

Project title Assessment of a number of new plant growth regulator products to control growth on commercial crops of bedding plants

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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 Date16 July 2010.....

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GROWER SUMMARY

Headline

- Regalis and Cerone have potential for growth control on bedding plant species.
- Care should be taken when applying Regalis to avoid flower petal bleach, earlier applications of the product may limit the degree of bleaching.
- Consider the potential impact of Bumper 250 EC on the growth of plants, and the phytotoxic damage it can cause, when integrating fungicides and growth regulators in a spray programme.

Background and expected deliverables

Currently there are three main chemical plant growth regulator active ingredients used within the bedding plant sector – chlormequat, daminozide and paclobutrazol. In terms of efficacy, paclobutrazol is the most effective of the three active ingredients on the majority of plant species grown. However, there is a potential future complication in that some triazole pesticides (including paclobutrazol) could be classified as endocrine disruptors when the methodology is available to determine this, so its long term future is not yet totally secure.

There have been recent issues with products containing daminozide with regards to having a stipulated re-entry period which had potential to make their use impractical for some short term protected crops like bedding plants. Thankfully this has been resolved but this does underline the vulnerability of the products currently used in the commercial production of ornamental crops.

Prohexadione-calcium (Regalis) has potential as an alternative growth regulator, being in the same chemical group as daminozide; it already possesses a Specific Off-Label Approval (SOLA 2866/2008) for use on outdoor nursery stock (which expires 31 December 2011). Limited trials work has been undertaken by BASF on a number of bedding plant species. Trials have indicated that the product works well on some species, resulting in compact growth. However, the work also highlighted

that the product impacts on anthocyanin formation in certain species, giving rise to a flower petal bleach. If the effects of Regalis on flower colour could be minimised then it could prove to be a useful alternative chemical plant growth regulator for use on bedding plant subjects.

Trinexapac-ethyl is a growth regulator used to control stem height and lodging in cereals and is also related to prohexadione-calcium. The active ingredient is sold as Moddus by Syngenta. There has been limited work undertaken with this product on protected ornamental crops, but like Regalis it has the potential to be a useful alternative growth regulator product.

2-chloroethylphosphonic acid possesses a SOLA (2743/2010) for use in ornamental plant production (with extra specific crop information in the advisory information section of the SOLA). The product is sold as Cerone by Bayer CropScience Limited, although it was previously marketed as Ethrel C (by Hortichem, now Certis). Its primary label use on bedding plant crops was to increase side branching in geranium crops.

The overall commercial objective of the project was to trial Regalis, Cerone and Moddus against a standard chemical growth regulator products currently used within the industry (Bonzi) and an untreated control. Additionally, two triazole fungicides (propiconazole (Bumper 250 EC) and myclobutanil (Systhane 20 EW)) were included in the trial to examine the potential effects of these products on plant growth. The aim was to show that some triazole fungicides, when applied for disease control, need to be taken into consideration within any growth control plan to avoid excessive growth control.

Summary of the project and main conclusions

In the first phase of this project, a review was undertaken of products with potential to expand the range currently available to UK growers for plant growth regulation. A summary of this review is detailed as Appendix 1 of the main project report. Chemicals deemed to have greatest promise were then evaluated in trials on a commercial nursery (W D Smith and Son, Battlesbridge, Essex). These trials were carried out between May and June 2010 on replicated blocks of plants separated

from commercial crop but grown to the same management regime (other than the application of plant growth regulators).

Eleven different bedding plant species were evaluated including the cutting raised subjects: Dahlia 'Gallery – Renoir Pink', Fuchsia 'Mojo – Deep Cerise and Pastel Violet', Surfinia 'Classic Vanilla' and Verbena 'Tamari Trailing Blue'; and the seed raised subjects: Begonia semperflorens 'Big', Dianthus 'Select – Whitefire', Geranium 'Black Velvet – Scarlet', Impatiens 'Envoy - White', Marigold 'Dorango -Tangerine', Petunia multiflora 'Dreams Blue' and Salvia 'Mohave'.

The cutting material was purchased from specialist suppliers; and the remaining plants were raised from seed on site into a range of appropriate plug tray sizes. A peat / bark growing media with base fertiliser and controlled release fertiliser was used as the potting media at transplanting. All the species were transplanted into 1 litre pots and placed down on mobile benching covered with perforated film and capillary matting. The plants were watered overhead by hand throughout the trial and treated for pest / disease as required.

The table below summarises the treatments applied:

Treatment	Product and application method	Rate
A	Untreated control	
B	Bonzi x 2 sprays	1.25 ml / litre of water
C	Regalis x 1 spray	1.25 g / litre of water
D	Regalis x 2 sprays	1.25 g / litre of water
E	Regalis x 1 drench	1.25 g / litre of water
F	Cerone x 1 spray	1.0 ml / litre of water
G	Moddus x 2 sprays	0.4ml / litre of water
H	Bumper 250 EC x 2 sprays	0.4 ml /litre of water
I	Systhane 20 EW x 2 sprays	0.3 ml / litre of water

Note that the triazole fungicide products were not applied specifically as chemical plant growth regulator products; they were included in the trial to demonstrate any issues when such products are used for disease control on bedding plants.

The spray treatments were applied in approximately 1,000 litres of water per hectare via a small pump action hand held sprayer (to the point of run-off from the foliage). The drench treatment was applied at 75 ml of solution per litre pot via a watering can and washed off the foliage afterwards. All applications were made in the late afternoon / early evening.

Plant height or width as appropriate was recorded to monitor change in plant growth over time in comparison with the untreated control and the Bonzi treatment included as a reference to standard commercial practice. Notes of any phytotoxic damage and time to flower were also recorded.

Good levels of growth control were achieved with **Regalis**, although flower petal bleaching occurred on some plant species. It may be that earlier applications of the product (soon after transplanting, or even at the plug stage, though this will require further examination) may be a suitable method of reducing the unwanted side effect. The symptoms recorded in the trial were less than those recorded in other trials undertaken by BASF and symptoms were totally avoided in the case of petunia multiflora 'Dreams Blue'. The drench treatment and two-spray treatments were generally more effective than a single spray treatment. An extension to the SOLA to include protected ornamental crops would be a useful addition.

Cerone was very effective with a number of the plant species but may prove excessive with some species, such as dahlia (see image on next page). As a result of its mode of action (it breaks down within the plant to release ethylene gas) it appeared to delay flowering with several species, by 10 days in verbena, 4 days in dahlia and 2 days in fuchsia. Such a relatively severe delay with verbena may be due to the product getting into the growing medium at the point of application (the plants were relatively small at treatment) exacerbating its effect on the plant. The continuation of the SOLA provides a potentially useful alternative product to growers.

Moddus was the least effective at controlling growth and caused more petal bleach (see image on next page) than Regalis (to which it is chemically related). As a stand-alone product it has limited potential use for growth control in bedding plants.

The results from the trial also indicate that some triazole fungicides used for disease control should be applied with care, although they don't all impact on plant growth to the same level. The application of **Bumper 250 EC** for rust control on bedding and

pot plants (under SOLA 0707/2009) for example could potentially result in a severe check to growth and even phytotoxic damage to flowers and growing points (see images on next page). **Systhane 20 EW** on the other hand had very little impact on plant growth and produced no phytotoxic damage to the plant species examined in the trial.

An overview of the effects of each treatment is included in the following tables. Overall it was clear that the chemical applied, the application method and frequency as well as the species treated will all impact the results achieved. The data from this trial provides some overall guidance but it is important for growers to carry out their own small scale trials before applying any of the treatments tested here to large scale areas of commercial production.

Phytotoxic symptoms noted during the trial



Begonia – flower distortion in response to applications of Bumper 250 EC



Fuchsia – growing point hardening in response to applications of Bumper 250 EC



Dahlia – flower stem shortening in response to applications of Cerone



Verbena – untreated v Moddus sprays (right), giving rise to petal bleach

Summary of response to growth regulators and two fungicides by plant species

Species	Bonzi	Regalis	Cerone	Moddus	Bumper 250 EC	Systhane 20 EW
Begonia semperflorens 'Big'	Obvious height reduction. No improvement in habit. Possible flower delay. Foliage darkened.	No obvious effect from x 1 spray treatment. x 2 spray treatment more effective, improvement in branching, some petal bleach though. Height reduction from drench treatment. No delay in flowering.	Obvious height reduction, comparable to Bonzi treatment.	Slight check to growth, possibly a paling of flower petals.	Obvious height reduction, very dark leaves but distortion to flowers (and growing points) noted. Delay in flowering.	Limited effect on plant growth or habit.
Dahlia 'Gallery - Renoir Pink'	Obvious height reduction, plants at least a third smaller. Leaf and flower size reduction. Flowers still borne above foliage.	x 1 spray treatment limited effect. Height reduction with x 2 spray treatment, obvious effect from drench. Flower petal bleach in response to x 2 spray and drench treatment. Flower stems shortened, flowers only just above foliage with drench. Foliage darkened with drench.	Obvious early growth control. Stems of first flush of flowers held back so that open flowers below foliage. Some delay in flowering, flower and leaf size reduced.	No affect in terms of plant height, but plants appear more upright in habit. Flower petal bleach obvious.	Plant upright in appearance, flowers smaller in size, slight height reduction.	No effect on plant growth or habit.
Dianthus 'Select - Whitefire'	Slight height reduction noted, slightly better branching gives rise to better plant habit.	Height reduction noted, but no improvement in plant habit. Delay in flowering with most treatments.	Improved plant habit, more branching and flower stems, good shape to the plants. Very slight reduction in plant height.	No impact on growth. Possible delay in flowering.	Darker foliage, significant reduction in height. Possible delay in flowering.	No effect on plant growth or habit.
Fuchsia 'Mojo - Deep Cerise and Pastel Violet'	Height reduction noted but not statistically significant, flowers well displayed. Slight reduction in flower size, either earlier flowering or flowering enhanced relative to other treatments.	No or very limited effect in terms of growth control with all treatments. Delay in flowering.	Comparable to Bonzi treatment in terms of height and growth control, but flowering not enhanced in the same way.	Some effect in terms of height control, possible delay in flowering.	Well branched, but transient growing point distortion noted. Good habit to plant, delay in flowering.	No effect on plant growth or habit.

Summary of response to growth regulators and two fungicides by plant species - continued...

Species	Bonzi	Regalis	Cerone	Moddus	Bumper 250 EC	Systhane 20 EW
Geranium 'Black Velvet - Scarlet'	Height reduction noted but not statistically significant, also reduction in leaf size. Intensifies the purple colouration in the leaf (darker leaves). No improvement in habit.	Variable effect on height control, no improvement in overall habit. Some leaf size reduction with drench and possible flower delay.	Height reduction noted but not statistically significant with improvement in number of side breaks.	Limited effect on growth and habit. Breaks up leaf margin zonal markings. Possible delay in flowering.	Limited growth control and slight intensification of leaf markings.	No effect on plant growth or habit. Possible delay in flowering.
Impatiens 'Envoy - White'	Tighter growth habit and perhaps a darkening of the foliage.	Variable effect on growth, possibly some distortion with higher rates. Possible delay in flowering.	Limited effect in terms of height control, plants appear more upright in habit.	Limited effect, plants appear more upright.	Limited effect on growth and habit.	No effect on plant growth or habit.
Marigold 'Dorango - Tangerine'	Slightly tighter canopy to plant, no obvious differences.	Slight response to x 2 spray treatment and drench treatment in terms of habit.	Some improvement in level of side branching and slight reduction in flower stem length.	No effect.	Slightly tighter growth habit to the plants.	No effect on plant growth or habit.
(Petunia) Surfinia 'Classic Vanilla'	Good leaf cover over the pot, slightly darker leaves.	x 1 spray treatment limited effect, improvement in habit with x 2 spray and drench treatment.	Obvious reduction in leaf size, possible reduction in flower size. Better habit to plants, less sprawling.	Darker foliage, some check to growth, plants less sprawling.	Improvement in growth habit, plants slightly less sprawling, darkening of foliage.	No effect on plant growth or habit. Plant more open in centre, more yellow leaf noted.
Petunia multiflora 'Dreams Blue'	Limited effect of treatment, perhaps slightly darker foliage and possibly earlier flowering.	No effect from x 1 spray treatment. Some height control and habit improvement with x 2 spray treatment and drench. Second spray treatment may have affected growing points – slight yellowing and distortion.	Some effect on height, habit appears slightly improved.	Good shape to plants, with only limited level of growth reduction.	Reduced level of branching noted, plants less well developed.	No effect on plant growth or habit.
Salvia 'Mohave'	Darker leaves, improved branching with very slight growth control.	Limited effect with all 3 treatments.	Possibly more branching and a reduction in flower stem length and flower size.	Good level of branching, very limited effect on height.	Very limited effect on growth, foliage slightly darker.	No effect on plant growth or habit.
Verbena 'Tamari Trailing Blue'	Tighter habit to the plant with more growth from the centre of the plant. Darker foliage.	Limited effect in terms of growth control and habit improvement. Some petal bleach with treatments.	Some height control, plants more upright in habit as opposed to sprawling. Delay in flowering.	No effect on growth, flower petal bleach noted.	Some height control noted, foliage darkened.	No effect on plant growth or habit.

Financial benefits

It is crucial that a range of chemical plant growth regulator products are available in case any of the three main active ingredients (chlormequat, daminozide or paclobutrazol) are lost to the industry for any particular reason. The option to use Regalis or Cerone over protected ornamental crops is therefore important to maintain the ability to respond quickly to market demands, changes in weather etc. and control plant growth to adhere to the required retailer plant specifications and minimise plant wastage levels.

In terms of costs relative to Bonzi, the alternative products examined in the trial are either similar in price or less expensive (see summary table below).

Approved status and relative costs of growth regular treatments examined in the trial (2010)

Product	Approval status		Average cost of product	Cost per litre of solution at rate trialled
	Outdoor	Protected		
Bonzi	✓ (Label)	✓ (Label)	6.9p per ml of product	8.6p per litre at 1.25 ml / litre rate
Regalis	✓ (SOLA)		8.2p per gram of product	10.3p per litre at 1.25 g / litre rate
Cerone		✓ (SOLA)	1.7p per ml of product	1.7p per litre at 1.0 ml / litre rate
Moddus	SOLA required for use on ornamentals.		4.6p per ml of product	1.8p per litre at 0.4 ml / litre rate

Action points for growers

- Check the published literature review which forms part of this project for further detail about other research work undertaken with the products examined in the trial. (See Appendix 1 of the full report for this project)
- If appropriate, trial Regalis and or Cerone on a small number of plants from a range of different plant species to become familiar with the responses they induce (note Regalis can only currently be applied to outdoor ornamental crops).

