height (mm)
09 June	23	Pre-treatment assessment (bedding)	Plant quality score, phytotoxicity score, height (mm), number of plants with open flowers
19 June	25	Pre-treatment assessment (New Guinea *Impatiens*)	Plant quality score, phytotoxicity score, height (mm)
19 June	25	Final assessment (bedding) and *Zantedeschia*	Plant quality score, phytotoxicity score, height (mm), number of plants with open flowers/number of plants with buds showing colour, number of dead plants
06 July	27	Interim assessment (New Guinea *Impatiens*)	Plant quality score, phytotoxicity score, height (mm), number of plants with open flowers/number of plants with buds showing colour, number of dead plants
06 July	27	Final assessment (Geranium)	Number of plants with open flowers or with buds
11 July	28	Interim assessment (New Guinea *Impatiens*)	Plant quality score, phytotoxicity score, height (mm), number of plants with open flowers / number of plants with buds showing colour, number of dead plants

20 July	29	Final assessment (New Guinea *Impatiens*)	Plant quality score, phytotoxicity score, height (mm), number of plants with open flowers/number of plants with buds showing colour, number of dead plants

Results

The effect of each PGR treatment on the height, growth, quality and flowering of the six plant species included in the trial is compared with that of the untreated control and Dazide Enhance (reference product). The effects of the different treatments is presented below including a summary listed by plant species. Detailed comments are tabulated in (**Appendix 1.1**). Temperature and humidity was monitored throughout the trial (**Appendix 1.2**).

All plants obtained for the trial were of good quality prior to transplant; *Zantedeschia* were supplied as corms.

Plant height and growth

Plant height graphs are presented in (Appendix 1.3). Plant growth between transplant and the final assessment, with a calculation of the percentage height difference compared with the untreated control are presented in (**Table 9**). It should be noted that for growers the focus is on products that will control plants sufficiently to bring them within the required height specification.

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

Spray applications

Dazide Enhance sprays provided some control of *Begonia* and Pansy under the conditions of this trial, 20 DAT. Terpal + Activator 90 showed most promise out of the new products, controlling growth of all plant species compared with the untreated control. The remaining products all controlled the growth of some species to varying degrees. Moddus did reduce growth of New Guinea *Impatiens* (41 DAT), however a single application was made as permitted by the approval (other products received two applications). Similarly a single application was made of Regalis Plus as the approval requires three weeks between treatments, and this reduced growth of Pansy (20 DAT) and *Zantedeschia* (20 and 33 DAT).

Spray application of HDC P005 showed promise, controlling growth in the *Dianthus,* Pansy, New Guinea *Impatiens* and *Zantedeschia*; while Primo Maxx II controlled the growth of Geranium, New Guinea *Impatiens* and *Zantedeschia*.

Drench applications

Drench application of HDC P005, Moddus, Primo Maxx II, Regalis Plus and Terpal + Activator 90 all had a strong effect at the rates used in this trial, controlling the height of all species to varying degrees. For some species the effect was too strong, resulting in plants that were too small.

Flowering

None of the treatments had a significant effect on flowering of Geranium (**Table 10**). Significantly fewer flowers were produced by the Pansy (20 DAT) due to the Terpal + Activator 90 spray and drench treatments compared with the untreated control, indicating delayed flowering. The New Guinea *Impatiens* was more sensitive than other species, producing significantly fewer flowers than the untreated control in the majority of treatments throughout the trial; the exceptions were the Dazide Enhance and Regalis Plus sprays.

Flowering was delayed by the Terpal + Activator 90 drench treatments, with significantly fewer flowers produced compared with the untreated control on the *Begonia, Dianthus,* and *Pansy* at 20 DAT, and on the New Guinea *Impatiens* at all assessments; no flowers were produced in the Geranium or New Guinea *Impatiens.* Within the timescale of this trial, the *Zantedeschia* did not produce any flowers in the untreated control, and few flowers in the treatments; an average of one plant produced any flowers in the HDC P005, Primo Maxx II and Regalis Plus spray treatments, and the HDC P005, Dazide Enhance and Regalis Plus drench treatments by 33 DAT. Notes on any treatment effect on flower size and flower colour intensity were made where relevant.

Table 9. Effect of treatments on average plant height and growth (height increase from transplant) and average height reduction relative to the untreated control

	Treatment	Application method and no. of treatments*	*Begonia*			*Dianthus*			Geranium		
			Ave. height (mm)	Ave. growth (mm)	Height change (%)	Ave. height (mm)	Ave. growth (mm)	Height change (%)	Ave. height (mm)	Ave. growth (mm)	Height change (%)
1	Untreated	N/A	66.0	30	-	144.7	61	-	61.3	27	-
2	Dazide Enhance	Spray x 2	62.3	26	-12%	167.0	83	37%	69.7	36	30%
3	Dazide Enhance	Drench x 2	64.3	28	-6%	191.3	108	77%	60.3	26	-4%
4	HDC P005	Spray x 2	83.3	47	59%	113.0	29	-52%	63.7	30	9%
5	HDC P005	Drench x 2	23.7	-13	-143%	106.7	23	-62%	16.0	-18	-166%
6	Moddus	Spray x 1	82.3	46	55%	151.0	67	10%	64.3	30	11%
7	Moddus	Drench x 1	23.7	-13	-143%	89.3	6	-91%	28.7	-5	-120%
8	Primo Maxx II	Spray x 2	79.3	43	45%	203.7	120	97%	41.7	8	-72%
9	Primo Maxx II	Drench x 2	21.0	-15	-152%	98.3	15	-76%	21.3	-13	-146%
10	Regalis Plus	Spray x 1	79.3	43	45%	161.0	77	27%	62.3	28	4%
11	Regalis Plus	Drench x 1	15.0	-21	-172%	108.7	25	-59%	23.7	-10	-138%
12	Terpal + Activator 90	Spray x 2	54.0	18	-41%	134.0	50	-18%	58.3	24	-11%
13	Terpal + Activator 90	Drench x 2	20.0	-16	-155%	43.7	-40	-166%	24.7	-9	-134%
	s.e.d.		18.37			18.37			18.37		
	l.s.d.		36.43	n/a	n/a	36.43	n/a	n/a	36.43	n/a	n/a
	F pr		0.002		36.43	0.002			0.002		
	Values highlighted red are significantly different to the untreated control.										

Final assessment dates were: 19 June 2017, week 25, 20 DAT (bedding varieties); 20 July 2017, week 29, 41 DAT (New Guinea *Impatiens*); and 19 June 2017, week 25, 20 and 33 DAT, spray and drench treatments respectively (*Zantedeschia* 'Captain Samba'). *Note that the *Zantedeschia* received one drench of Moddus, two drenches of Regalis Plus (

Table 4) and three drenches of all other products; spray treatments were the same for all plant species. DAT = Days after first treatment. Height specification for pack bedding is 80mm – 120mm.

Table 9 contd. Effect of treatments on plant height and growth (height increase from transplant) and average height reduction relative to the untreated control

	Treatment	Application method and no. of treatments*	Pansy			New Guinea *Impatiens*			*Zantedeschia* 'Captain Samba'		
			Ave. Height (mm)	Ave. growth (mm)	Height change (%)	Ave. height (mm)	Ave. growth (mm)	Height change (%)	Ave. Height (mm)	Ave. growth (mm)	Height change (%)
1	Untreated	N/A	109.7	48	-	70.7	45	-	257.3	129	-
2	Dazide Enhance	Spray x 2	93.0	32	-34%	74.0	48	-1%	288.0	222	16%
3	Dazide Enhance	Drench x 2	116.7	55	14%	67.3	41	-14%	357.3	224	17%
4	HDC P005	Spray x 2	85.7	24	-50%	64.0	38	-21%	273.0	130	-32%
5	HDC P005	Drench x 2	90.3	29	-40%	37.3	11	-76%	320.7	163	-15%
6	Moddus	Spray x 1	127.3	66	37%	70.0	44	-9%	298.7	193	1%
7	Moddus	Drench x 1	93.0	32	-34%	35.7	10	-80%	223.7	168	-12%
8	Primo Maxx II	Spray x 2	115.7	54	12%	66.0	40	-17%	238.3	171	-11%
9	Primo Maxx II	Drench x 2	36.3	-25	-152%	24.7	-1	-103%	312.7	158	-17%
10	Regalis Plus	Spray x 1	102.3	41	-15%	77.3	51	6%	279.0	173	-10%
11	Regalis Plus	Drench x 1	62.7	1	-97%	27.0	1	-98%	290.0	178	-7%
12	Terpal + Activator 90	Spray x 2	58.7	-3	-105%	55.3	29	-39%	216.7	144	-25%
13	Terpal + Activator 90	Drench x 2	45.7	-16	-132%	28.7	3	-94%	156.0	74	-61%
	s.e.d.		18.37			8.11					
	l.s.d.		36.43	n/a	n/a	16.73	n/a	n/a	No statistical	n/a	n/a
	F pr		0.002			<.001			analysis		
	Values highlighted red are significantly different to the untreated control.										

Final assessment dates were: 19 June 2017, week 25, 20 DAT (bedding varieties); 20 July 2017, week 29, 41 DAT (New Guinea *Impatiens*); and 19 June 2017, week 25, 20 and 33 DAT, spray and drench treatments respectively (*Zantedeschia* 'Captain Samba'). *Note that the *Zantedeschia* received one drench of Moddus, two drenches of Regalis Plus (

Table 4) and three drenches of all other products; spray treatments were the same for all plant species. DAT = Days after first treatment. Height specification for pack bedding is 80mm – 120mm.

Table 10. Number of plants in flower

	Treatment	Application method and no. of treatments*	*Begonia*		*Dianthus*		Geranium		Pansy		New Guinea *Impatiens*			*Zantedeschia* 'Captain Samba'
			10 DAT	20 DAT	10 DAT	20 DAT	10 DAT	20 DAT	10 DAT	20 DAT	27 DAT	32 DAT	41 DAT	20 and 33 DAT
1	Untreated	N/A	9.3	11.3	1.0	8.7	0.0	2.0	0.0	7.7	3.7	9.7	9.7	0.0
2	Dazide Enhance	Spray x 2	8.0	11.3	0.7	8.3	0.0	1.0	0.0	8.3	4.0	7.7	10.3	0.0
3	Dazide Enhance	Drench x 2	9.7	11.7	0.7	7.3	0.0	1.0	0.0	8.3	3.0	5.7	10.3	1.0
4	HDC P005	Spray x 2	8.7	11.7	0.7	7.7	0.0	1.3	0.0	7.3	1.7	3.7	4.7	1.0
5	HDC P005	Drench x 2	7.0	3.3	0.3	6.3	0.0	0.3	0.0	8.3	1.3	3.3	5.3	1.0
6	Moddus	Spray x 1	7.0	12.0	0.7	9.0	0.0	1.3	0.0	8.3	2.0	6.7	9.0	0.0
7	Moddus	Drench x 1	9.7	5.7	2.3	8.3	0.0	0.3	0.0	8.0	0.3	0.3	0.0	0.0
8	Primo Maxx II	Spray x 2	10.0	12.0	1.3	10.3	0.0	0.7	0.0	9.3	0.7	4.7	6.3	1.0
9	Primo Maxx II	Drench x 2	8.7	3.3	3.0	8.7	0.0	0.3	0.0	7.0	0.0	0.0	0.0	0.0
10	Regalis Plus	Spray x 1	9.0	12.0	1.7	7.7	0.0	2.0	0.3	9.7	3.0	9.0	10.0	1.0
11	Regalis Plus	Drench x 1	5.7	2.3	0.7	7.0	0.0	1.3	0.0	10.0	0.0	0.0	0.3	1.0
12	Terpal + Activator 90	Spray x 2	9.3	11.3	0.7	7.3	0.0	1.0	0.0	4.3	0.7	1.7	1.0	0.0
13	Terpal + Activator 90	Drench x 2	4.3	0.0	1.7	2.3	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0
	s.e.d		0.8908	0.9637	0.8908	0.9637				0.9637	1.033	1.241	1.862	
	l.s.d		1.7734	1.9186	1.7734	1.9186	Not sig	Not sig	Not sig	1.9186	2.132	2.562	3.842	No statistical analysis
	F pr		0.002	<0.001	0.002	<0.001				<0.001	0.002	<0.001	<0.001	
	Values highlighted red are significantly different to the untreated control. P = 0.05.													

Assessment dates for the bedding species were prior to the second treatment on the 09 June 2017 (week 23, 10 DAT) and at the final assessment on the 19 June 2017 (week 25, 20 DAT). NGImps were assessed prior to the second treatment on 19 June 2017, week 25, 10 DAT (no flowers present), and then assessed on the 06 July 2017 (week 27, 27 DAT), 11 July 2017 (week 28, 32 DAT) and 20 July 2017 (week 29, 41 DAT). *Zantedeschia* data presented is for the final assessment for spray treatments (19 June 2017, week 25, 20 DAT) and drench treatments (19 June 2017, week 25, 33 DAT). *Note that the *Zantedeschia* received one drench of Moddus, two drenches of Regalis Plus (

Table 4) and three drenches of all other products; spray treatments were the same for all plant species. DAT = days after first treatment.

Phytotoxicity

Spray treatments

Minimal or no phytotoxicity was recorded in the Dazide Enhance and HDC P005 spray treatments on all plant species. Similarly, little phytotoxicity was recorded for the Moddus spray treatments, with the exception of treatments on *Dianthus*, which showed significant phytotoxicity 10 DAT (9 June 2017); this was not evident by 20 DAT (19 June 2017).

Strong phytotoxicity was recorded in treatments of Primo Maxx II on *Dianthus* (10 DAT); and slight phytotoxicity was present on *Dianthus, Begonia and* Pansy (20 DAT) (**Figure 2**). Similarly, strong phytotoxicity was recorded in treatments of Terpal + Activator 90 treatment on *Dianthus* (10 DAT); and some phytotoxicity was present on *Dianthus,* Geranium and Pansy (20 DAT).

Drench treatments

The Dazide Enhance did not cause significant phytotoxicity, with the exception of some leaf yellowing present in Pansy, 10 DAT, but these symptoms were no longer evident by 20 DAT. None of the drench treatments caused phytotoxicity symptoms on the *Zantedeschia.*

Regarding the HDC P005 drench, no phytotoxicity symptoms were apparent 10 DAT, but were present by 20 DAT in all the bedding species and New Guinea *Impatiens;* no phytotoxicity was present on the *Zantedeschia.*

In the case of the Moddus drench (**Figure 3**), phytotoxicity symptoms appeared by 10 DAT in Pansy and New Guinea *Impatiens*; and by 20 DAT in *Begonia,* Geranium, Pansy and New Guinea *Impatiens.* No phytotoxicity was present in *Zantedeschia.*

Regalis Plus caused phytotoxicity in the *Begonia,* Geranium and New Guinea *Impatiens* by 20 DAT. Symptoms were also visible in response to Primo Maxx II (**Figure 4**).

Terpal + Activator 90 drench treatment was too strong, phytotoxicity was present on all plant species with the exception of *Zantedeschia* (**Figure 5**).

Pansy Dianthus

Figure 2. Phytotoxic effects of Primo Maxx II spray treatments on Pansy and *Dianthus*

Geranium

Pansy

Figure 3. Phytotoxic effects of Moddus drench treatments on Geranium and Pansy

Geranium: leaf yellowing

Pansy: leaf yellowing

Figure 4. Phytotoxic effects of Primo Maxx II drench treatments on Geranium and pansy

Dianthus: leaf yellowing

Geranium: leaf yellowing and necrosis

Pansy: leaf yellowing, stunted growth

Figure 5. Phytotoxic effects of Terpal + Activator 90 drench treatments

Table 11. Average phytotoxicity scores

	Product	Application method and no. of treatments*	Begonia		Dianthus		Geranium		Pansy		New Guinea *Impatiens*	
			10 DAT	20 DAT	10 DAT	20 DAT	10 DAT	20 DAT	10 DAT	20 DAT	10 DAT	41 DAT
1	Untreated	N/A	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
2	Dazide Enhance	Spray x 2	9.0	8.7	9.0	8.3	9.0	9.0	9.0	8.7	9.0	8.7
3	Dazide Enhance	Drench x 2	9.0	8.7	9.0	8.7	9.0	9.0	2.3	8.7	9.0	8.3
4	HDC P005	Spray x 2	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	8.0
5	HDC P005	Drench x 2	9.0	4.7	9.0	7.7	9.0	5.0	9.0	7.7	9.0	6.3
6	Moddus	Spray x 1	9.0	9.0	2.7	9.0	9.0	9.0	9.0	9.0	9.0	8.7
7	Moddus	Drench x 1	9.0	4.7	9.0	8.0	9.0	5.7	4.7	6.7	8.0	2.0
8	Primo Maxx II	Spray x 2	9.0	7.7	2.0	6.7	9.0	9.0	9.0	7.3	9.0	8.0
9	Primo Maxx II	Drench x 2	9.0	4.0	6.3	6.3	2.3	4.0	2.3	3.3	8.7	0.7
10	Regalis Plus	Spray x 1	9.0	9.0	9.0	8.7	9.0	8.7	2.7	9.0	9.0	8.3
11	Regalis Plus	Drench x 1	9.0	3.3	9.0	7.7	9.0	4.7	9.0	8.0	7.7	2.3
12	Terpal + Activator 90	Spray x 2	9.0	8.3	2.0	7.3	9.0	7.7	9.0	7.3	9.0	8.0
13	Terpal + Activator 90	Drench x 2	9.0	3.0	2.3	5.0	2.3	2.0	4.3	2.7	6.0	0.7
	s.e.d.		1.53	0.55	1.53	0.55	1.53	0.55	1.53	0.55	0.45	0.71
	l.s.d		3.04	1.09	3.04	1.09	3.04	1.09	3.04	1.09	0.93	1.46
	F pr			<0.001		<0.001		<0.001		<0.001	<0.001	<0.001
	Values highlighted red are significantly different to the untreated control. P = 0.05											