- Contact the HDC to enquire about the extension of the Regalis SOLA beyond 2011 and the potential for protected ornamental crops to be also included on the SOLA.

SCIENCE SECTION

Introduction

Although physical and cultural methods of growth control should always be considered before the use of chemicals it's not always appropriate to use such methods to achieve the desired effects on plants. Quite often chemical growth regulators are required to programme crops or hold crops back as a result of sudden changes in demand for plants. For example, easing back on the level of irrigation will help to hold back plants, but to get the desired effect over a longer time period plant quality may be reduced (lower leaf yellowing, flower bud drop etc.) as a consequence. Therefore, chemical growth regulator products should be viewed as one of many potential integral methods of growth control on bedding and pot plants. Currently there are three main chemical plant growth regulator active ingredients used within the bedding plant sector – chlormequat, daminozide and paclobutrazol. In terms of efficacy, paclobutrazol is the most effective of the three active ingredients on the majority of plant species grown. However, there is a potential future complication in that triazole pesticides (including paclobutrazol) could be classified as endocrine disruptors when the methodology is available to determine this, so its long term future is not yet totally secure (CRD 2010).

Prohexadione-calcium (Regalis) could be seen as a potential alternative growth regulator, being in the same chemical group as daminozide (Rademacher, W. 2000). It already possesses a Specific Off-Label Approval (SOLA 2866/2008) for use on outdoor nursery stock. Limited trials work has been undertaken by BASF on a number of bedding plant species including ageratum, antirrhinum, bellis, fuchsia, myosotis, nicotiana, osteospermum, petunia, verbena and viola. The trials indicated that the product works well on some species, giving rise to compact growth. However, the work also highlighted that the product impacts on anthocyanin formation in certain species, giving rise to flower petal bleach (dark blue petunia flowers turn pale blue / white, orange gerbera flowers turn yellow and red geranium flowers turn pink) (Townsend, S, 2009). If the effects of Regalis on flower colour could be minimised then it could prove to be a useful plant growth regulator product for use on a range of bedding plant species.

Trinexapac-ethyl is a growth regulator used to control stem height and lodging in

cereals and is also related to prohexadione-calcium (Rademacher, W, 2000). The active ingredient is sold as Moddus by Syngenta. There has been limited work undertaken with this product on protected ornamental crops, but like Regalis it has the potential to be a useful alternative growth regulator.

2-chloroethylphosphonic acid possesses a SOLA (2743/2010) for use in ornamental plant production. The product is sold as Cerone by Bayer CropScience Limited, although it was previously marketed as Ethrel C (by Hortichem, now Certis). Its primary label use on bedding plant crops was to increase side branching in geranium crops.

The overall commercial objective of the project was to trial Regalis, Cerone and Moddus against a standard chemical growth regulator product currently used within the industry (Bonzi) and an untreated control. Bonzi possesses a label recommendation for use on bedding plants; Cerone possesses a Specific Off-Label Approval (SOLA) for use on protected ornamental crops (2743/2010), Regalis possesses a SOLA for use on outdoor ornamentals only (2866/2008), whilst Moddus is approved only for cereal crops. An experimental permit (COP2010/00664) was therefore obtained for the use of Regalis and Moddus in this project.

Additionally, two triazole fungicides (propiconazole (Bumper 250 EC) and myclobutanil (Systhane 20 EW)) were included in the trial to examine the potential effects of these products on plant growth. The aim was to show that some triazole fungicides, when applied for disease control, need to be taken into consideration within any growth control plan to avoid excessive growth control (Banko, T.J. 2003).

Materials and methods

The project was divided into two parts; the first part was a desk based study to review chemical plant growth regulator use within the protected ornamentals industry and to combine this with a wider literature review of novel / new growth regulator active ingredients with potential for use on bedding and pot plant crops.

This was combined with a replicated trial to examine the response of a range of bedding plants to Regalis, Cerone and Moddus compared with a standard chemical

plant growth regulator treatment (Bonzi). Two triazole fungicide treatments (Bumper 250 EC and Systhane 20 EW) were also included as a demonstration of the growth regulatory effects of these products and how such effects need to be considered when the products are applied for disease control.

The trial was held in a commercial glasshouse at W D Smith and Son, Battlesbridge, Essex. Eleven different seed or cutting raised bedding plant species were included in the trial (listed in table 1) along with key agronomic details.

The cutting raised subjects were purchased from specialist suppliers and the seed raised subjects were sown on site into plug trays (Table 1). All subjects were transplanted into a peat / bark growing medium with base fertiliser and controlled release fertiliser in 1 litre pots and placed down on mobile benching covered with perforated film and capillary matting. The plants were watered overhead by hand throughout the trial and treated for pest / disease as required avoiding triazole fungicides.

Up to June the glasshouse was heated to 15°C with venting at 18°C. No heating was used in June (achieving an average of 20°C during this period). Shading and fan ventilation were provided to minimise plant stress, though water stress was noted with certain subjects (for example fuchsia) and on plants around the edges of benches.

The treatments (as detailed in Table 2) commenced on 14 May 2010 when the plants were laid out on the growing benches. Further details of the products applied are given in Appendix 2. Figure 1 illustrates the stage of plant growth at which these treatments were applied with the actual timing of treatments detailed in Table 2.

The trial was arranged in blocks consisting of pots of each of the eleven species to be tested and with three blocks arranged per bench. There were three replicate blocks treated with each of the nine treatments to be tested. The trial layout is detailed in Figure 2.

Crop growth was recorded on two labelled pots in each plot by measuring plant height for all species except Surfinia where plant width was a more suitable measure. Measurements were taken on 14/05/10 (prior to first treatment), 28/05/10, 18/06/10

and 28/06/10 for cuttings raised species and geranium; and on 04/06/10 (prior to first treatment), 18/06/10 and 28/06/10 (remaining seed raised species).

Growth scores were also allocated prior to the application of treatments and at the final assessment (using a 1 – 5 scale where 1 = some new growth, 2 = visible root / shoot establishment, 3 = established, 4 = established with visible bud, 5 = marketable with flower visible).

Final assessments on 28/06/10 were also supplemented with records of phytotoxic damage and time to flower.

Height and days to flowering data were analysed (analysis of variance) using GenStat software.

Digital images were taken throughout the trial period.

Table 1. Production and growth regulator treatment summary detail

Species	Seed raised	Cutting raised	Plug size	Sowing / bought in date	Potting on date	First PGR application	Second PGR application	Third PGR application	Other comments
Begonia semperflorens 'Big'	x		240 / 40	Wk 12	Wk 18/22*		04/06	18/06	Transplanted twice
Dahlia 'Gallery - Renoir Pink'		X	84	Wk 17	Wk 18	14/05	04/06		
Dianthus 'Select - Whitefire'	x		240	Wk 18	Wk 22		04/06	18/06	
Fuchsia 'Mojo - Deep Cerise and Pastel Violet'		X	84	Wk 17	Wk 18	14/05	04/06		
Geranium 'Black Velvet - Scarlet'	x		104	Wk 13	Wk 19	14/05	04/06		
Impatiens 'Envoy - White'	x		240	Wk 17	Wk 22		04/06	18/06	
Marigold 'Dorango - Tangerine'	x		240	Wk 19	Wk 22		04/06	18/06	
(Petunia) Surfinia 'Classic Vanilla'		X	126	Wk 18	Wk 18	14/05	04/06		
Petunia multiflora 'Dreams Blue'	x		240	Wk 17	Wk 22		04/06	18/06	
Salvia 'Mohave'	x		240	Wk 18	Wk 22		04/06	18/06	
Verbena 'Tamari Trailing Blue'		X	126	Wk 18	Wk 18	14/05	04/06		PGR use evident on plugs when bought in

* Begonia transplanted into an intermediate pot size.

First plant growth regulator (PGR) application date – all spray and drench treatments applied to cutting raised subjects plus geranium.

Second PGR application date - all spray and drench treatments applied to seed raised subjects and second spray treatments (two spray treatments detailed below) applied to cutting raised subjects plus geranium.

Third PGR application date - second spray treatments (two spray treatments detailed below) applied to seed raised subjects.

Table 2. Summary of treatments applied

Treatment	Chemical	Rate
A	Untreated control	
B	Bonzi x 2 sprays	1.25 ml / litre of water
C	Regalis x 1 spray	1.25 g / litre of water
D	Regalis x 2 sprays	1.25 g / litre of water
E	Regalis x 1 drench	1.25 g / litre of water
F	Cerone x 1 spray	1.0 ml / litre of water
G	Moddus x 2 sprays	0.4ml / litre of water
H	Bumper 250 EC x 2 sprays	0.4 ml /litre of water
I	Systhane 20 EW x 2 sprays	0.3 ml / litre of water



Figure 1. Plant size at first plant growth regulator application

Key

From top left across: fuchsia, dahlia, Surfinia, geranium, verbena, salvia, begonia, petunia, dianthus, marigold and impatiens.

Bench 1	Bench 2	Bench 3
Treatment I 5,10,3,6,2,8,4,1,7,9	Treatment A 4,8,7,2,5,9,10,3,1,6	Treatment G 2,7,10,6,9,4,3,5,8,1
Treatment F 3,7,1,5,4,6,8,2,9,10	Treatment H 7,5,2,6,1,9,4,8,3,10	Treatment B 5,1,7,4,10,6,2,3,9,8
Treatment C 2,1,3,5,7,9,8,4,10,6	Treatment D 6,7,3,4,2,9,5,10,1,8	Treatment E 9,10,2,7,1,5,3,6,8,4
Bench 4	Bench 5	Bench 6
Treatment A 3,7,2,1,10,9,8,4,5,6	Treatment D 1,7,8,5,10,2,3,6,4,9	Treatment H 7,5,3,4,6,10,2,9,8,1
Treatment F 9,5,1,4,7,6,3,10,2,8	Treatment C 5,8,4,9,1,10,6,2,7,3	Treatment I 6,4,10,1,3,7,5,8,9,2
Treatment B 10,7,5,3,6,9,8,4,1,2	Treatment E 4,5,7,1,2,3,6,8,9,10	Treatment G 3,2,10,1,7,8,9,6,4,5
Bench 7	Bench 8	Bench 9
Treatment E 1,9,3,10,8,2,5,4,7,6	Treatment I 6,9,2,5,7,4,10,8,3,1	Treatment C 8,5,6,2,7,4,10,3,1,9
Treatment H 7,10,2,3,5,4,6,1,9,8	Treatment G 9,1,10,7,6,4,5,3,2,8	Treatment F 2,5,8,7,3,1,10,6,4,9
Treatment D 4,5,7,9,2,10,6,3,8,1	Treatment B 2,7,5,4,1,8,9,10,6,3	Treatment A 1,9,2,7,10,6,4,5,8,3

Figure 2. Trial layout

Treatment key

A	Untreated control
B	Bonzi spray x 2
C	Regalis spray x 1
D	Regalis spray x 2
E	Regalis drench
F	Cerone spray x 1
G	Moddus spray x 2
H	Bumper 250 EC spray x 2
I	Sythane 20 EW spray x 2

Species key

1	Dahlia 'Gallery - Renoir Pink'
2	Dianthus 'Select - Whitefire'
3	Fuchsia 'Mojo - Deep Cerise and Pastel Violet'
4	Geranium 'Black Velvet - Scarlet'
5	Impatiens 'Envoy - White'
6	Marigold 'Dorango - Tangerine'
7	(Petunia) Surfinia 'Classic Vanilla'
8	Petunia multiflora 'Dreams Blue'
9	Salvia 'Mohave'
10	Verbena 'Tamari Trailing Blue'

The begonia was used as an extra 'guard species' to mark the end of each treatment but still recorded.

The spray treatments were applied in approximately 1,000 litres of water per hectare via a small pump action hand held sprayer (to the point of run-off from the foliage). The drench treatment was applied at 75 ml of solution per litre pot via a watering can and washed off the foliage afterwards. All applications were made in the late afternoon / early evening.

Results

The desk based review work is summarised in Appendix 1.

For the experimental work described below, differences are reported to be statistically significant where FPr values are <0.05 and treatment means are separated by the relevant figure for least significant difference (L.S.D.) at the 5% level.

(1) Height control

The standard treatment (two Bonzi sprays), significantly reduced the height of begonia, dahlia and impatiens in comparison with the untreated plants (Table 3). Calculated change in plant height (i.e. based on the difference between the first and last measurements) further supports this evidence with Bonzi resulting in the greatest plant height reduction of all treatments applied to both begonia (with 51% reduction in plant growth as indicated by height, compared with the untreated plants) and impatiens (at 56% reduction in growth) (Table 4). Growth of geranium and fuchsia was also judged to have been controlled by the Bonzi sprays which reduced growth by 29% and 11% respectively compared with the untreated plants, but differences in plant height for these species were not significantly different to the untreated plants at the final assessment stage (Table 3) based on values of least significant difference (L.S.D.). This is likely to be due to the large inherent variance in plant height data for these species giving rise to a large L.S.D. Bonzi had little or no effect on the height/width of marigold, petunia, salvia and verbena.

Regalis was effective at controlling the growth of a range of subjects tested with significant reductions resulting in the height/width of begonia, dahlia, dianthus,

impatiens, marigold and Surfinia. As would be expected, the two spray and drench Regalis treatments had a greater impact than the one spray treatment. There was also some apparent reduction in the height of geranium as a result of treatment with Regalis as two sprays or a drench but as noted above for Bonzi, this difference was not statistically significant. The impact of Regalis in comparison with the standard (i.e. Bonzi) varies with subject. For begonia and impatiens, Bonzi resulted in the greater reduction in plant height but for dahlia, dianthus, marigold, petunia and Surfinia, Regalis produced greater reductions in plant height/width than Bonzi. Of course maximum height control is not usually the only aim of applying PGRs and hence the treatment selected would need to consider the extent of growth manipulation achieved which will clearly vary with both application method and subject as well as product selected.

Cerone significantly reduced the height/width of begonia, dahlia, and Surfinia and gave equivalent control to the Regalis for the first two of these plant species. Moddus was largely ineffective on the range of subjects tested with the exception of Surfinia where growth in plant width was reduced by 24% (i.e. greater than that achieved using Bonzi).

Of the two fungicide products examined, Bumper 250 EC had the greatest overall impact on plant height with significant reductions noted for begonia, dianthus and marigold, with the reduction achieved exceeding that resulting from the Bonzi sprays in these species. Bumper also produced the greatest reduction in the height of fuchsia (at 24%) compared with all treatments applied but as noted previously these differences were not statistically significant. By contrast Systhane 20 EW had little impact on height/width of the subjects tested.

Plant height/width was also monitored at intervals during production to indicate if any of the treatments would produce an unusual pattern of growth that would need to be considered as part of managing treated plants, e.g. an initial check on growth which later recovers. In general, all subjects followed similar patterns of increase in plant height/width over time (Appendix 3). Cerone is the only notable exception to this trend. When applied to impatiens for example (Figure 3), Cerone produced an initial check on plant growth (i.e. resulting in the shortest plants at the interim measurement stage) but at final assessment, plant growth had recovered notably which in practice may result in taller plants at final harvest than may be anticipated earlier in

production. Cerone also produced a similar early growth check on dahlia, Surfinia and petunia.

Other plant habit features influenced by the treatments applied were as follows:

- Regalis improved the habit of several subjects, most notably begonia, petunia, Surfinia and verbena by reducing internode length (keeping the plant compact).
- Cerone increased the number of side shoots of dianthus and geranium in particular and also of marigold and salvia to a lesser extent (Appendix 4).
- Moddus had a slight positive impact on petunia plant habit (keeping plants compact), but conversely impaired the habit of dahlia and impatiens by making the canopy appear more upright.

(2) Flowering time

Treatments either delayed or advanced flowering depending on both the subject and treatment applied (Tables 4 and 5). Bonzi delayed begonia flowering by 3 days. Regalis significantly delayed flowering of dianthus and impatiens (by 4-5 days) but advanced flowering of petunia and verbena (by 3-4 days). Cerone delayed flowering of dahlia by 4 days and of verbena by 10 days but had no significant influence over the flowering time of the other subjects tested. Moddus advanced flowering of verbena by 3 days. Bumper 250 EC delayed flowering of begonia by 3 days. Systhane 20 EW had no significant influence on flowering of the subjects tested.

Table 3. Average final plant height / width (Surfinia only) measured on 28 June 2010 (after all treatments) – cutting and seed raised subjects (including data analysis). Growth scores are shown in brackets.

Treatment	Species – average height (cm)										
	Begonia	Dahlia	Dianthus	Fuchsia	Geranium	Impatiens	Marigold	Petunia	Salvia	Surfinia*	Verbena
Untreated control	21.8 (5)	26.3 (5)	26.7 (5)	29.5 (5)	32.5 (4)	11.3 (5)	15.0 (5)	14.0 (5)	11.5 (5)	56.5 (5)	19.3 (5)
Bonzi x 2 sprays	14.0 (5)	18.7 (5)	24.7 (5)	26.8 (5)	24.5 (4)	6.3 (5)	14.8 (5)	13.5 (5)	12.5 (5)	52.2 (5)	18.5 (5)
Regalis x 1 spray	20.7 (5)	22.2 (5)	19.2 (4)	29.8 (5)	26.0 (4)	9.2 (5)	14.7 (5)	15.7 (5)	14.8 (5)	58.3 (5)	18.2 (5)
Regalis x 2 sprays	16.8 (5)	17.0 (5)	19.0 (4)	28.5 (4)	29.5 (4)	7.0 (5)	14.0 (5)	10.5 (5)	14.2 (5)	43.7 (5)	20.8 (5)
Regalis x 1 drench	16.2 (5)	17.7 (5)	24.0 (4)	30.5 (4)	27.5 (4)	8.2 (5)	15.0 (5)	15.8 (5)	14.3 (4)	35.0 (5)	21.3 (5)
Cerone x 1 spray	16.0 (5)	19.2 (5)	26.7 (5)	26.2 (5)	27.8 (5)	9.8 (5)	15.0 (5)	11.2 (5)	11.3 (5)	47.7 (5)	19.3 (5)
Moddus x 2 sprays	20.2 (5)	26.3 (5)	24.7 (4)	28.8 (5)	28.2 (4)	9.3 (5)	16.3 (5)	15.2 (5)	14.0 (5)	43.7 (5)	20.2 (5)
Bumper 250 EC x 2 sprays	13.0 (5)	22.3 (5)	22.0 (5)	24.3 (5)	32.8 (5)	8.7 (5)	12.8 (5)	16.8 (5)	12.7 (5)	51.8 (5)	18.7 (5)
Systhane 20 EW x 2 sprays	18.3 (5)	26.3 (5)	27.5 (5)	31.3 (5)	31.8 (4)	9.8 (5)	14.3 (5)	15.3 (5)	13.5 (5)	64.7 (5)	22.3 (5)
<i>Degrees of freedom</i>	16	16	16	16	16	16	16	16	16	16	16
<i>Least significant differences of means (5% level)</i>	3.6	5.9	4.4	6.3	8.2	2.9	1.8	4.0	3.0	8.4	3.5
<i>Significance</i>	<0.001	0.010	0.005	0.380	0.383	0.051	0.057	0.046	0.199	<0.001	0.243

* Width recorded in the case of Surfinia.

Growth scored on a 1 – 5 scale: 1 – some new growth, 2 – visible root / shoot establishment, 3 – established, 4 – established with visible bud, 5 – marketable with flower visible.

Table 4. Average plant height / width (Surfinia only) increase from transplanting and percentage reduction relative to untreated control

Treatment	Average plant height / width increase from transplanting (cms) and percentage reduction relative to untreated control									
	Begonia		Dahlia		Dianthus		Fuchsia		Geranium	
	Av increase	% reduction	Av increase	% reduction	Av increase	% reduction	Av increase	% reduction	Av increase	% reduction
Untreated control	14.0		20.5		20.7		23.0		27.0	
Bonzi x 2 sprays	6.8	51	13.4	35	18.2	12	20.5	11	19.2	29
Regalis x 1 spray	13.2	6	16.5	19	12.4	40	23.0	0	18.3	32
Regalis x 2 sprays	9.5	32	11.7	43	12.2	41	22.8	1	24.2	10
Regalis x 1 drench	8.9	36	10.9	47	16.8	19	23.8	0	21.0	22
Cerone x 1 spray	9.5	32	13.2	36	20.4	1	19.2	16	20.6	24
Moddus x 2 sprays	12.9	8	20.6	0	18.9	7	21.5	6	21.0	22
Bumper 250 EC x 2 sprays	4.7	66	16.0	22	16.0	23	17.5	24	26.0	4
Sythane 20 EW x 2 sprays	10.8	23	20.3	1	20.7	0	25.1	0	25.1	7

Treatment	Average plant height / width increase from transplanting (cms) and percentage reduction relative to untreated control											
	Impatiens		Marigold		Petunia		Salvia		Surfinia*		Verbena	
	Av increase	% reduction	Av increase	% reduction	Av increase	% reduction	Av increase	% reduction	Av increase	% reduction	Av increase	% reduction
Untreated control	9.3		11.7		12.2		9.3		53.8		16.1	
Bonzi x 2 sprays	4.1	56	11.3	3	12.3	0	10.7	0	48.5	10	15.5	4
Regalis x 1 spray	7.2	22	10.9	7	14.0	0	12.6	0	54.6	0	15.0	7
Regalis x 2 sprays	5.2	44	10.7	8	8.7	29	12.0	0	40.4	25	18.0	0
Regalis x 1 drench	6.2	33	11.5	2	13.8	0	11.8	0	31.5	41	18.8	0
Cerone x 1 spray	7.8	16	11.5	2	9.5	22	9.3	0	44.9	16	16.0	1
Moddus x 2 sprays	7.3	21	12.3	0	13.9	0	12.2	0	40.9	24	16.9	0
Bumper 250 EC x 2 sprays	6.9	26	9.8	16	15.5	0	10.4	0	48.5	10	15.2	5
Sythane 20 EW x 2 sprays	7.5	19	11.1	5	13.6	0	11.3	0	61.5	0	19.3	0

* Width recorded in the case of Surfinia.

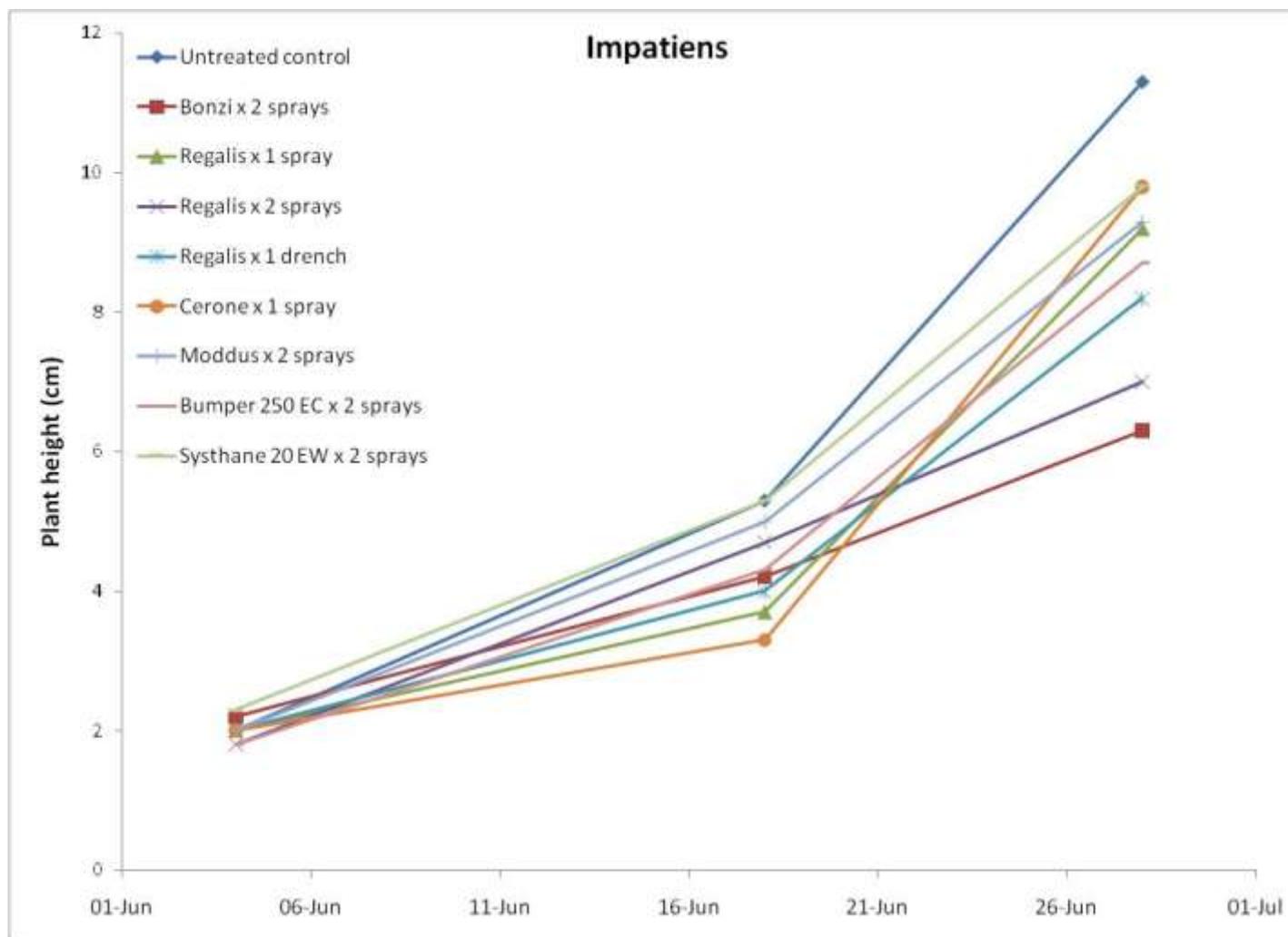


Figure 3. Growth over time for impatiens treated with a range of PGR applications.

Table 5. Average days to flowering from transplanting

Treatment	Species – days to flower from transplanting										
	Begonia	Dahlia	Dianthus	Fuchsia	Geranium	Impatiens	Marigold	Petunia	Salvia	Surfinia	Verbena
Untreated control	46	46	28	49	50	18	19	22	20	33	33
Bonzi x 2 sprays	49	47	27	48	51	19	19	20	23	33	32
Regalis x 1 spray	44	46	30	48	52	23	19	18	21	33	30
Regalis x 2 sprays	45	47	32	56	51	21	19	23	20	33	30
Regalis x 1 drench	44	48	29	57	51	19	19	23	20	33	31
Cerone x 1 spray	45	50	27	51	48	18	19	23	21	33	43
Moddus x 2 sprays	44	45	30	52	52	19	19	20	21	33	30
Bumper 250 EC x 2 sprays	49	45	29	54	50	17	19	22	19	33	32
Systhane 20 EW x 2 sprays	44	45	28	47	51	18	19	21	20	33	33
<i>Degrees of freedom</i>	16	16	16	16	16	16	16	16	16	16	16
<i>Least significant differences of means (5% level)</i>	3.2	3.4	3.3	8.3	3.0	4.4	-	3.5	3.6	-	2.5q
<i>Significance level</i>	0.028	0.116	0.104	0.144	0.456	0.364	<i>Not significant</i>	0.152	0.546	<i>Not significant</i>	<0.001

Table 6. Difference in average days to flowering relative to untreated control

Treatment	Difference in flowering time (days) between untreated control and treatments										
	Begonia	Dahlia	Dianthus	Fuchsia	Geranium	Impatiens	Marigold	Petunia	Salvia	Surfinia	Verbena
Untreated control											
Bonzi x 2 sprays	+3	+1	-1	-1	+1	+1	0	-2	+3	0	-1
Regalis x 1 spray	-2	0	+2	-1	+2	+5	0	-4	+1	0	-3
Regalis x 2 sprays	-1	+1	+4	+7	+1	+3	0	+1	0	0	-3
Regalis x 1 drench	-2	+2	+1	+8	+1	+1	0	+1	0	0	-2
Cerone x 1 spray	-1	+4	-1	+2	-2	0	0	+1	+1	0	+10
Moddus x 2 sprays	-2	-1	+2	+3	+2	+1	0	-2	+1	0	-3
Bumper 250 EC x 2 sprays	+3	-1	+1	+5	0	-1	0	0	-1	0	-1
Systhane 20 EW x 2 sprays	-2	-1	0	-2	+1	0	0	-1	0	0	0

(3) Phytotoxic damage and other symptoms

A number of different symptoms were noted through the trial, some were mild and improved the appearance of the plant (darkening of the foliage in response to Bonzi for example) whilst others were more severe and impaired the appearance of the plant.