Assessment dates for each species were prior to second treatment (bedding varieties, 09 June 2017, week 23, 10 DAT; NGImp, 19 June 2017, week 25, 10 DAT and at the final assessment (bedding varieties, 19 June 2017, week 25, 20 DAT; NGImp 20 July, week 29, 41 DAT). Phytotoxicity score: scale of 0-9, where 0 = dead; 5 = slight damage, slight yellowing; 9 = comparable with untreated control. NGImp = New Guinea *Impatiens.* No phytotoxicity was recorded on *Zantedeschia* by the final assessment on 19 June 2017, week 25, 20 and 33 DAT (spray and drench treatments respectively). *Note that the *Zantedeschia* received one drench of Moddus, two drenches of Regalis Plus (

Table 4) and three drenches of all other products; spray treatments were the same for all plant species. DAT = days after first treatment.

Summary of results by plant species

Detailed comments are presented in **Appendix 1.1**.

- *Begonia semperflorens* 'Heaven'
    - Spray treatments generally did not effectively control growth; the exception was the Terpal spray which had a strong effect.
    - Drench treatments were generally too strong, producing plants that were too small, except for Dazide Enhance which had a slight effect on plant growth.
    - Phytotoxicity ranged from slight (HDC P005, Dazide Enhance, Moddus and Primo Maxx II) to severe (Regalis Plus and Terpal + Activator 90).
    - Flowering time was significantly delayed in the drench treatments (HDC P005, Moddus, Primo Maxx II, Regalis Plus and Terpal + Activator 90) at the final assessment. Spray treatments did not delay flowering.
- *Dianthus* 'Festival'
    - Spray treatments of HDC P005 were effective on *Dianthus* growth compared with the untreated control, but Dazide Enhance, Moddus, Primo Maxx II, and Regalis Plus were not effective. Terpal + Activator 90 had a slight effect on growth.
    - Drench treatments of HDC P005, Moddus, Primo Maxx II and Terpal + Activator 90 all had a strong effect. Dazide Enhance and Regalis Plus (single application) were either ineffective or had a slight effect respectively.
    - Slight phytotoxicity was caused by the Terpal drench treatment.
    - Significantly fewer flowers were produced in the HDC P005 and Terpal + Activator 90 drench treatments at the final assessment.
- Geranium 'Horizon'
    - Spray applications of Primo Maxx II and Terpal + Activator 90 were effective in controlling growth, HDC P005, Dazide Enhance, Moddus, Primo Maxx II and Regalis Plus did not control growth.
    - Terpal + Activator 90 treatment caused slight chlorosis at the rate used when applied as a spray.
    - Drench treatments of HDC P005, Moddus, Primo Maxx II, Regalis Plus and Terpal + Activator 90 were too strong at the rates used, controlling growth but also causing slight to severe phytotoxicity.
- Pansy 'Matrix'
    - The Pansy in all treatments including the untreated control were below 80mm in height.

    - Spray treatments of HDC P005, Dazide Enhance, Regalis Plus and Terpal + Activator 90 were all effective in controlling growth compared with the untreated control; Moddus and Primo Maxx II were not effective.
    - Drench treatments of HDC P005, Moddus and Regalis Plus were effective on Pansy with no or minimal phytotoxicity. Dazide Enhance was not effective. Primo Maxx II, and Terpal + Activator 90 were too strong and caused severe phytotoxicity.
    - Fewer flowers were produced in both the spray and drench treatments of Terpal + Activator 90; no other treatments affected flowering.
- New Guinea *Impatiens* Divine 'Cherry Red'
    - All products except for Regalis Plus (single spray) reduced plant growth when applied as sprays.
    - Drench treatments were all too strong and with varying degrees of phytotoxicity ranging from slight (HDC P005, Dazide Enhance and Moddus) to severe (Primo Max II, Regalis Plus and Terpal + Activator 90).
    - Fewer flowers were produced in the spray and drench treatments of HDC P005 and Terpal + Activator 90; and drench treatments of Moddus, Primo Maxx II and Regalis Plus.
- *Zantedeschia* 'Captain' series
    - No phytotoxicity was observed in either spray or drench treatments.
    - Spray treatments of Terpal + Activator 90 effectively controlled plant growth; HDC P005 and Regalis Plus had some effect on plant growth; other products had no effect.
    - Drench treatment of Terpal + Activator 90 had the strongest effect on plant growth; all other treatments had a slight effect except for Dazide Enhance which had no effect.
    - Few flowers were produced on the *Zantedeschia* within the timeframe of this trial.

Discussion

Terpal + Activator 90 was perhaps the most promising product of those tested, controlling growth of all subjects when applied both as a spray and drench. However, the drench rate used was too strong, producing plants that were too small, delaying flowering and causing phytotoxicity. The spray treatment delayed flowering in New Guinea *Impatiens* and Pansy but not the other species.

Growers find it particularly difficult to control the growth of *Dianthus*, therefore it was promising that spray applications of HDC P005 had an effect in this trial.

While spray applications of Moddus and Regalis Plus did not control growth as effectively as some other products, only one application was made to all species. No phytotoxicity was recorded as a result of either of these treatments at the final assessment, therefore these products may prove useful as part of a PGR spray programme, particularly for plant species with a longer production time.

While the drench treatments of most of the products tended to be too strong, this does provide the opportunity to test lower application rates to achieve good growth control without phytotoxicity and delayed flowering.

Conclusions

- Drench treatments were generally too strong at the rates used in this trial, but it is recommended that further trials are carried out using lower dose rates.
- Dazide Enhance was generally not effective as a drench treatment.
- There is the potential to combine treatments in a PGR spray programme, particularly of Moddus and Regalis Plus where a limited number of applications are permitted.

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Our thanks to:

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- The Management Group for steering the project.

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Appendices

Appendix 1.1

Summary of treatment effects on height (efficacy), phytotoxicity and quality for each plant species. Note that the *Zantedeschia* received one drench of Moddus, two drenches of Regalis Plus and three drenches of all other products; spray treatments were the same for all plant species. DAT = days after first treatment

	Treatment	**Dazide Enhance**	**HDC P005**	**Moddus**	**Primo Maxx II**	**Regalis Plus**	**Terpal + Activator 90**
	Application method; no. of treatments	**Spray x 2 Drench x 2 Reference product.**	**Spray x 2 Drench x 2**	**Spray x 1 Drench x 1**	**Spray x 2 Drench x 2**	**Spray x 1 Drench x 1**	**Spray x 2 Drench x 2**
A	***Begonia***	Spray: more effective than the Dazide Enhance drench. Minimal phytotoxicity. Drench: slight effect via root activity; not significant. Minimal phytotoxicity.	Spray: no effect on height. No phytotoxicity. Drench: too strong, plants too small, few roots present. Slight phytotoxicity. Significantly fewer flowers produced than the untreated control.	Spray: no effect on height. No phytotoxicity. Significantly fewer flowers produced than the untreated control by 10 DAT (but not at 20 DAT). Drench: too strong, plants too small, few roots present. Slight phytotoxicity. Significantly fewer flowers produced than the untreated control by 20 DAT (but not at 10 DAT).	Spray: no effect on height. Slight phytotoxicity. Drench: too strong, plants too small. Poor root quality. Significant chlorosis. Significantly fewer flowers produced than the untreated control by 20 DAT (but not at 10 DAT).	Spray: no effect on height. No phytotoxicity. Drench: too strong, plants too small. Poor root quality. Phytotoxicity; leaves dull and chlorotic. Significantly fewer flowers produced than the untreated control.	Spray: strong height control, plants slightly too small. Slight phytotoxicity, leaf yellowing. Drench: too strong, plants too small, severe phytotoxicity. Significantly fewer flowers produced than the untreated control.