Both Regalis and Moddus impacted on flower petal colour, bleaching the flowers on verbena (Figure 3), dahlia and, to a lesser extent, begonia. The dark blue flowers of petunia multiflora 'Dreams Blue' were however not bleached by these treatments.

Cerone reduced flower stem development on dahlia to such an extent that when the flowers did open they were below the canopy formed by later developing side shoots (Figure 3).

Bumper 250 EC caused a flower distortion on begonia and a transient hardening of the growing points on fuchsia (Figure 3).



Begonia – flower distortion in response to applications of Bumper 250 EC



Fuchsia – growing point hardening in response to applications of Bumper 250 EC



Dahlia – flower stem shortening in response to applications of Cerone



Verbena – untreated v Moddus sprays (right), giving rise to petal bleach

Figure 3. Plant symptoms noted in response to the treatments

A summary of the effects of the PGR treatments on the species included in these trials is given in Table 7.

Table 7. Summary of treatment response by plant species

Species	Bonzi	Regalis	Cerone	Moddus	Bumper 250 EC	Systhane 20 EW
Begonia semperflorens 'Big'	Obvious height reduction. No improvement in habit. Possible flower delay. Foliage darkened.	No obvious effect from x 1 spray treatment. x 2 spray treatment more effective, improvement in branching, some petal bleach though. Height reduction from drench treatment. No delay in flowering.	Obvious height reduction, comparable to Bonzi treatment.	Slight check to growth, possibly a paling of flower petals.	Obvious height reduction, very dark leaves but distortion to flowers (and growing points) noted. Delay in flowering.	Limited effect on plant growth or habit.
Dahlia 'Gallery - Renoir Pink'	Obvious height reduction, plants at least a third smaller. Leaf and flower size reduction. Flowers still borne above foliage.	x 1 spray treatment limited effect. Height reduction with x 2 spray treatment, obvious effect from drench. Flower petal bleach in response to x 2 spray and drench treatment. Flower stems shortened, flowers only just above foliage with drench. Foliage darkened with drench.	Obvious early growth control. Stems of first flush of flowers held back so that open flowers below foliage. Some delay in flowering, flower and leaf size reduced.	No affect in terms of plant height, but plants appear more upright in habit. Flower petal bleach obvious.	Plant upright in appearance, flowers smaller in size, slight height reduction.	No effect on plant growth or habit.
Dianthus 'Select - Whitefire'	Slight height reduction noted, slightly better branching gives rise to better plant habit.	Height reduction noted, but no improvement in plant habit. Delay in flowering with most treatments.	Improved plant habit, more branching and flower stems, good shape to the plants. Very slight reduction in plant height.	No impact on growth. Possible delay in flowering.	Darker foliage, significant reduction in height. Possible delay in flowering.	No effect on plant growth or habit.
Fuchsia 'Mojo - Deep Cerise and Pastel Violet'	Height reduction noted but not statistically significant, flowers well displayed. Slight reduction in flower size, either earlier flowering or flowering enhanced relative to other treatments.	No or very limited effect in terms of growth control with all treatments. Delay in flowering.	Comparable to Bonzi treatment in terms of height and growth control, but flowering not enhanced in the same way.	Some effect in terms of height control, possible delay in flowering.	Well branched, but transient growing point distortion noted. Good habit to plant, delay in flowering.	No effect on plant growth or habit.

Species	Bonzi	Regalis	Cerone	Moddus	Bumper 250 EC	Systhane 20 EW
Geranium 'Black Velvet - Scarlet'	Height reduction noted but not statistically significant, also reduction in leaf size. Intensifies the purple colouration in the leaf (darker leaves). No improvement in habit.	Variable effect on height control, no improvement in overall habit. Some leaf size reduction with drench and possible flower delay.	Height reduction noted but not statistically significant with improvement in number of side breaks.	Limited effect on growth and habit. Breaks up leaf margin zonal markings. Possible delay in flowering.	Limited growth control and slight intensification of leaf markings.	No effect on plant growth or habit. Possible delay in flowering.
Impatiens 'Envoy - White'	Tighter growth habit and perhaps a darkening of the foliage.	Variable effect on growth, possibly some distortion with higher rates. Possible delay in flowering.	Limited effect in terms of height control, plants appear more upright in habit.	Limited effect, plants appear more upright.	Limited effect on growth and habit.	No effect on plant growth or habit.
Marigold 'Dorango - Tangerine'	Slightly tighter canopy to plant, no obvious differences.	Slight response to x 2 spray treatment and drench treatment in terms of habit.	Some improvement in level of side branching and slight reduction in flower stem length.	No effect.	Slightly tighter growth habit to the plants.	No effect on plant growth or habit.
(Petunia) Surfinia 'Classic Vanilla'	Good leaf cover over the pot, slightly darker leaves.	x 1 spray treatment limited effect, improvement in habit with x 2 spray and drench treatment.	Obvious reduction in leaf size, possible reduction in flower size. Better habit to plants, less sprawling.	Darker foliage, some check to growth, plants less sprawling.	Improvement in growth habit, plants slightly less sprawling, darkening of foliage.	No effect on plant growth or habit. Plant more open in centre, more yellow leaf noted.
Petunia multiflora 'Dreams Blue'	Limited effect of treatment, perhaps slightly darker foliage and possibly earlier flowering.	No effect from x 1 spray treatment. Some height control and habit improvement with x 2 spray treatment and drench. Second spray treatment may have affected growing points – slight yellowing and distortion.	Some effect on height, habit appears slightly improved.	Good shape to plants, with only limited level of growth reduction.	Reduced level of branching noted, plants less well developed.	No effect on plant growth or habit.
Salvia 'Mohave'	Darker leaves, improved branching with very slight growth control.	Limited effect with all 3 treatments.	Possibly more branching and a reduction in flower stem length and flower size.	Good level of branching, very limited effect on height.	Very limited effect on growth, foliage slightly darker.	No effect on plant growth or habit.
Verbena 'Tamari Trailing Blue'	Tighter habit to the plant with more growth from the centre of the plant. Darker foliage.	Limited effect in terms of growth control and habit improvement. Some petal bleach with treatments.	Some height control, plants more upright in habit as opposed to sprawling. Delay in flowering.	No effect on growth, flower petal bleach noted.	Some height control noted, foliage darkened.	No effect on plant growth or habit.

Discussion

Good levels of growth control were achieved with Regalis, although there were issues with flower petal bleaching with this product on some species. It may be that earlier applications of the product (soon after transplanting, or even at the plug stage) may be a suitable method of reducing the unwanted side effect. The symptoms recorded in the trial were less severe than those recorded in other trials (Townsend, S, 2009) and symptoms were totally avoided in the case of the dark blue flowered petunia multiflora 'Dreams Blue'. The drench treatment and the two spray application treatment were generally more effective in terms of growth control than the single spray treatment. An extension to the SOLA to include protected ornamental crops would be useful.

Cerone was very effective as a spray on a number of the plant species examined, including begonia, dahlia and Surfinia. The growth control achieved may actually prove excessive with some species, such as dahlia where the flower stem height on early flowers was excessively reduced. Cerone's mode of action (it breaks down within the plant to release ethylene gas) probably explains the delay in flowering recorded in several species, i.e. by 10 days in verbena, 4 days in dahlia and 2 days in fuchsia (although in the latter species the difference was not significant. The greater delay in flowering of verbena may be partially a result of spray contaminating the growing media at the point of application which could increase its uptake and hence impact (verbena plants were the smallest plants at the point of first treatment and hence had the smallest canopy covering the growing media surface). The continuation of the SOLA provides a useful alternative product to growers.

Moddus was the least effective in controlling the growth of the species tested and also caused more petal bleach than Regalis (to which it is chemically related). As a stand-alone product it has limited potential use for growth control in bedding plants, also the active ingredient currently only possesses a label recommendation for use on cereals and it is therefore doubtful if the product will be available for use on hand-harvested crops grown under protection in the short term.

The results from the trial indicate that some triazole fungicides used for disease control will impact on plant growth but the extent of this effect does vary with the plant species in question. The application of Bumper 250 EC for rust control on

bedding and pot plants (under SOLA 0707/2009) for example could potentially result in a severe check to growth and even phytotoxic damage to flowers and growing points. PGR treatments would therefore need to be adjusted where crops are to be treated with this fungicide to control disease problems. In contrast, Systhane 20 EW had very little impact on plant growth and produced no phytotoxic damage to the plant species examined in the trial.

Conclusions

The effectiveness of chemicals to regulate plant growth clearly varies with species as well as application method. Even Bonzi, included to represent the industry standard, had no significant influence over the height of some of the species included in these trials. Growers are recommended to carry out their own small scale trials on treatments which are new to their production system (i.e. either a new product or a new plant species / cultivar). At worst the risks are unmarketable plants due to quality defects or failure to meet plant height specifications, but there is also the risk of investing in the cost of chemicals and labour for spraying with no resultant control of growth. Although not tested here it is also important to highlight the need to apply treatments at a suitable growth stage, PGRs cannot for example reverse existing stretched growth.

Both Regalis and Cerone have potential for growth control on bedding plant species. The former product will require an extension to the current SOLA to permit use under protection; the latter product can already be used via its current SOLA.

Care should be taken when applying Regalis to avoid flower petal bleach, earlier applications of the product may limit the degree of bleaching. Care should also be taken when applying Cerone to avoid run-off into the growing media as this could otherwise lead to a greater level of growth restriction and a delay in flowering.

Moddus provided little benefit for the plant species tested but did result in flower petal bleach, hence this product appears to offer less potential as a PGR treatment for bedding plant species.

In terms of product cost and cost per litre of final solution, Regalis is comparable to Bonzi whilst Cerone and Moddus are much less expensive (Table 8).

Table 8. The relative costs of growth regulator treatments examined in the trial (2010)

Product	Average cost of product	Cost per litre of solution at rate trialled
Bonzi	6.9p per ml of product	8.6p per litre at 1.25 ml / litre rate
Regalis	8.2p per gram of product	10.3p per litre at 1.25 g / litre rate
Cerone	1.7p per ml of product	1.7p per litre at 1.0 ml / litre rate
Moddus	4.6p per ml of product	1.8p per litre at 0.4 ml / litre rate

Average costs not taking into account discounts etc.

Care should be taken when applying some triazole fungicides for disease control on bedding plants. The trial highlighted the potential impact of Bumper 250 EC on the growth of plants and the potential phytotoxic damage it can cause and this should be borne in mind when integrating fungicides and growth regulators in any spray programme.

Technology transfer

An afternoon open day was staged on the 1 July 2010 so growers could view the plant responses to the various treatments at the end of the trial. A summary handout was prepared for the event.

An article will be prepared for the HDC News during the late summer / early autumn 2010, summarising the trial and questionnaire responses received back from the from the industry.

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APPENDICES

Appendix 1.

Grower survey summary

Most growers said they use a range of cultural techniques to regulate or manipulate plant growth, including grouping crops with similar temperature requirements together to prevent excessive growth; batch scheduling; and using water deficit stress to keep growth in check. Two thirds of those surveyed use potassium or calcium nitrate fertiliser instead of ammonium nitrate to prevent too much soft growth. Fewer than half were using temperature control techniques such as 'drop' or 'dif'. Of those who responded to the survey, only one grower used spectral polythene filters such as BP Agri Solatrol or XL SmartBlue.

The majority of growers surveyed applied chemical growth regulators to more than 50% of their crops, mostly as sprays because the labour costs were usually cheaper than for making drench applications, plus they gave finer growth control. Chemicals were generally applied regularly, at low rates, although some growers preferred a single high rate application, depending on the crop and chosen product. All respondents from the survey who used the fungicide product Bumper 250 EC (propiconazole) for disease control said they reduced their growth regulator rates to take account of the strong growth check this particular product can have. A few growers reported instances of crop damage associated with chemical growth regulator use, in one instance, the use of an adjuvant was thought to be the cause.

No particular crop stood out as being especially sensitive in terms of phytotoxicity, instances of crop damage were most probably linked to over application or allowing the product to run off into the growing media, leading to damage via root uptake. More than a third of growers suspected residues of paclobutrazol in the growing environment – in capillary matting for example – were responsible for problems in subsequent crops. Most growers either shaded crops following growth regulator applications or applied the product in the evening to prevent evaporation off the leaves before uptake which can reduce the effectiveness of some products.

Assessment of a number of new plant growth regulator products to control growth on commercial crops of bedding plants.

This document is a summary of published plant growth regulator use on bedding plants. It is intended to be used as a reference document to support the HDC project PO 004. Rates are presented as guidance only to provide an indication of potential suitable rates under UK growing conditions. Where the crop response is not known it is advised that a small proportion of a given crop is treated prior to widespread use of the chemical plant growth regulator. Neither HDC nor ADAS can be held responsible for crop losses or damage incurred from the rates detailed within this publication.

There may be a need to make use of different chemical plant growth regulators (due to changes in approval status of key plant growth regulators) to manipulate the growth of bedding plants. Plant growth regulator products are used to reduce plant internode length, reduce plant height, improve the degree of side branching and hence improve plant habit enabling more plants to be transported on each trolley. This potentially gives growers more control over crop development reducing the need for costly operations such as pinching and hand cleaning at dispatch, whilst reducing wastage.

To maximise their effect, plant growth regulator products should be applied to new growth prior to any rapid extension. They can also be applied to plants at the flower bud initiation stage, but note when applied at this stage they can also potentially delay the time to flower and reduce flower size.

Depending upon their mode of action, plant growth regulator products can be applied to plants either as a spray or drench. Spray applications tend to have less impact on plant growth (depending upon the product and rate applied) and so often need to be applied on several occasions to have the desired effect. Drench applications are generally more effective, although they can be more costly to apply in terms of application time and there may be issues with product build up in capillary matting etc. beneath the crop.

Chemical plant growth regulator use on bedding plants is summarised within the tables within this document; Table A1.1 lists the various products available in the UK, Table A1.2 their approval status whilst Table A1.3 onwards summarises the various published work undertaken relating to their use on bedding plants (sources are listed

in the reference section for further information). Product labels / technical information / SOLAs should be read prior to application to ascertain the relevant or maximum rate, frequency of application, water volume etc. for UK products.

Table A1.1. Plant growth regulators currently approved for use on ornamentals in the UK

Product name	MAPP Number	Active ingredient (A.I.)	A.I. content	Main supplier	Final use date
B-Nine SG	12698	Daminozide	85% w/w	Chemtura Europe Limited	31/08/11
B-Nine SG	12734	Daminozide	85% w/w	Certis	31/08/11
B-Nine SG	14435	Daminozide	85% w/w	Certis	28/02/16
Dazide Enhance	11943	Daminozide	85% w/w	Fine	31/08/11
Dazide Enhance	14433	Daminozide	85% w/w	Fine	28/02/16
Agrovista 3 See 750	14797	Chlormequat*	750 g / litre	Agrovista UK Limited	31/12/21**
BASF 3C Chlormequat 720	06514	Chlormequat*	720 g / litre	BASF	31/12/21**
CCC 720	14891	Chlormequat*	720 g / litre	European Agrichemicals Limited	31/12/21**
Ciba Chlormequat 460	09525	Chlormequat*	460 g /litre	Ciba Speciality Chemicals, Water Treatments Limited	30/11/11
Ciba Chlormequat SC 460:320	09527	Chlormequat*	460 g / litre	Ciba Speciality Chemicals, Water Treatments Limited	30/11/11
Clayton Standup	11760	Chlormequat*	700 g / litre	Clayton Plant Protection (UK) Ltd	30/11/11
Cropsafe SC Chlormequat	07897	Chlormequat*	645 g / litre	Hortichem Limited	30/11/11
Cropsafe 5C Chlormequat	11179	Chlormequat*	645 g / litre	Certis	30/11/11
CS Chlormequat 750	14946	Chlormequat*	750 g / litre	Chemsource Ltd	31/12/21**
Fargro Chlormequat	02600	Chlormequat*	460 g / litre	Fargro	31/12/21**
Hive	11392	Chlormequat*	730 g / litre	Nufarm UK Limited	31/10/13
Mirquat	11406	Chlormequat*	730 g / litre	Nufarm UK Limited	31/10/13
New 5C Cycocel	01482	Chlormequat*	645 g / litre	BASF	31/12/21**
New 5c Quintacel	12074	Chlormequat*	645 g / litre	Nufarm UK Limited	31/12/21**
Stabilan 700	11393	Chlormequat*	700 g / litre	Nufarm UK Limited	31/12/21**
Supaquat	09381	Chlormequat*	720 g / litre	Agform Limited	30/11/11
Terbine	11407	Chlormequat*	730 g / litre	Nufarm UK Limited	31/12/21**
Cerone	09985	2-chloroethylphosphonic acid (ethephon)	480 g / litre	Bayer CropScience Limited	30/07/12
Cerone	15087	Ethephon	480 g / litre	Bayer CropScience Limited	27/09/14
Bonzi	13623	Paclobutrazol	4 g / litre	Syngenta Bioline	31/12/21**
Pirouette	13073	Paclobutrazol	4 g / litre	Fine	31/12/21**
Regalis	12414	Prohexadione-calcium*	10% w/w	BASF	31/12/11
Moddus	08801	Trinexapac-ethyl	250 g / litre	Syngenta Crop Protection UK Limited	31/10/12

* Adjuvants: A suitable non-ionic surfactant should be used with chlormequat. A water conditioner must be used with Regalis e.g. X-Change at a rate of 1litre in 400 litres.

** Products that currently have a final use date of 31/12/21 may be subject to revocation prior to the date listed in this table. The recent change in backstop expiry date was implemented by a blanket notice of approval issued on 11 November 2010 which covers all products still approved under the Control of Pesticide Regulations where an earlier expiry date has not been set (for example, as the result of Annex I inclusion/non-inclusion of the active substance)- see <http://www.pesticides.gov.uk/approvals.asp?id=2947>. The notices of approval for individual products will not be updated specifically as a result of this change; however, any new notices of approval issued as the results of other changes to the approval – for example, changes to approval holder or marketing company, changes in packaging, changes in crops, application rates and timings etc – will carry the new backstop expiry dates.

If a product approval with a final use expiry date of 31/12/2021 is then subject to revocation following an inclusion/non-inclusion decision for the active substances in that product, the expiry dates will be brought forward. It would therefore be possible for a products final use expiry date to be brought forward to 31/12/2013.

Table A1.2. Approval status of plant growth regulators approved in the UK

Product name	MAPP Number	Approval status
B-Nine SG	12698	Label approval for use in ornamental plant production.
B-Nine SG	12734	Label approval for use in ornamental plant production.
B-Nine SG	14435	Label approval for use in ornamental plant production (protected).
Dazide Enhance	11943	Label approval for use in ornamental plant production.
Dazide Enhance	14433	Label approval for use in ornamental plant production (protected).
Agrovista 3 See 750	14797	Label approval for use in ornamental plant production.
BASF 3C Chlormequat 720	06514	Label approval for use in geranium, <i>Pelargonium</i> , poinsettia **.
CCC 720	14891	Label approval for use in ornamental plant production.
Ciba Chlormequat 460	09525	Label approval for use in ornamental plant production.
Ciba Chlormequat SC 460:320	09527	Label approval for use in ornamental plant production.
Clayton Standup	11760	Label approval for use in ornamental plant production.

Product name	MAPP Number	Approval status
Cropsafe SC Chlormequat	07897	Label approval for use in geranium, <i>Pelargonium</i> , poinsettia **.
Cropsafe 5C Chlormequat	11179	Label approval for use in geranium, <i>Pelargonium</i> , poinsettia **.
CS Chlormequat 750	14946	Label approval for use in ornamental plant production.
Fargro Chlormequat	02600	Label approval for use in ornamental crops.
Hive	11392	Label approval for use in ornamental plant production.
Mirquat	11406	Label approval for use in ornamental plant production.
New 5C Cycocel	01482	Label approval for use in ornamental plant production.
New 5c Quintacel	12074	Label approval for use in ornamental plant production.
Stabilan 700	11393	Label approval for use in ornamental plant production.
Supaquat	09381	Label approval for use in geranium, <i>Pelargonium</i> , poinsettia **.
Terbine	11407	Label approval for use in ornamental plant production.
Cerone	09985	Specific Off-Label Approval (ref. SOLA 1382/09) for use in protected ornamental plant production.
Cerone	15087	Specific Off-Label Approval (ref. SOLA 2743/10) for use in ornamental plant production.
Bonzi	13623	Label approval for use in ornamental plant production.
Pirouette	13073	Label approval for use in ornamental plant production (container grown).
Regalis	12414	Specific Off-Label Approval (ref. SOLA 2866/08) for use in outdoor ornamental plant production as a horticultural growth regulator.
Moddus +	08801	SOLA for use in ornamentals to be requested by HDC.

** It is worth noting that the Chemicals regulation directorate (CRD) no longer specifies approvals in this way and any future approvals will probably just specify 'Ornamental Plant Production'. In such a case products can be used on any ornamental at growers own risk as long as there are no other restrictions on the product label.

+ Moddus is only likely to be effective on monocotyledon plant species (e.g. grasses); its main use is for growth regulation of cereals.

Plant responses

It is not safe to assume that a plant growth regulator that is effective on one species will be effective on another species. It is also generally not safe to assume that all cultivars within a species respond in the same way to a given plant growth regulator. More than one application of a plant growth regulator, using the recommended rate, at 7-14 day intervals is generally required to achieve height control. This will normally reduce plant height by the desired amount. Growth regulation typically lasts from two to four weeks before plants return to their normal rates of growth.

Table A1.3. Rates relating to foliar applications of daminozide, chlormequat (as 46% formulation) and paclobutrazol tested on bedding plants (rates based on UK formulations)

Plant species	Rate daminozide (g/l)	Effects on growth / comments	Rate of chlormequat (ml/l)	Effects on growth / comments	Rate of paclobutrazol (ml/l)	Effect on growth / comments	Source of data
<i>Ageratum</i>	2.9 – 5.9	Lower rates relate to use on plugs whilst higher rates relate to use in pots/pack culture	0.9 – 6.5	Lower rates relate to use on plugs whilst higher rates relate to plants in pots/packs	0.1 – 1.1 l	Lower rates relate to use on plugs whilst higher rates relate to plants in pots/packs	N.USA
<i>Alyssum</i>	3.5 – 5.9	Apply low rate 3 weeks after transplanting, apply high rate 10 days after transplanting plugs. High rate may also be used to tone and harden growth	-		0.25 – 1.5	Lower rates relate to use on plugs whilst higher rates relate to plants in pots/packs	N.USA
<i>Antirrhinum</i>	5.9	Use as needed to tone and harden growth, most effective when combined with cool temperatures, start application two weeks after transplanting	-		0.25 – 2.3	Lower rates relate to use on plugs whilst higher rates relate to tall varieties in pots/packs	N.USA

Plant species	Rate daminozide (g/l)	Effects on growth / comments	Rate of chlormequat (ml/l)	Effects on growth / comments	Rate of paclobutrazol (ml/l)	Effect on growth / comments	Source of data
<i>Argyranthemum frutescens</i>	-		1.6 – 3.2		-		N.USA
<i>Bacopa sutera</i>	0.9 – 1.8	Soft pinch to promote lateral shoot development at transplanting, Try lower rate first	-		-		N.USA
<i>Begonia</i>	2.9 – 5.9 (seed raised)	Lower rates relate to use on plugs whilst higher rates relate to plants in pots/packs	0.9 – 2.2 (vegetative)	To control plant growth	0.08 – 0.1	Use only if need to stop growth. Extremely active on this crop, spray drift can cause stunting.	N.USA
<i>Bidens ferulifolia</i>	1.8 – 2.9	Soft pinch to promote lateral shoot development at transplanting	-		-		N.USA
<i>Brachyscome</i>	2.9 – 5.9	To control plant growth	-		-		N.USA
<i>Bracteantha bracteata</i>	-		-		0.5 – 0.8	To control plant growth	N.USA
<i>Browallia</i>	2.9 – 5.9	Lower rates relate to use on plugs whilst higher rates relate to plants in pots/packs	-		-		N.USA
<i>Calendula</i>	2.9 – 5.9	Lower rates relate to use on plugs whilst higher rates relate to plants in pots/packs	-		-		N.USA
<i>Calibrachoa spp.</i>	2.9 – 5.9	Soft pinch at transplanting to promote lateral branching. Repeat applications may be required	-		-		N.USA

Plant species	Rate daminozide (g/l)	Effects on growth / comments	Rate of chlormequat (ml/l)	Effects on growth / comments	Rate of paclobutrazol (ml/l)	Effect on growth / comments	Source of data
<i>Celosia</i>	2.9 – 5.9	Lower rates relate to use on plugs whilst higher rates relate to toning/hardening growth in pots/packs, apply 3 weeks after transplanting	1.7 – 3.3	Lower rates relate to use on plugs whilst higher rates relate to plants in pots/packs	0.1 – 1.1	Lower rates relate to use on plugs whilst higher rates relate to plants in pots/packs	N.USA
<i>Chrysanthemum</i> (potted)	2.9 – 5.9	Spray when new growth from pinch is 2.5 – 5 cm long. Some varieties may require a second application 3 weeks later	-		1.25 – 5	Lower rates relate to use on plugs whilst higher rates relate to plants in pots/packs	N.USA
<i>Cleome</i>	-		1.7 – 3.3	Lower rates relate to use on plugs whilst higher rates relate to plants in pots/packs	-		N.USA
<i>Cosmos</i>	2.9 – 5.9	Lower rates relate to use on plugs whilst higher rates relate to plants in pots/packs	-		-		N.USA
<i>Dahlia</i> (bedding)	2.9 – 5.9	Lower rates relate to use on plugs whilst higher rates relate to plants in pots/packs	1.7 – 3.3	Lower rates relate to use on plugs whilst higher rates relate to plants in pots/packs	0.1 – 1.1	Lower rates relate to use on plugs whilst higher rates relate to plants in pots/packs	N.USA
<i>Dianthus</i>	2.9 – 5.9	Lower rates relate to use on plugs whilst higher rates relate to plants in pots/packs	1.7 – 3.3	Lower rates relate to use on plugs whilst higher rates relate to plants in pots/packs	0.25 – 1.5	Lower rates relate to use on plugs whilst higher rates relate to plants in pots/packs	N.USA

Plant species	Rate daminozide (g/l)	Effects on growth / comments	Rate of chlormequat (ml/l)	Effects on growth / comments	Rate of paclobutrazol (ml/l)	Effect on growth / comments	Source of data
<i>Eustoma</i> <i>syn.</i> <i>Lisianthus</i>	2.9 – 5.9	Lower rates relate to use on plugs whilst higher rates relate to plants in pots/packs	-		-		N.USA
<i>Exacum</i>	2.9 – 5.9	Lower rates relate to use on plugs whilst higher rates relate to plants in pots/packs	-		-		N.USA
<i>Fuchsia</i>	1.5 – 2.9	To control plant height	-		-		N.USA
<i>Geranium</i> <i>(Pelargonium)</i>	-		1.7 – 3.3	First application should be made 2 to 4 weeks after potting (after stems have started elongating). Multiple applications may be required. Alternatively make two applications at the higher rate at 35 and 42 days after seeding to promote earlier flowering, increase branching and reduce height. Note that high rates can cause leaf yellowing.	0.25 – 0.75 0.075	Apply to Zonal geranium when new growth is 3.7 – 5 cm long. Apply to seed raised geraniums approximately 2 – 4 weeks after transplanting. Apply after transplant	N.USA
<i>Helianthus</i>	-		1.7 – 3.3	Lower rates relate to use on plugs whilst higher rates relate to plants in pots/packs	-		N.USA

Plant species	Rate daminozide (g/l)	Effects on growth / comments	Rate of chlormequat (ml/l)	Effects on growth / comments	Rate of paclobutrazol (ml/l)	Effect on growth / comments	Source of data
<i>Impatiens</i>	5.9	This rate did not result in significantly shorter plants	-		0.01 – 1.1	Lower rates relate to use on plugs whilst higher rates relate to plants in pots/packs. Up to 1.5 ml/l may be used on tall varieties	N.USA
<i>Impatiens</i> (New Guinea)	-		-		0.006 – 0.4	Lower rates relate to use on plugs whilst higher rates relate to plants in pots/packs	N.USA
<i>Lantana</i>	-		-		0.5 – 1	Cultivar response varies	N.USA
<i>Nasturtium</i>	-		1.7 – 3.3	Lower rates relate to use on plugs whilst higher rates relate to plants in pots/packs	-		N.USA
Ornamental cabbage and kale	2.9 – 5.9	Use the higher rates for more vigorous cultivars. Two applications at the lower rate can be effective	-		>2	2 ml/l reported as having no effect on height.	N.USA
<i>Osteospermum</i> spp.	<4.8	4.8 g/l is reported to damage the foliage of some cultivars	1.6		>0.8	0.8 ml/l reported as suboptimal for some cultivars	Denmark
<i>Pansy</i>	-		-		0.02 – 0.4		N.USA