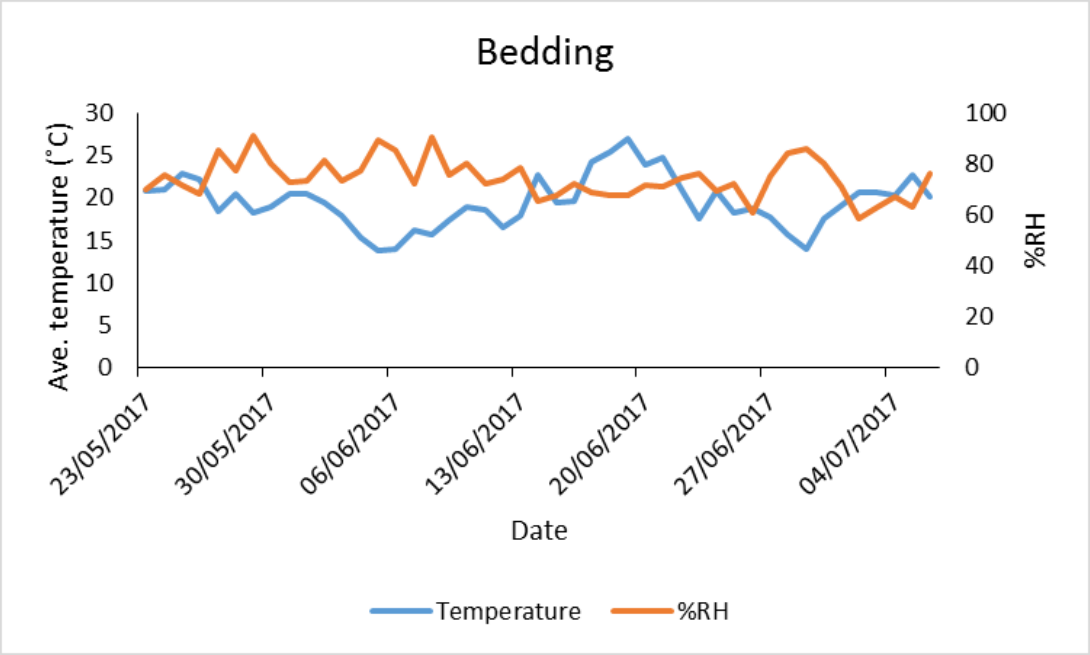
	Treatment	Dazide Enhance	HDC P005	Moddus	Primo Maxx II	Regalis Plus	Terpal + Activator 90
B	***Dianthus***	Spray: no effect on height. Minimal phytotoxicity. Drench: no effect. Minimal phytotoxicity.	Spray: effective height control. No phytotoxicity. Drench: plants too small, poor roots. Minimal phytotoxicity. Significantly fewer flowers produced than the untreated control by 20 DAT (but not at 10 DAT).	Spray: no effect on height. Severe phytotoxicity at 10 DAT, but not evident at 20 DAT. Drench: plants too small, but with good form and roots. No phytotoxicity.	Spray: no effect on height. Severe phytotoxicity at 10 DAT reducing to slight phytotoxicity at 20 DAT. Drench: plants too small, poor roots, uneven plant form. Very slight phytotoxicity. Significantly fewer flowers produced than the untreated control by 10 DAT (but not at 20 DAT).	Spray: no effect on height. Minimal phytotoxicity. Drench: Some effect on height. Slight phytotoxicity.	Spray: some effect on height. Severe phytotoxicity at 10 DAT, slight phytotoxicity at 20 DAT. Drench: too strong, poor roots, severe phytotoxicity. Significantly fewer flowers produced than the untreated control by 20 DAT (but not at 10 DAT).
C	**Geranium**	Spray: no significant effect on height, flower size or flowering time. No phytotoxicity. Drench: slight effect via root activity but not significant. No phytotoxicity. No significant effect on flowering time or size.	Spray: no effect on height. No phytotoxicity. Marketable plants. Drench: very strong effect on growth, plants too small with poor root development. Slight leaf chlorosis.	Spray: no effect on height. No phytotoxicity. Marketable plants. Drench: too strong. Plants too small. Poor root quality. Slight leaf chlorosis.	Spray: strong effect on height. No phytotoxicity. Marketable plants. Drench: too strong, plants and flowers too small. Poor root quality. Severe leaf chlorosis.	Spray: no effect on height. Minimal phytotoxicity. Marketable plants. Drench: too strong, plants too small. Leaf chlorosis. Slightly small flowers.	Spray: effective height control. Slight leaf chlorosis. Drench: too strong, poor roots, severe phytotoxicity, leaf yellowing, some dead plants. No flowers produced.

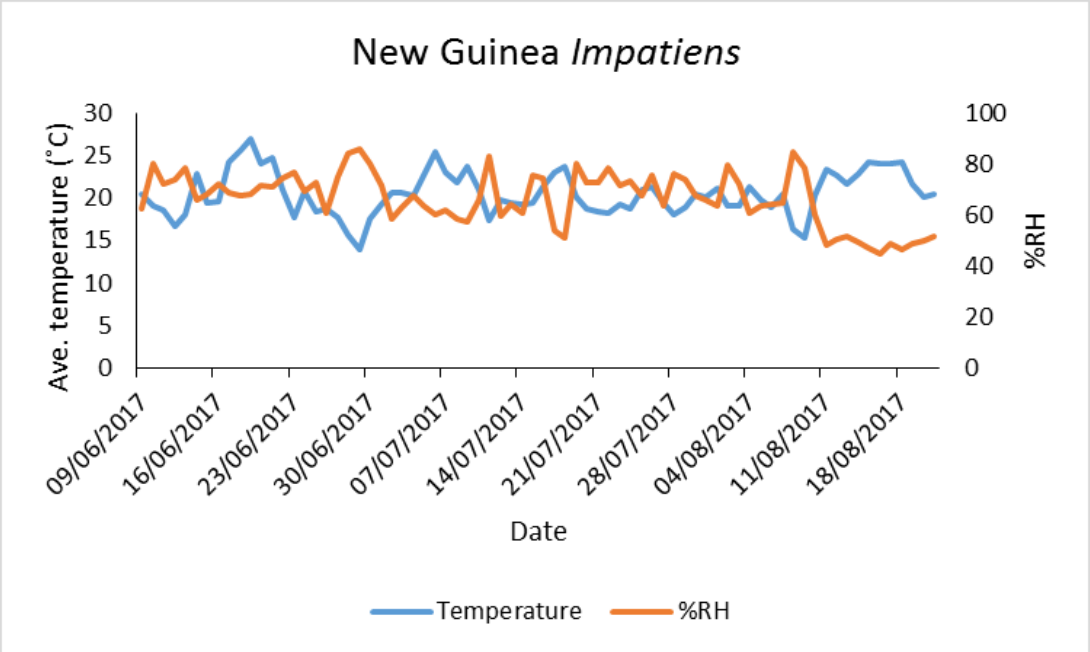
	Treatment	Dazide Enhance	HDC P005	Moddus	Primo Maxx II	Regalis Plus	Terpal + Activator 90
D	**Pansy**	Spray: effective, minimal phytotoxicity. Drench: No effect. Initial slight chlorosis at 10 DAT, improved by 20 DAT.	Spray: effective height control. No phytotoxicity. Drench: effect comparable to the Dazide Enhance spray treatment. Minimal phytotoxicity.	Spray: no effect on height. No phytotoxicity. Drench: effect comparable to the Dazide Enhance spray treatment. Minimal phytotoxicity by 10 DAT.	Spray: no effect on height. Slight phytotoxicity. Drench: too strong, plants too small. Poor root quality. Severe phytotoxicity, leaf chlorosis.	Spray: strong effect on height. Severe phytotoxicity at 10 DAT, no longer evident by 20 DAT. Drench: effect on plant height. Negative effect on root development. No phytotoxicity.	Spray: strong effect on height. Slight phytotoxicity, leaf yellowing. Significantly fewer flowers produced than the untreated control by 20 DAT (but not at 10 DAT). Drench: too strong, poor roots, severe phytotoxicity, leaf yellowing. Significantly fewer flowers produced than the untreated control by 20 DAT (but not at 10 DAT).
E	**New Guinea *Impatiens***	Spray: some effect on height. Minimal phytotoxicity. Drench: slight effect via root activity; not significant. Minimal phytotoxicity.	Spray: effective height control. Minimal phytotoxicity. Significantly fewer flowers produced. Drench: strong effect on growth. Very slight phytotoxicity. Significantly fewer flowers produced.	Spray: some effect on height. Minimal phytotoxicity. Drench: strong effect on growth, plants too small. Slight phytotoxicity by 10 DAT; severe damage by 20 DAT. Significantly fewer flowers produced.	Spray: effective height control. Minimal phytotoxicity. Drench: too strong, plants too small. Poor root quality. Severe phytotoxicity by 20 DAT. No flowers produced.	Spray: no effect on height. Minimal phytotoxicity. Drench: effect on plant height. Severe phytotoxicity by 41 DAT. Significantly fewer flowers produced.	Spray: effective height control. Minimal phytotoxicity. Significantly fewer flowers produced. Drench: strong effect on height. Severe phytotoxicity, leaf yellowing. No flowers produced.

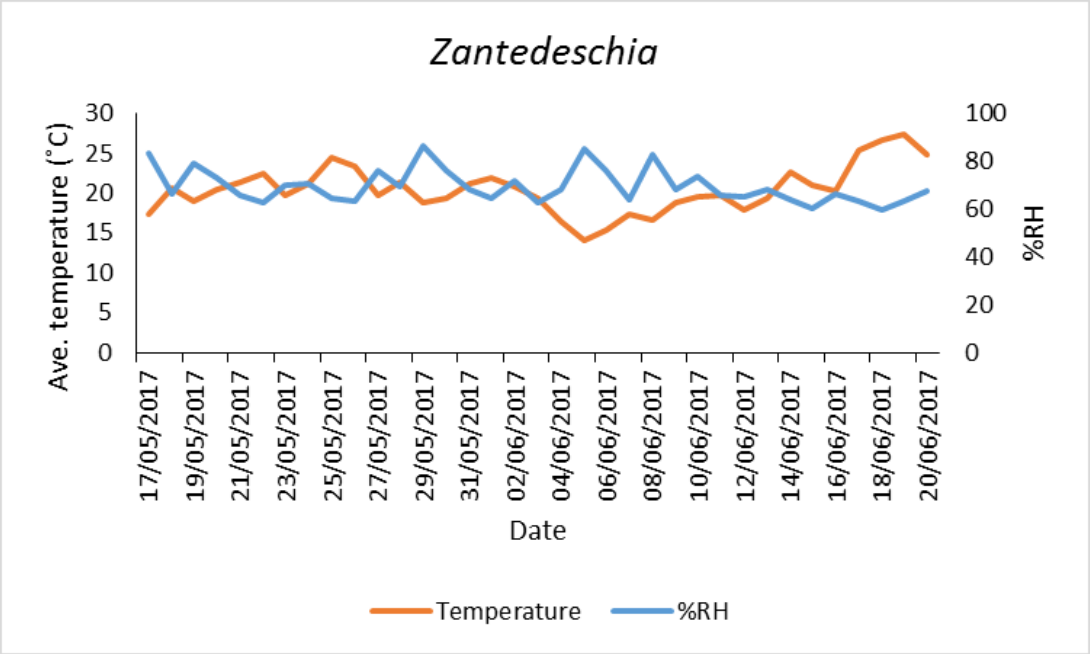
	Treatment	Dazide Enhance	HDC P005	Moddus	Primo Maxx II	Regalis Plus	Terpal + Activator 90
F	***Zantedeschia* 'Captain' Series**	Spray: no effect on height. No phytotoxicity. No flowers produced. Drench: no effect. No phytotoxicity	Spray: some effect on height. No phytotoxicity. Drench: some effect on growth compared with the untreated control. No phytotoxicity.	Spray: no effect on height. No phytotoxicity. No flowers produced. Drench: some effect on growth compared with the untreated control. No phytotoxicity. No flowers produced.	Spray: some effect on height. No phytotoxicity. Drench: some effect on growth compared with the untreated control. No phytotoxicity. No flowers produced.	Spray: some effect on height. No phytotoxicity. Drench: some effect on growth compared with the untreated control. No phytotoxicity.	Spray: effective height control. No phytotoxicity. No flowers produced. Drench: strong effect on growth, no phytotoxicity. No flowers produced.

Appendix 1.2

Glasshouse temperature and humidity for bedding plants, New Guinea *Impatiens* and *Zantedeschia*