Plant species	Rate daminozide (g/l)	Effects on growth / comments	Rate of chlormequat (ml/l)	Effects on growth / comments	Rate of paclobutrazol (ml/l)	Effect on growth / comments	Source of data
<i>Petunia</i>	2.9 – 5.9	Lower rates relate to use on plugs whilst higher rates relate to plants in pots/packs	-		0.1 – 1.1		N.USA
<i>Plectranthus</i>	-		-		0.1 – 0.5	Cultivar response varies	N.USA
<i>Salvia</i>	2.9 – 5.9	Use as needed to tone and harden growth	1.7 – 3.2	To control plant height	0.08 – 1.5	Apply as needed depending on plant growth and weather	N.USA
<i>Scaevola aemula</i>	-		-		0.5 – 1	To control plant growth	N.USA
<i>Tagetes</i>	2.9 – 5.9	Lower rates relate to use on plugs whilst higher rates relate to plants in pots/packs	1.7 – 3.3	Lower rates relate to use on plugs whilst higher rates relate to plants in pots/packs	0.1 – 1.5	Lower rates relate to use on plugs whilst higher rates relate to plants in pots/packs	N.USA
<i>Verbena</i>	2.9 – 5.9	Lower rates relate to use on plugs whilst higher rates relate to plants in pots/packs	1.7 – 3.3	Lower rates relate to use on plugs whilst higher rates relate to plants in pots/packs	0.07 – 1.1	High rates should only be applied once	N. USA

Plant species	Rate daminozide (g/l)	Effects on growth / comments	Rate of chlormequat (ml/l)	Effects on growth / comments	Rate of paclobutrazol (ml/l)	Effect on growth / comments	Source of data
<i>Zinnia</i>	2.9 – 5.9	Lower rates relate to use on plugs whilst higher rates relate to plants in pots/packs	1.7 – 3.3	Lower rates relate to use on plugs whilst higher rates relate to plants in pots/packs	0.1 – 1.1	Lower rates relate to use on plugs whilst higher rates relate to plants in pots/packs	N.USA
General rates suitable for a range of bedding plant plugs	1.8 – 2.9	Conduct own trials	0.8 – 3.3	Conduct own trials	0.00025 – 0.5	Conduct own trials. Plants should develop 1 or 2 true leaves prior to first application	N.USA
General rates suitable for a range of bedding plants	-		1.7 – 3.3	Conduct own trials, rates up to 6.5 ml/l may be required for some species	0.1 – 2.3	Conduct own trials, not recommended for use on fibrous <i>Begonia</i> or <i>Vinca</i>	N.USA

Table A1.4. Rates of paclobutrazol tested as a drench (rates based on UK formulation)

Plant species	Rate of paclobutrazol (ml/l)	Effects on growth / comments	Source of data
<i>Chrysanthemum</i> (potted)	0.025 – 0.1	Rate and volume varies with pot size	N. USA.
<i>Helianthus</i>	0.025 – 0.050		N.USA
<i>Impatiens</i>	0.012 – 0.025	Rate and volume varies with pot size, to control vegetative propagated <i>Impatiens</i>	N. USA
New Guinea <i>Impatiens</i>	0.006 – 0.05	Rate and volume varies with pot size, cultivars response varies greatly	N.USA
Ornamental cabbage	0.4 - 0.8	Modified shape from open cup to cone	N.USA
<i>Osteospermum</i>	0.7 – 1.35 during production 0.05 – 0.075 to hold	Rate and volume varies with pot size, cultivars response varies greatly	N.USA
<i>Scaevola aemula</i>	0.025 – 0.075	Rate and volume varies with pot size, cultivars response varies	N.USA
General rates suitable for a range of bedding plants	0.025	Drenches are only recommended for bedding plants in 15cm or larger containers. Not recommended for use on fibrous <i>Begonia</i> .	N.USA

Growing media containing bark can reduce the effectiveness of plant growth regulators applied as drenches.

Application of Bonzi as a drench (taken from Fargro product label): The substrate must be moist at the time of application to ensure uniform distribution of the drench. Volume of drench liquid required is related to the pot/container size. Recommended volume rates are:

Pot size	Drench volume per pot
10 cm	50 ml
15cm	100 ml
20cm	200 ml

Table A1.5. Rate of chlormequat (46% formulation) tested as a drench

Plant species	Rate of Fargo Chlormequat (ml/l)	Effects on growth / comments	Source of data
<i>Osteospermum</i>	3.3 – 6.5	Rate and volume varies with pot size, cultivars response varies greatly	N.USA

Table A1.6. Growth regulatory effects of 2-chloroethylphosphonic acid (rates based on UK formulation)

Plant species	Rate of 2-chloroethylphosphonic acid (ml/l)	Effects on growth / comments	Source of data
<i>Begonia</i>	1.25	Increases lateral branching, prevents flower initiation and development and inhibits internode elongation	N.USA
<i>Bracteantha bracteata</i>	0.75 - 1.25	Increases lateral branching	N.USA
<i>Fuchsia</i>	1.25	Some growth regulatory effects. A delay in flowering will also occur	N.USA
Geranium (<i>Pelargonium</i>)	0.75 - 1.25	Increases lateral branching and some growth regulatory effect. Use the lower rate for ivy leaved geraniums. Apply at the normal time of pinching and at least 6 – 8 weeks before flowering as delay of flowering will occur	N.USA
<i>Lantana</i>	1.25	Apply at the normal time of pinching and at least 6 – 8 weeks before flowering	N.USA
<i>New Guinea Impatiens</i>	0.75	Increases branching and reduces premature flowering. Do not apply within 8 weeks of intended flowering	N.USA
<i>Petunia</i>	1.25	Height reductions compared to untreated plants, however plant spread was not affected. Some flowering delay	N.USA
<i>Verbena</i>	1.25	Apply at the normal time of pinching and at least 6 – 8 weeks before flowering. Increases lateral branching, prevents flower initiation / development and inhibits internode elongation	N.USA

Note - UK SOLA specifies that Cerone can only be used once per crop up to 1 litre per 1000 litres of water.

Table A1.7. Growth regulatory effects of prohexadione-calcium (rates based on UK formulation)

Plant species	Rate of prohexadione-calcium (g/l)	Effects on growth / comments	Source of data
<i>Ageratum houstonianum</i>	1.25 / 2.5	Lower rate improved plant quality whilst the higher rate significantly improved plant quality	Germany
<i>Antirrhinum majus</i>	2.5	No effect on plant quality	Germany
<i>Bidens ferulifolia</i>	2.5	Plant quality significantly improved	Germany
<i>Bracteantha bracteata</i>	2.5	Plant quality improved, lower rates were not effective	Germany
<i>Calibrachoa spec.</i>	2.5	No effect on plant quality	Germany
<i>Cuphea llavea</i>	2.5	No effect on plant quality	Germany
<i>Dahlia</i>	2.5	Plant quality improved	Germany
<i>Eustoma grandiflorum syn Lisianthus</i>	1.25 / 2.5	Plant quality improved in response to both treatments	Germany
<i>Fuchsia spec. hybrids</i>	2.5	No effect on plant quality	Germany
<i>Gallardia pulchella</i>	1.25 / 2.5	Lower rate improved plant quality whilst the higher rate significantly improved plant quality	Germany
<i>Godetia 'Grace' F1</i>	1.25 / 2.5	Lower rate improved plant quality whilst the higher rate significantly improved plant quality	Germany
<i>Helianthus annuus</i>	1.25 / 2.5	Plant quality improved in response to both treatments	Germany
<i>Heliotropium peruvianum</i>	1.25 / 2.5	Plant quality improved in response to both treatments	Germany
<i>Lantana camara</i>	2.5	No effect on plant quality	Germany
<i>Lobelia erinus</i>	2.5	Plant quality improved / significantly improved	Germany
<i>Mimulus</i> Fl 'Magic'	2.5	No effect on plant quality	Germany
<i>Myosotis sylvatica</i>	2.5	No effect on plant quality	Germany
<i>Nicotiana sanderae</i>	1.25 / 2.5	Lower rate improved plant quality whilst the higher rate significantly improved plant quality	Germany
Ornamental kale	0.5 – 4	Earlier leaf colouration allows earlier sales, prior to senescence	Source not available
<i>Osteospermum</i>	2.5	Plant quality improved	Germany
<i>Pelargonium</i> (Zonal)	2.5	Lowered plant quality	Germany
<i>Petunia hybridum</i>	2.5	No effect on plant quality	Germany

Plant species	Rate of prohexadione-calcium (g/l)	Effects on growth / comments	Source of data
<i>Primula obconica</i>	1.25 - 2.5	Lower rate had no effect, whilst highest rates resulted in reductions in quality	Germany
<i>Salpiglossis sinuata</i>	2.5	Plant quality improved	Germany
<i>Salvia farinacea</i>	2.5	Plant quality improved	Germany
<i>Sanvitalia procumbens</i>	2.5	Plant quality improved	Germany
<i>Scaevola aemula</i>	2.5	Plant quality significantly improved	Germany
<i>Senecio cruentus</i>	2.5	Plant quality significantly improved, 1.25 g/l resulted in an improvement compared to controls while 2.5 g/l significantly improved plant quality	Germany
<i>Tagetes patula</i>	1.25 / 2.5	No effect on plant quality	Germany
<i>Torenia fournieri</i>	1.25 / 2.5	Plant quality improved in response to both treatments	Germany
<i>Verbena x hybrida</i>	2.5	Lowered quality improved	Germany
<i>Viola Wittrockiana</i> -Hybrids	1.25 / 2.5	No effect on plant quality	Germany
<i>Zinnia</i> F1 hybrids	2.5	Plant quality improved	Germany

Tank mixes

Growth regulators are generally applied to crops as a single product, however there is increasing interest in using a combination of two growth regulators as a tank mix on certain crops to obtain the desired effect. To gain experience as to how plants respond, it is generally best to apply plant growth regulators singly initially. Where varieties do not respond to individual products consider a tank mix to improve growth control. Check product label for guidance on tank mixes. Always test tank mixes on a small proportion of the crop prior to widespread use.

Table A1.8. Tank mix suggestions (rates based on UK formulations)

Plant species	Rate of daminozide (g/l) + chlormequat (ml/l)	Effects on growth	Rate of daminozide (g/l) + paclobutrazol (ml/l)	Effects on growth / comments	Source of data
<i>Ageratum</i>	-		2.9 + 0.5	Apply from 10 – 14 days after transplanting, weekly unless plants show no signs of stretch	N.USA
<i>Angelonia</i>	1.7 – 3.5 + 1.6 – 2.1	At transplanting soft pinch to promote lateral shoot development	-		N.USA
<i>Antirrhinum</i>	-		2.9 + 0.5	Apply from 10 – 14 days after transplanting, weekly unless plants show no signs of stretch	N.USA
<i>Celosia</i>	-		2.9 + 0.5	Apply from 10 – 14 days after transplanting, weekly unless plants show no signs of stretch	N.USA
<i>Impatiens</i>	-		2.9 + 0.5	Apply from 10 – 14 days after transplanting, weekly unless plants show no signs of stretch. High rates of Bonzi can result in delayed flowering in <i>Impatiens</i>	N.USA
<i>Lantana</i>	2.9 – 5.9 + 2.1 – 3.3		-		N.USA
<i>Osteospermum</i>	1.8 – 3.5 + 2.1 – 3.2	Multiple sprays required, stop applying after visible bud to prevent delays in flowering and smaller flowers	-		N.USA

Plant species	Rate of daminozide (g/l) + chlormequat (ml/l)	Effects on growth	Rate of daminozide (g/l) + paclobutrazol (ml/l)	Effects on growth / comments	Source of data
<i>Petunia</i>	-		2.9 + 0.5	Apply from 10 – 14 days after transplanting, weekly unless plants show no signs of stretch	N.USA
<i>Plectranthus</i>	1.7 – 2.9 + 1.6 – 2.1	Cultivar response varies	-		N.USA
<i>Salvia</i>	-		2.9 + 0.5	Apply from 10 – 14 days after transplanting, weekly unless plants show no signs of stretch	N.USA
<i>Tagetes</i>	-	The use of daminozide on seedlings may impact upon flowering time	2.9 + 0.5	Apply from 10 – 14 days after transplanting, weekly unless plants show no signs of stretch	N.USA / Poland
General rates suitable for a range of bedding plants	0.9 – 5.9 + 2.1 – 3.3	It is recommended to use the highest rate of chlormequat that does not cause excessive leaf yellowing, adjust the rate of daminozide with the label range to achieve desired height control	-		N.USA
General rates suitable for a range of bedding plant plugs	0.9 – 5.9 + 2.1 – 3.3	It is recommended to use the highest rate of chlormequat that does not cause excessive leaf yellowing, adjust the rate of daminozide with the label range to achieve desired height control	-		N.USA

Check product label for guidance on tank mixes.

In the case of Tables 3, 5 and 8:

Rates of chlormequat from abroad are based on ppm conversions using Fargo Chlormequat (460g/l). The rate will have to be adjusted for other chlormequat formulations of different concentrations.

– this symbol indicates no crop response was reported or no data was available.

Where information is obtained from the USA the rates stated are from trials from Northern States as opposed to Southern States to make the data more relevant to UK growing conditions.

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Rates of Regalis are reproduced by kind permission of Wilfried Hennes of UAK-Lück Zierpflanzen, Germany and BASF.

Appendix 2. Product detail of the treatments used in the trial

<i>Product name</i>	<i>Active ingredient</i>	<i>A.I. content</i>	<i>Main supplier</i>
Bonzi	paclobutrazol	4 g / litre	Syngenta Bioline
Regalis	prohexadione-calcium	10% w / w	BASF
Cerone	2-chloroethylphosphonic acid	480 g / litre	Bayer Crop Science
Moddus	trinexapac-ethyl	250 g / litre	Syngenta Crop Protection
Bumper 250 EC	propiconazole	250 g / litre	Makhteshim
Systhane 20 EW	mycobutanil	200 g / litre	Landseer

Appendix 3. Average plant height by treatment

(1) 14 May 2010 (prior to treatments) – cutting raised subjects plus geranium. Growth scores are shown in brackets.