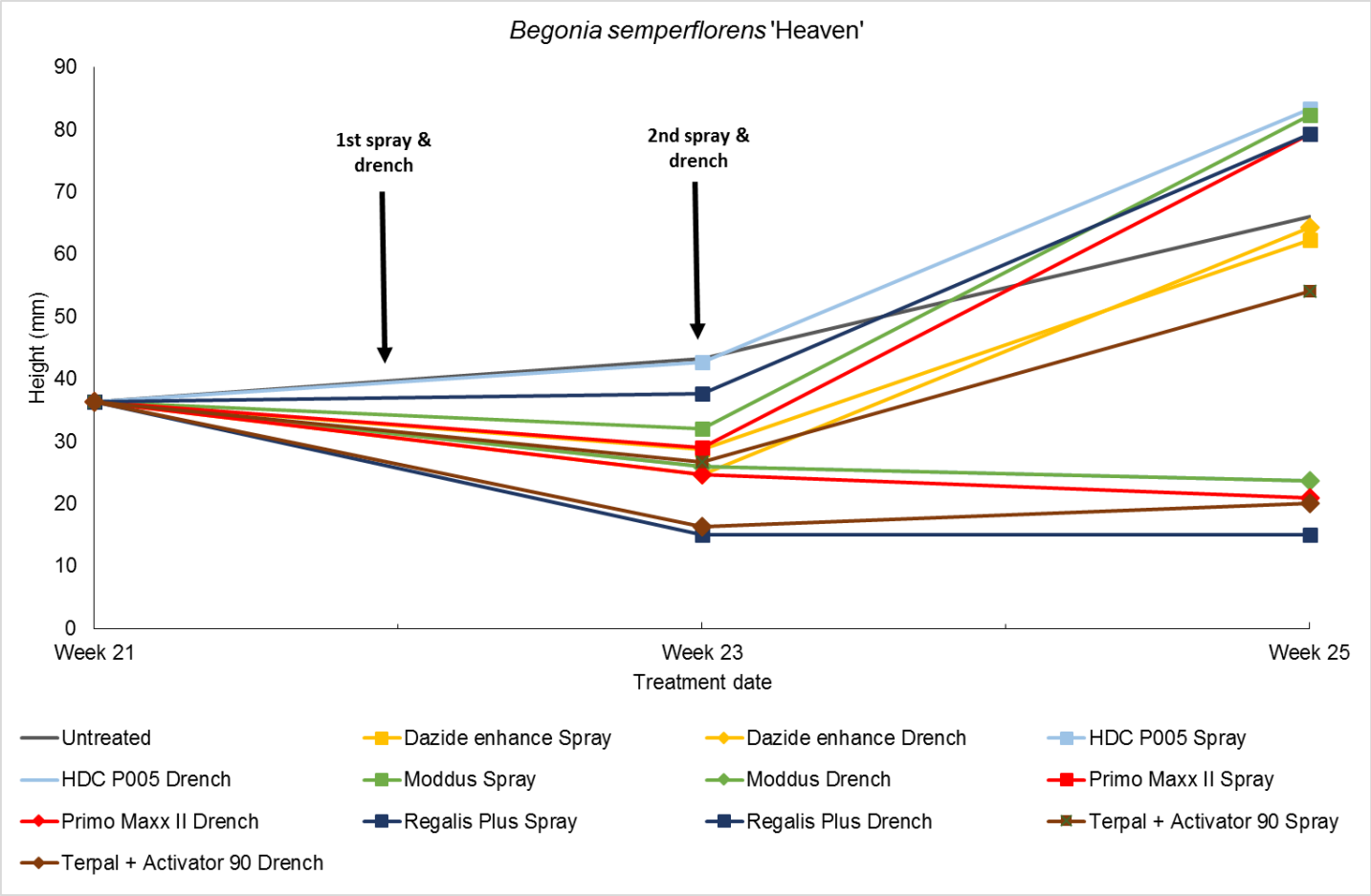




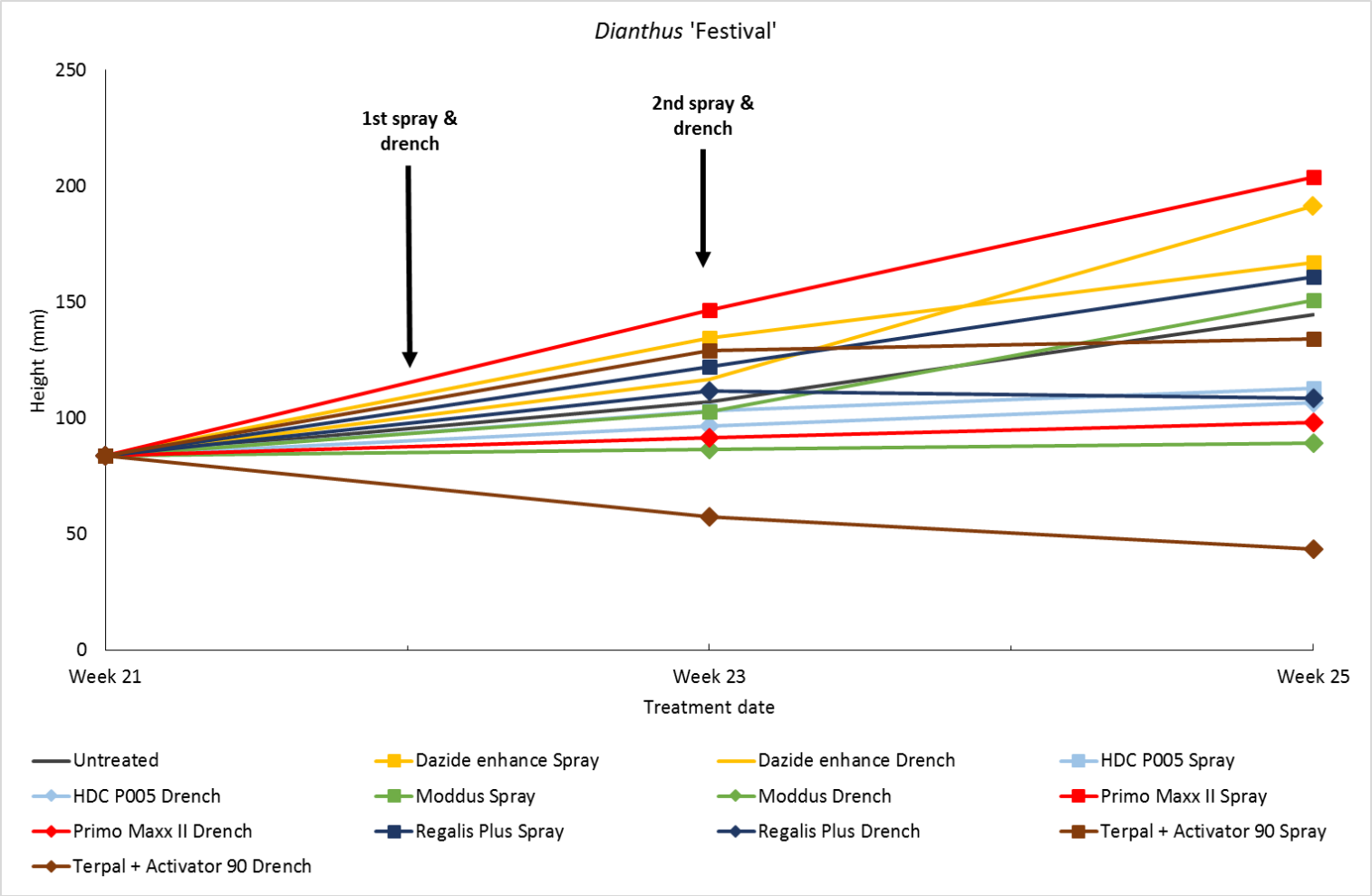


Appendix 1.3

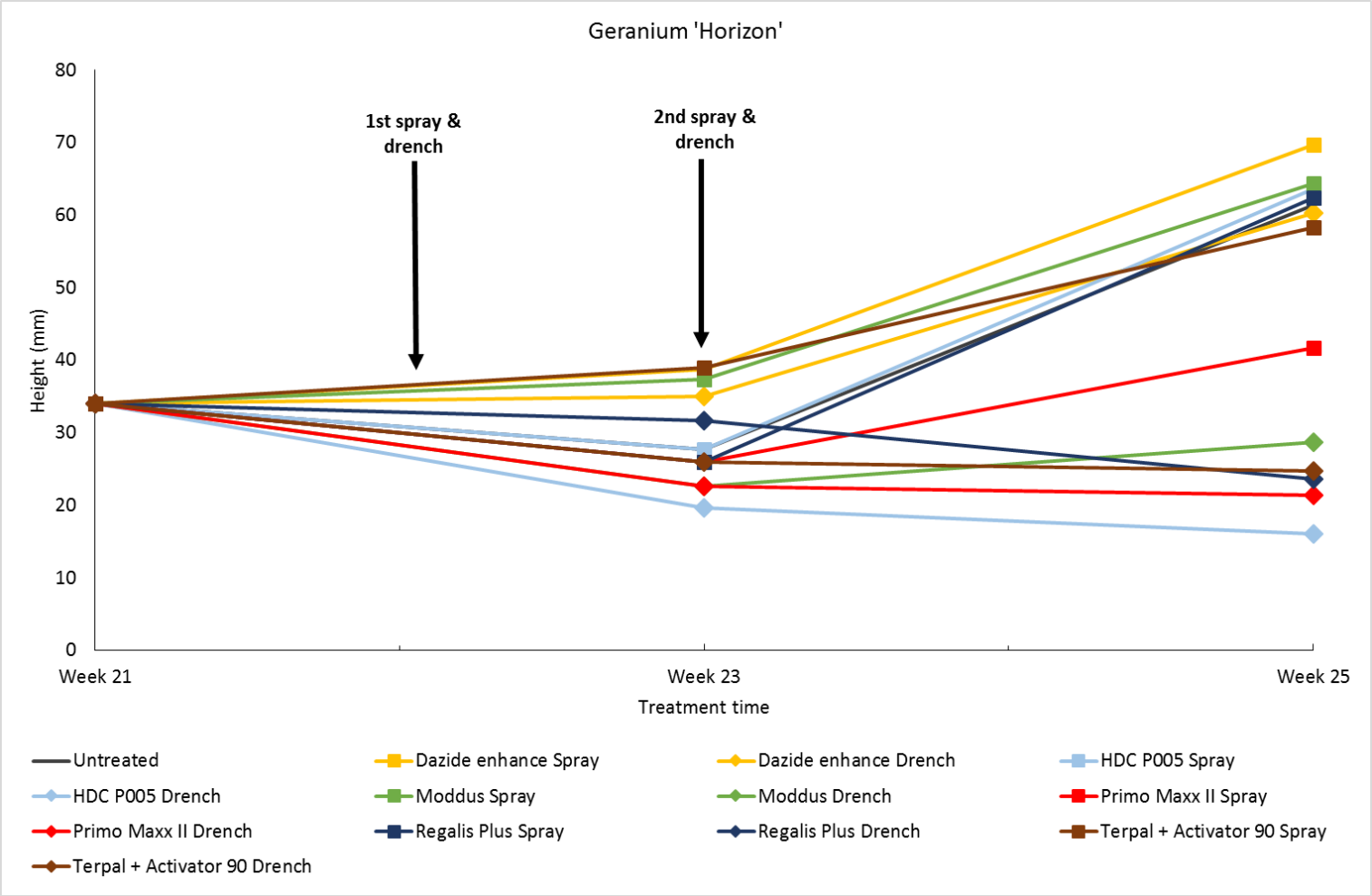
Plant height



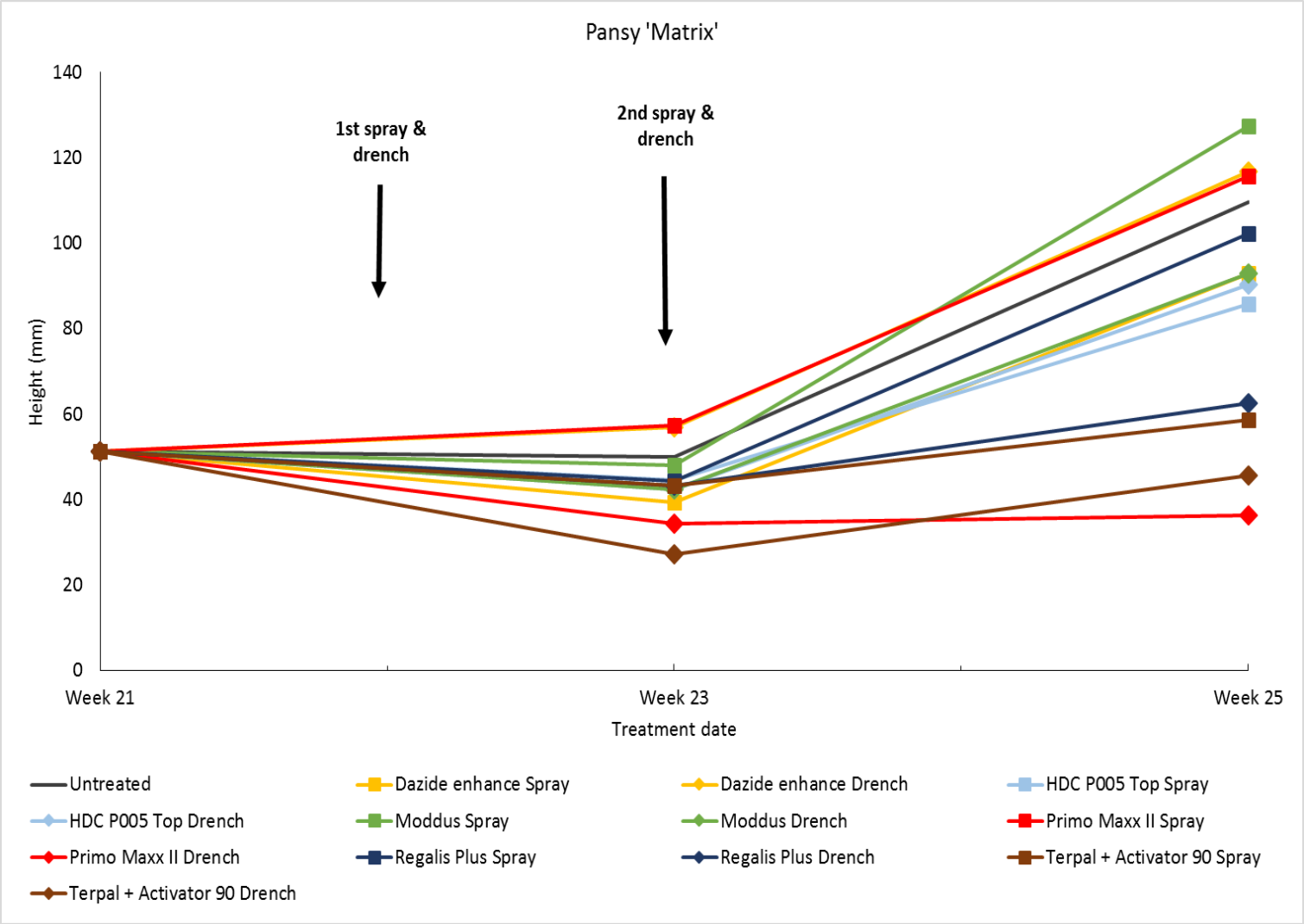
A. *Begonia semperflorens* 'Heaven' height (mm). Height was assessed at transplant (23 May 2017, week 21), prior to the second treatment on 09 June 2017 (week 23, 10 DAT) and on 19 June 2017 (week 25, 20 DAT). Plants were treated with one spray and one drench of Moddus and Regalis Plus (week 23); two sprays and two drenches of all other treatments. Apparent