Treatment	Species – average height (cm)				
	Dahlia	Fuchsia	Geranium	Surfinia*	Verbena
Untreated control	5.8 (2)	6.5 (2)	5.5 (2)	2.7 (1)	3.2 (1)
Bonzi x 2 sprays	5.3 (2)	6.3 (2)	5.3 (2)	3.7 (1)	3.0 (1)
Regalis x 1 spray	5.7 (2)	6.8 (2)	7.7 (2)	3.7 (1)	3.2 (1)
Regalis x 2 sprays	5.3 (2)	5.7 (2)	5.3 (2)	3.3 (1)	2.8 (1)
Regalis x 1 drench	6.8 (2)	6.7 (2)	6.5 (2)	3.5 (1)	2.5 (1)
Cerone x 1 spray	6.0 (2)	7.0 (2)	7.2 (2)	2.8 (1)	3.3 (1)
Moddus x 2 sprays	5.7 (2)	7.3 (2)	7.2 (2)	2.8 (1)	3.3 (1)
Bumper 250 EC x 2 sprays	6.3 (2)	6.8 (2)	6.8 (2)	3.3 (1)	3.5 (1)
Systhane 20 EW x 2 sprays	6.0 (2)	6.2 (2)	6.7 (2)	3.2 (1)	3.0 (1)

* Width recorded in the case of Surfinia.

Growth scored on a 1 – 5 scale: 1 – some new growth, 2 – visible root / shoot establishment, 3 – established, 4 – established with visible bud, 5 – marketable with flower visible.

(2) 28 May 2010 (after 1 treatment) – cutting raised subjects plus geranium. Growth scores are shown in brackets.

Treatment	Species – average height (cm)				
	Dahlia	Fuchsia	Geranium	Surfinia*	Verbena
Untreated control	14.2 (3)	13.2 (3)	9.2 (3)	20.7 (4)	13.8 (3)
Bonzi x 2 sprays	11.5 (3)	13.0 (3)	8.7 (3)	21.8 (4)	12.2 (3)
Regalis x 1 spray	12.0 (3)	14.2 (3)	8.7 (3)	19.3 (4)	16.2 (3)
Regalis x 2 sprays	10.0 (3)	12.5 (3)	9.7 (3)	18.2 (4)	12.8 (3)
Regalis x 1 drench	11.0 (3)	13.7 (3)	7.3 (3)	17.0 (4)	16.5 (3)
Cerone x 1 spray	7.7 (3)	11.8 (3)	7.2 (3)	12.8 (3)	11.2 (3)
Moddus x 2 sprays	14.0 (3)	13.7 (3)	8.0 (3)	21.5 (3)	13.8 (3)
Bumper 250 EC x 2 sprays	14.3 (3)	12.7 (3)	10.2 (3)	21.8 (4)	11.2 (3)
Systhane 20 EW x 2 sprays	15.5 (3)	13.7 (3)	8.8 (3)	23.8 (4)	12.7 (3)

* Width recorded in the case of Surfinia.

Growth scored on a 1 – 5 scale: 1 – some new growth, 2 – visible root / shoot establishment, 3 – established, 4 – established with visible bud, 5 – marketable with flower visible.

(3) 4 June 2010 (prior to treatments) – seed raised subjects. Growth scores are shown in brackets.

Treatment	Species – average height (cm)					
	Begonia	Dianthus	Impatiens	Marigold	Petunia	Salvia
Untreated control	7.8 (3)	6.0 (1)	2.0 (1)	3.3 (1)	1.8 (1)	2.2 (1)
Bonzi x 2 sprays	7.2 (3)	6.5 (1)	2.2 (1)	3.5 (1)	1.2 (1)	1.8 (1)
Regalis x 1 spray	7.5 (3)	6.8 (1)	2.0 (1)	3.8 (1)	1.7 (1)	2.2 (1)
Regalis x 2 sprays	7.3 (3)	6.8 (1)	1.8 (1)	3.3 (1)	1.8 (1)	2.2 (1)
Regalis x 1 drench	7.3 (3)	7.2 (1)	2.0 (1)	3.5 (1)	2.0 (1)	2.5 (1)
Cerone x 1 spray	6.5 (3)	6.3 (1)	2.0 (1)	3.5 (1)	1.7 (1)	2.0 (1)
Moddus x 2 sprays	7.3 (3)	5.8 (1)	2.0 (1)	4.0 (1)	1.3 (1)	1.8 (1)
Bumper 250 EC x 2 sprays	8.3 (3)	6.0 (1)	1.8 (1)	3.0 (1)	1.3 (1)	2.3 (1)
Sythane 20 EW x 2 sprays	7.5 (3)	6.8 (1)	2.3 (1)	3.2 (1)	1.7 (1)	2.2 (1)

Growth scored on a 1 – 5 scale: 1 – some new growth, 2 – visible root / shoot establishment, 3 – established, 4 – established with visible bud, 5 – marketable with flower visible.

(4) 18 June 2010 (both treatments cutting raised subjects plus geranium, one treatment seed raised subjects). Growth scores are shown in brackets.

Treatment	Species – average height (cm)										
	Begonia	Dahlia	Dianthus	Fuchsia	Geranium	Impatiens	Marigold	Petunia	Salvia	Surfinia*	Verbena
Untreated control	14.8 (5)	23.5 (5)	18.5 (3)	25.7 (4)	22.0 (4)	5.3 (4)	12.7 (4)	6.2 (3)	7.0 (4)	45.3 (5)	16.8 (5)
Bonzi x 2 sprays	10.7 (4)	16.3 (5)	18.5 (3)	23.8 (4)	16.0 (3)	4.2 (4)	13.0 (4)	6.0 (4)	6.3 (4)	48.3 (5)	17.0 (5)
Regalis x 1 spray	14.2 (5)	20.2 (5)	14.3 (3)	25.0 (4)	18.7 (4)	3.7 (4)	12.0 (4)	7.2 (4)	7.7 (4)	50.7 (5)	17.2 (5)
Regalis x 2 sprays	12.0 (5)	15.7 (4)	14.3(3)	25.2 (4)	19.0 (4)	4.7 (4)	11.7 (4)	5.5 (4)	7.7 (4)	37.5 (5)	20.5 (5)
Regalis x 1 drench	11.7 (5)	15.7 (4)	15.3 (3)	26.0 (4)	17.2 (3)	4.0 (4)	12.3 (4)	6.8 (3)	7.0 (4)	29.8 (5)	20.3 (5)
Cerone x 1 spray	11.3 (4.5)	15.8 (4)	17.0 (3)	22.8 (4)	15.2 (4)	3.3 (4)	12.0 (4)	4.2 (3)	5.8 (4)	35.2 (5)	15.0 (5)
Moddus x 2 sprays	14.7 (5)	22.8 (5)	16.7 (3)	25.0 (4)	17.5 (4)	5.0 (4)	13.5 (4)	7.3 (4)	6.8 (4)	41.0 (5)	17.7 (5)
Bumper 250 EC x 2 sprays	9.7 (5)	19.2 (5)	17.3 (3)	20.8 (4)	21.7 (4)	4.3 (4)	10.3 (4)	7.3 (4)	7.2 (4)	48.5 (5)	13.8 (5)
Sythane 20 EW x 2 sprays	13.0 (5)	23.5 (5)	19.3 (3)	27.2 (4)	20.7 (4)	5.3 (5)	13.7 (4)	6.2 (4)	7.3 (4)	58.8 (5)	17.2 (5)

* Width recorded in the case of Surfinia.

Growth scored on a 1 – 5 scale: 1 – some new growth, 2 – visible root / shoot establishment, 3 – established, 4 – established with visible bud, 5 – marketable with flower visible.

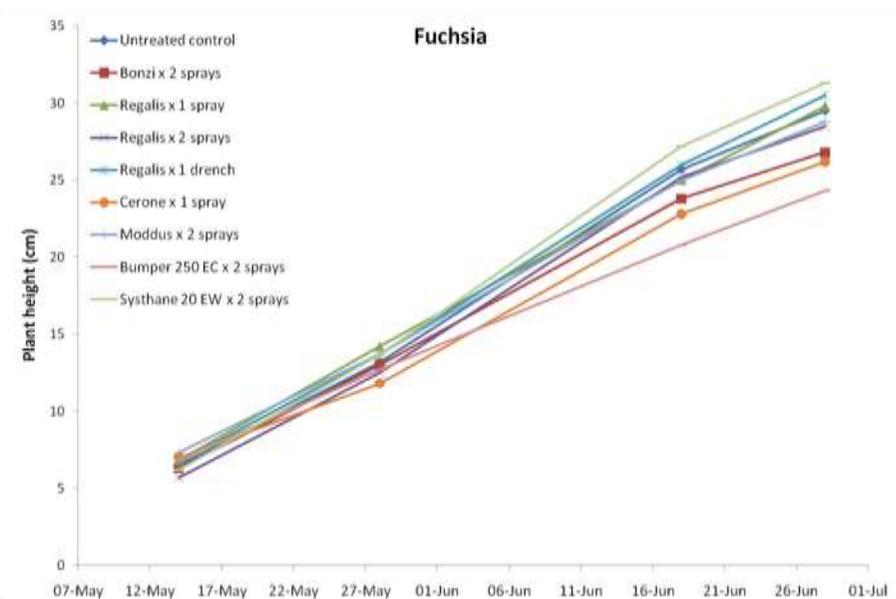
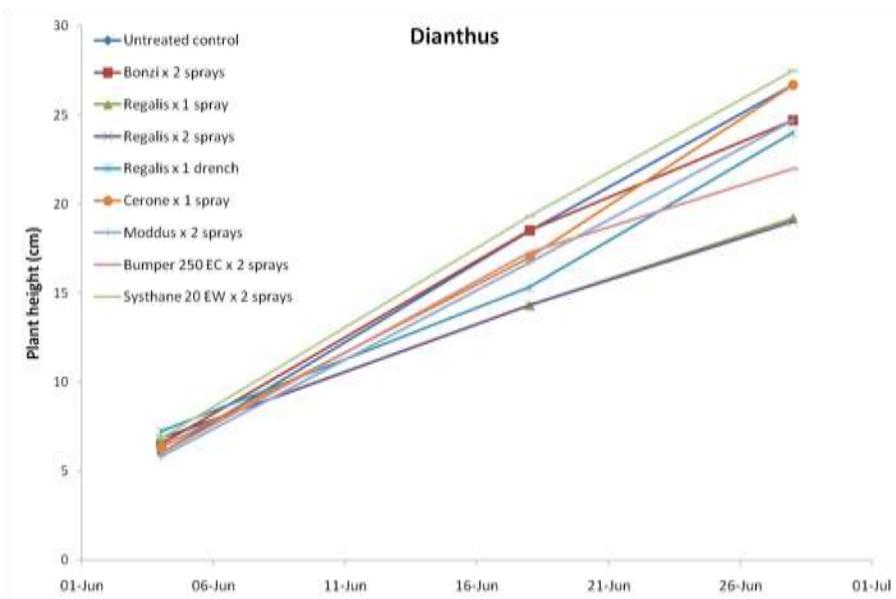
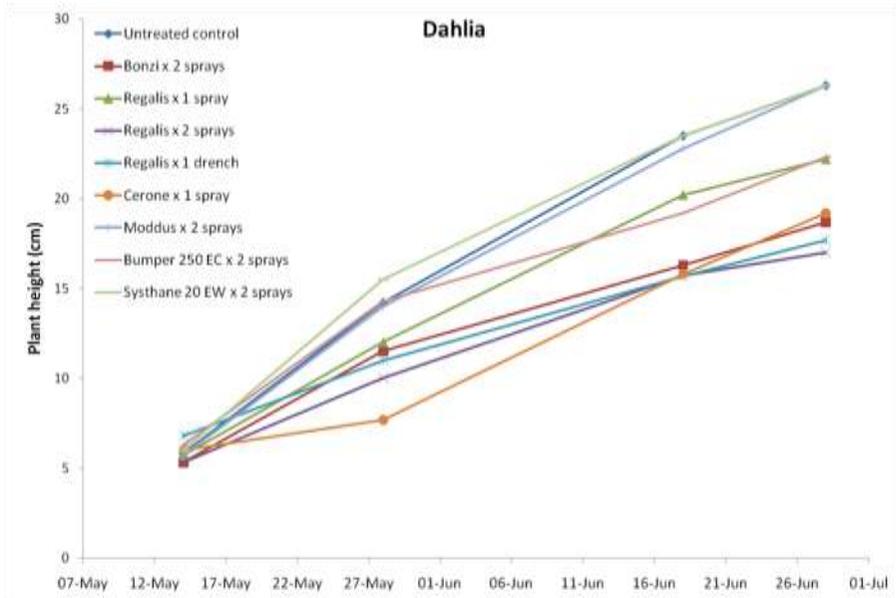
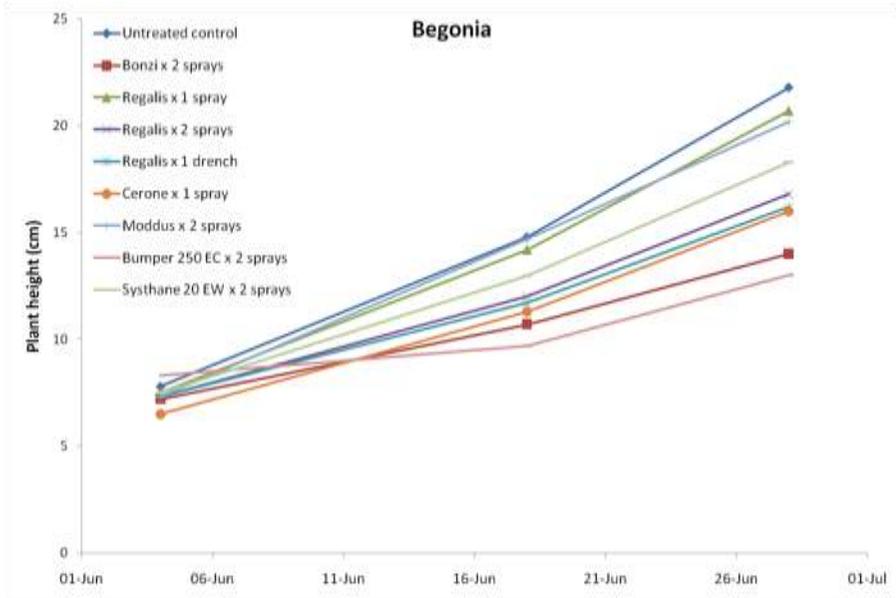
(5) 28 June 2010 (after both treatments) – cutting and seed raised subjects (including data analysis). Growth scores are shown in brackets.