decreases in plant height are the effect of using mean heights of multiple plants.



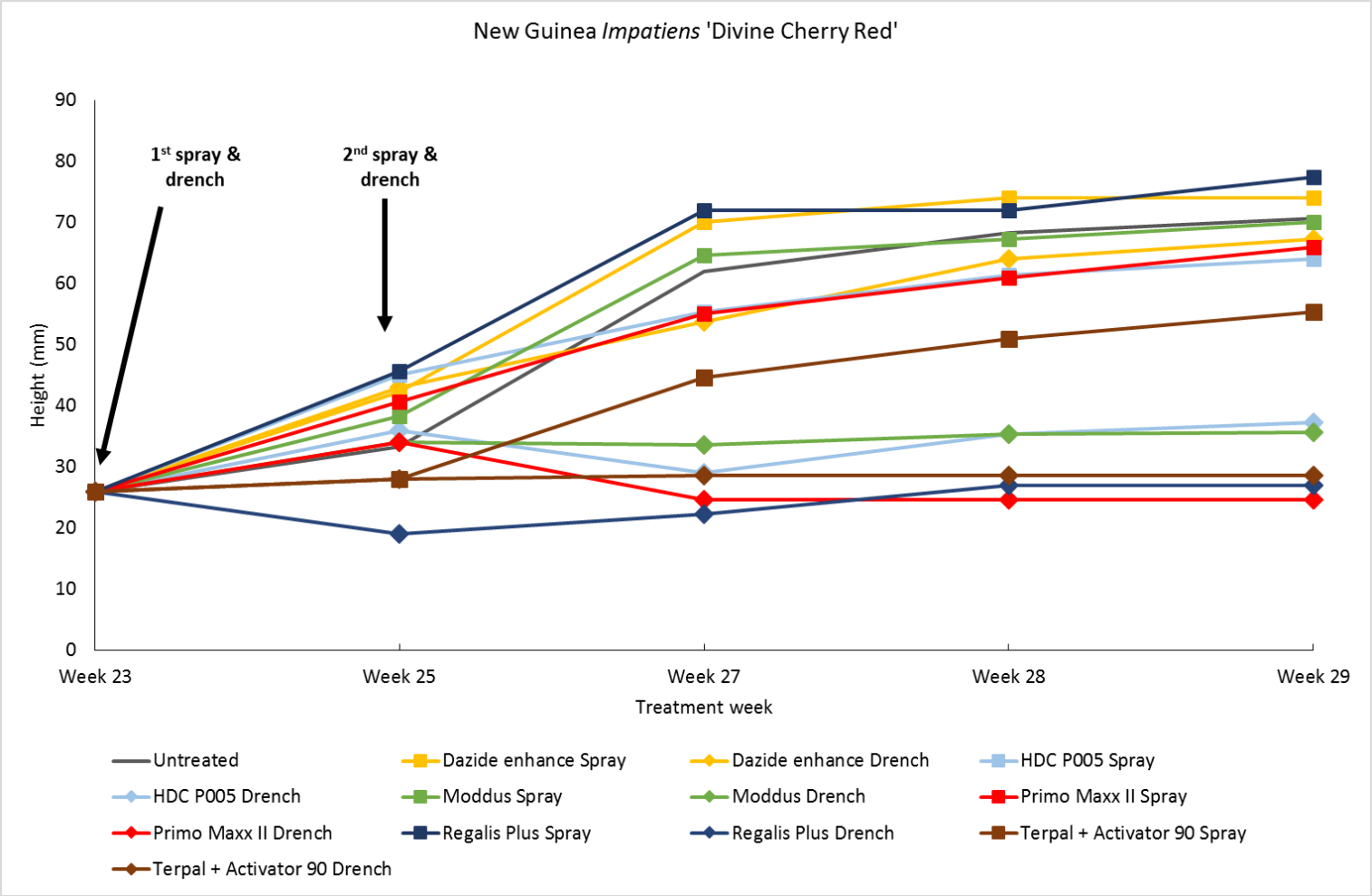
B. *Dianthus* 'Festival' height (mm). Height was assessed at transplant (23 May 2017, week 21), prior to the second treatment on 09 June 2017 (week 23, 10 DAT) and on 19 June 2017 (week 25, 20 DAT). Plants were treated with one spray and one drench of Moddus and Regalis Plus (week 23); two sprays and two drenches of all other treatments. Apparent decreases in plant height are the effect of using mean heights of multiple plants.



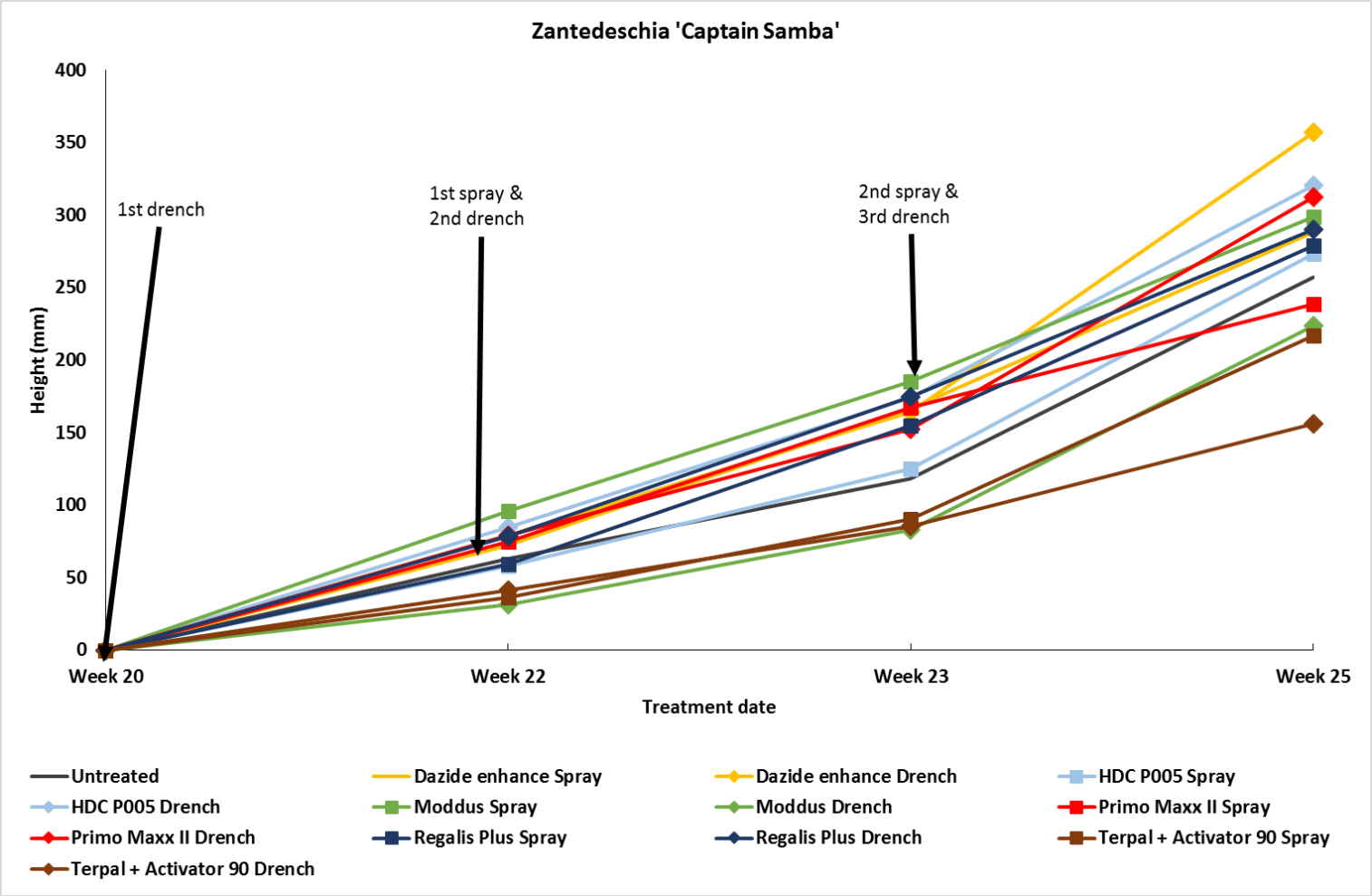
C. Geranium 'Horizon' height (mm). Height was assessed at transplant (23 May 2017, week 21), prior to the second treatment on 09 June 2017 (week 23, 10 DAT) and on 19 June 2017 (week 25, 20 DAT). Plants were treated with one spray and one drench of Moddus and Regalis Plus (week 23); two sprays and two drenches of all other treatments. Apparent decreases in plant height are the effect of using mean heights of multiple plants.



D. Pansy 'Matrix' height (mm). Height was assessed at transplant (23 May 2017, week 21), prior to the second treatment on 09 June 2017 (week 23, 10 DAT) and on 19 June 2017 (week 25, 20 DAT). Plants were treated with one spray and one drench of Moddus and Regalis Plus (week 23); two sprays and two drenches of all other treatments. Apparent decreases in plant height are the effect of using mean heights of multiple plants.



E. New Guinea *Impatiens* 'Divine Cherry Red' height (mm). Height was assessed prior to the first treatment on 09 June (week 23) with further assessments on 19 June 2017 (week 25, 10 DAT), 6 July 2017 (week 27, 27 DAT), 11 July 2017 (week 28, 32 DAT) and 20 July 2017 (week 29, 41 DAT). Plants were treated with one spray and one drench of Moddus and Regalis Plus (week 23); two sprays and two drenches of all other treatments. Apparent decreases in plant height are the effect of using mean heights of multiple plants.



F. *Zantedeschia* 'Captain Samba' height (mm). Corms were planted on the 17 May 2017 (week 20). Height was assessed on 30 May 2017 (week 22), 09 June 2017 (week 23) and 19 June 2017 (week 25). For spray treatments, these were the day of the first treatment, 10 DAT and 20 DAT respectively. For drench treatments, these were 13 DAT, 23 DAT and 33 DAT respectively. The *Zantedeschia* received one drench of Moddus, two drenches of Regalis Plus (weeks 20 and 23) (

Table 4) and three drenches of all other products; one spray treatment of Moddus and Regalis Plus (week 22) and two sprays of all other products. DAT = days after first treatment. Apparent decreases in plant height are the effect of using mean heights of multiple plants.

Appendix 1.4

Photographic records of treatment effects.

A. *Begonia semperflorens* 'Heaven' mixed. Effects of treatments compared with the untreated control

Untreated vs Dazide Enhance spray

Untreated vs Dazide Enhance drench

Untreated vs HDC P005 spray

Untreated vs HDC P005 drench

Untreated vs Moddus spray

Untreated vs Moddus drench

	
Untreated vs Primo Maxx II spray	Untreated vs Primo Maxx II drench
	
Untreated vs Regalis Plus spray	Untreated vs Regalis Plus drench
	
Untreated vs Terpal + Activator 90 spray	Untreated vs Terpal + Activator 90 drench

B. *Dianthus* 'Festival' mixed. Effects of treatments compared with the untreated control

Untreated vs Dazide Enhance spray

Untreated vs Dazide Enhance drench

Untreated vs HDC P005 spray

Untreated vs HDC P005 drench

Untreated vs Moddus spray

Untreated vs Moddus drench

Untreated vs Primo Maxx II spray

Untreated vs Primo Maxx II drench

Untreated vs Regalis Plus spray

Untreated vs Regalis Plus drench

Untreated vs Terpal + Activator 90 spray

Untreated vs Terpal + Activator 90 drench

C. Geranium 'Horizon' mixed. Effects of treatments compared with the untreated control

Untreated vs Dazide Enhance spray

Untreated vs Dazide Enhance drench

Untreated vs HDC P005 spray

Untreated vs HDC P005 drench

Untreated vs Moddus spray

Untreated vs Moddus drench

Untreated vs Primo Maxx II spray

Untreated vs Primo Maxx II drench

Untreated vs Regalis Plus spray

Untreated vs Regalis Plus drench

Untreated vs Terpal + Activator 90 spray

Untreated vs Terpal + Activator 90 drench

D. Pansy 'Matrix' mixed. Effects of treatments compared with the untreated control

Untreated vs Dazide Enhance spray

Untreated vs Dazide Enhance drench

Untreated vs HDC P005 spray

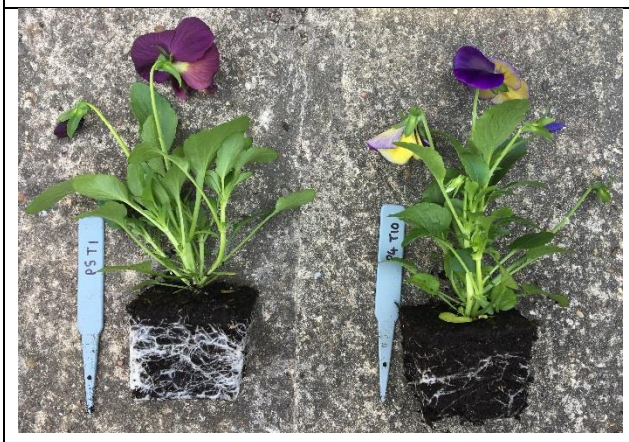
Untreated vs HDC P005 drench

Untreated vs Moddus spray

Untreated vs Moddus drench

Untreated vs Primo Maxx II spray

Untreated vs Primo Maxx II drench



Untreated vs Regalis Plus spray

Untreated vs Regalis Plus drench

Untreated vs Terpal + Activator 90 spray

Untreated vs Terpal + Activator 90 drench

E. New Guinea *Impatiens* 'Divine Cherry Red'. Effects of treatments compared with the untreated control

 Untreated vs Dazide Enhance spray	 Untreated vs Dazide Enhance drench
 Untreated vs HDC P005 spray	 Untreated vs HDC P005 drench
 Untreated vs Moddus spray	 Untreated vs Moddus drench

 Untreated vs Primo Maxx II spray	 Untreated vs Primo Maxx II drench
 Untreated vs Regalis Plus spray	 Untreated vs Regalis Plus drench
 Untreated vs Terpal + Activator 90 spray	 Untreated vs Terpal + Activator 90 drench

F. *Zantedeschia*. Effects of treatments and the untreated control. Note that each plot contains twelve *Zantedeschia* varieties from the 'Captain' series: 'Captain Brunello', 'Captain Cheerio', 'Captain Fargo', 'Captain Fresco', 'Captain Fuego', 'Captain Lido', 'Captain Lovely', 'Captain Marrero', 'Captain Morelli, 'Captain Samba', 'Mercedes' and 'Red Alert'.

Untreated control

Untreated vs Dazide Enhance spray

Untreated vs Dazide Enhance drench

Untreated vs HDC P005 spray

Untreated vs HDC P005 drench

 Untreated vs Moddus spray	 Untreated vs Moddus drench
 Untreated vs Primo Maxx II spray	 Untreated vs Primo Maxx II drench
 Untreated vs Regalis Plus spray	 Untreated vs Regalis Plus drench
 Untreated vs Terpal + Activator 90 spray	 Untreated vs Terpal + Activator 90 drench