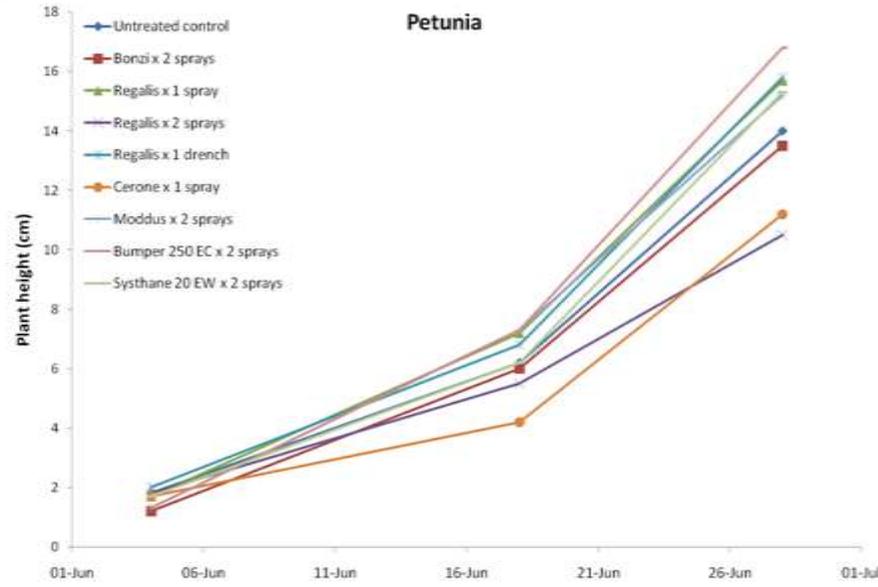
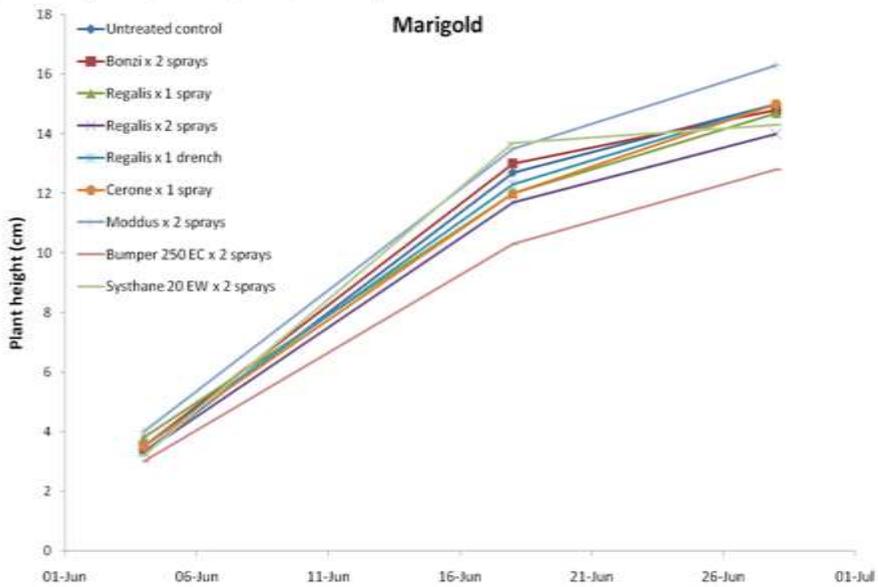
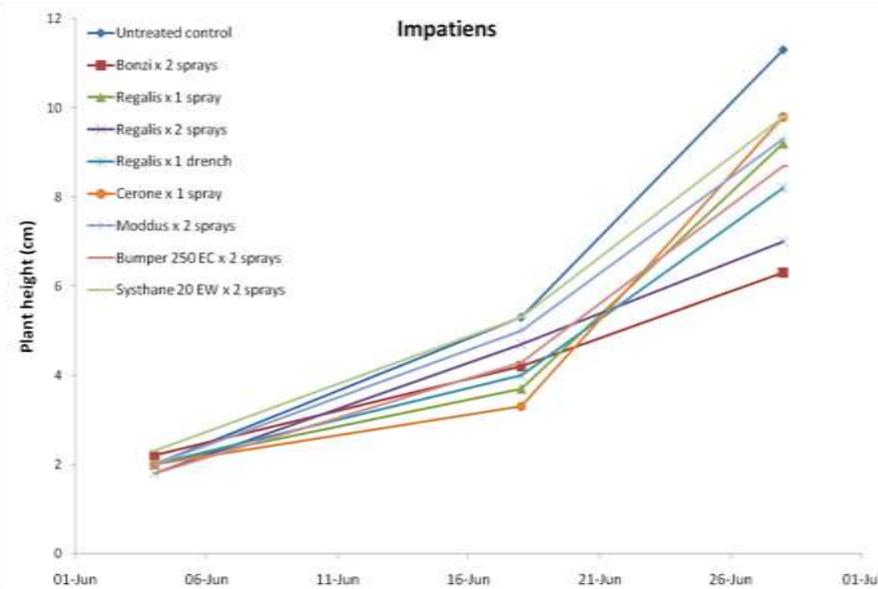
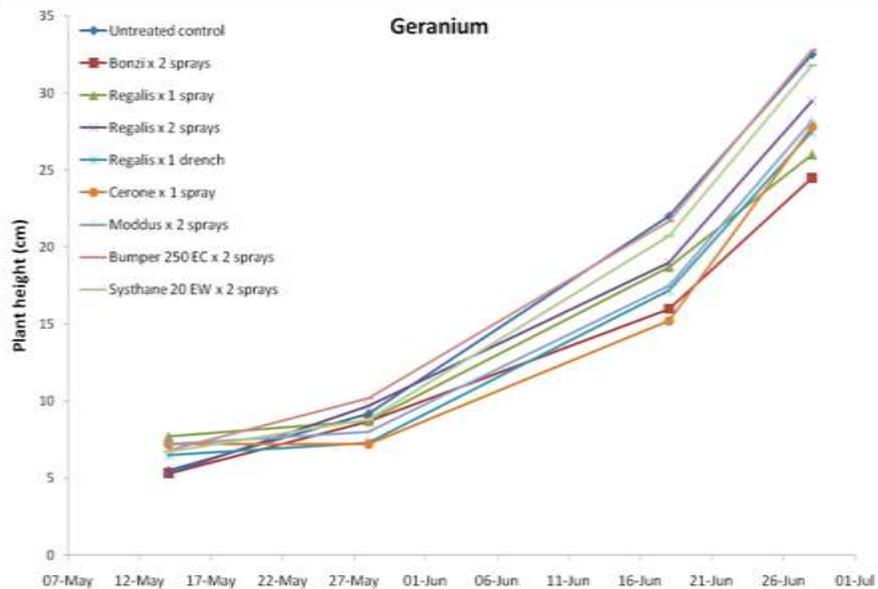
Treatment	Species – average height (cm)										
	Begonia	Dahlia	Dianthus	Fuchsia	Geranium	Impatiens	Marigold	Petunia	Salvia	Surfinia*	Verbena
Untreated control	21.8 (5)	26.3 (5)	26.7 (5)	29.5 (5)	32.5 (4)	11.3 (5)	15.0 (5)	14.0 (5)	11.5 (5)	56.5 (5)	19.3 (5)
Bonzi x 2 sprays	14.0 (5)	18.7 (5)	24.7 (5)	26.8 (5)	24.5 (4)	6.3 (5)	14.8 (5)	13.5 (5)	12.5 (5)	52.2 (5)	18.5 (5)
Regalis x 1 spray	20.7 (5)	22.2 (5)	19.2 (4)	29.8 (5)	26.0 (4)	9.2 (5)	14.7 (5)	15.7 (5)	14.8 (5)	58.3 (5)	18.2 (5)
Regalis x 2 sprays	16.8 (5)	17.0 (5)	19.0 (4)	28.5 (4)	29.5 (4)	7.0 (5)	14.0 (5)	10.5 (5)	14.2 (5)	43.7 (5)	20.8 (5)
Regalis x 1 drench	16.2 (5)	17.7 (5)	24.0 (4)	30.5 (4)	27.5 (4)	8.2 (5)	15.0 (5)	15.8 (5)	14.3 (4)	35.0 (5)	21.3 (5)
Cerone x 1 spray	16.0 (5)	19.2 (5)	26.7 (5)	26.2 (5)	27.8 (5)	9.8 (5)	15.0 (5)	11.2 (5)	11.3 (5)	47.7 (5)	19.3 (5)
Moddus x 2 sprays	20.2 (5)	26.3 (5)	24.7 (4)	28.8 (5)	28.2 (4)	9.3 (5)	16.3 (5)	15.2 (5)	14.0 (5)	43.7 (5)	20.2 (5)
Bumper 250 EC x 2 sprays	13.0 (5)	22.3 (5)	22.0 (5)	24.3 (5)	32.8 (5)	8.7 (5)	12.8 (5)	16.8 (5)	12.7 (5)	51.8 (5)	18.7 (5)
Systhane 20 EW x 2 sprays	18.3 (5)	26.3 (5)	27.5 (5)	31.3 (5)	31.8 (4)	9.8 (5)	14.3 (5)	15.3 (5)	13.5 (5)	64.7 (5)	22.3 (5)
<i>Degrees of freedom</i>	16	16	16	16	16	16	16	16	16	16	16
<i>Least significant differences of means (5% level)</i>	3.6	5.9	4.4	6.3	8.2	2.9	1.8	4.0	3.0	8.4	3.5
<i>Significance</i>	<0.001	0.010	0.005	0.380	0.383	0.051	0.057	0.046	0.199	<0.001	0.243

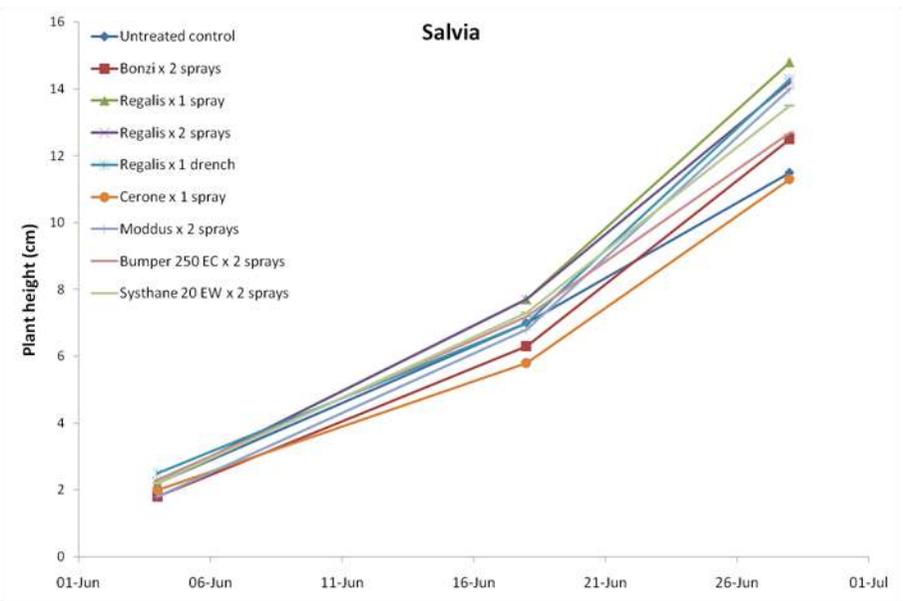
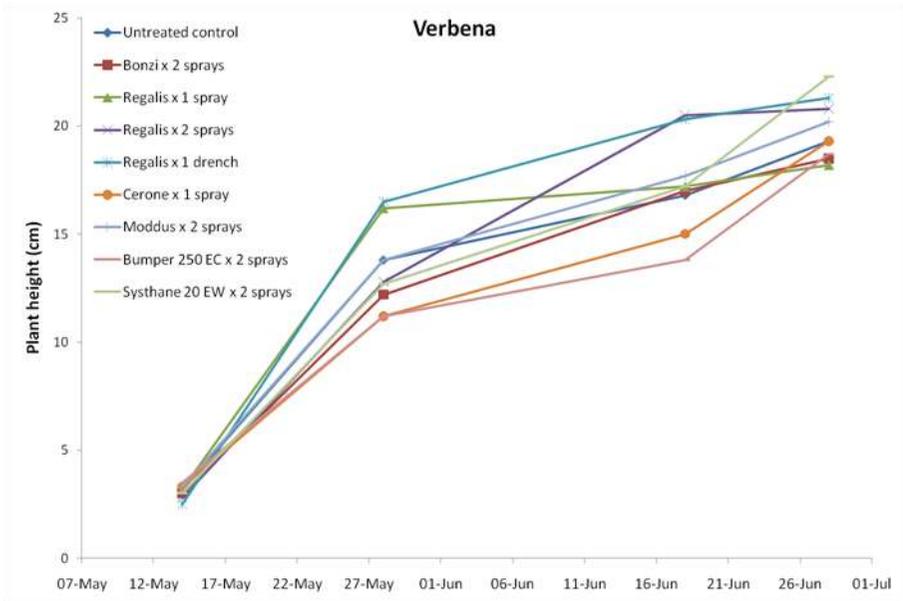
* Width recorded in the case of Surfinia.

Growth scored on a 1 – 5 scale: 1 – some new growth, 2 – visible root / shoot establishment, 3 – established, 4 – established with visible bud, 5 – marketable with flower visible.

(6) Summary graphs of change in plant height with time taken from data in tables 1-5 above. See following pages.







Appendix 4. Species response to some of the treatments examined in the trial



Begonia – untreated v Bumper 250 EC sprays (right)



Dahlia – untreated v Bonzi sprays treatment (right)



Dahlia – untreated v Regalis drench (right)



Dahlia – untreated v Cerone spray (right)



Dahlia – untreated v Moddus sprays (right)



Dianthus – untreated v Cerone spray (right)



Fuchsia – untreated v Bonzi sprays (right)



Fuchsia – untreated v Cerone spray (right)



Fuchsia – untreated v Bumper 250 EC sprays (right)



Geranium – untreated v Bonzi sprays (right)



Geranium – untreated v Cerone spray (right)



Petunia – untreated v Regalis sprays (right)



(Petunia) Surfinia – untreated v Bumper 250 EC sprays (right)



(Petunia) Surfinia – untreated v Cerone spray (right)



Salvia – untreated v Cerone spray (right)



Verbena – untreated v Cerone spray (right)