Project title:	Herbicides screening for Ornamental plant production (nursery stock, cut flowers and wallflowers)
Project number:	HNS PO 192a
Project leader:	John Atwood, ADAS UK Ltd.
Report:	Final report, June 2016
Previous report:	
Key staff:	David Talbot, Emma Worrall, Chloe Whiteside (ADAS)
Location of project:	ADAS Boxworth, Cambridge, CFC Lincs, grower sites Norfolk, Lincolnshire, Warwickshire, Herefordshire
Industry Representative:	Mark Cade, James Coles & Sons (Nurseries) Ltd, Leicester Bob Hollister, Country Garden Plant Sales Ltd, Wareham, Dorset Mark Eves, Belmont Nursery Ltd, Terrington St Clement, Norfolk
Date project commenced:	1 March 2016
Date project completed (or expected completion date):	30 June 2016

DISCLAIMER

The results and conclusions in this report are based on an investigation conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.

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.

John Atwood

Principal Horticultural Consultant

ADAS UK Ltd.

Signature Date 15 June 2016

Report authorised by:

Barry Mulholland

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Executive Summary

The aim of the project was to develop new herbicide options for ornamental plant growers in order to achieve effective, economic weed control with minimal crop damage.

A range of herbicide treatments were tested on drilled cut flower species; sweet williams, china aster, larkspur, wallflower and transplanted; china aster and peony. Stomp Aqua (pendimethalin), Gamit 36 CS (clomazone) and Goltix 70SC (metamitron) were the most promising residual treatments for the cut flowers although for the sweet williams only low rates were tolerated. A post emergence application of Shark (carfentrazone-ethyl) was tolerated with a temporary check in sweet williams and asters.

Six different herbicide programmes were compared for crop safety in 40 container-grown hardy nursery stock shrub subjects when used as post-potting, late summer and winter applications to provide season long weed control. Programmes which started with the granular HDC H25 were the safest for use after potting. The use of Flexidor 500 (isoxaben) + Dual Gold (s-metolachlor) as an alternative after potting gave rise to temporary phytotoxicity in a number of the subjects but most grew out of it after two to six weeks. The use of Springbok (dimethenamid-p + metazachlor) and Successor (pethoxamid) as a late summer treatment was tolerated by most subjects with only slight symptoms. The safest winter treatment was Devrinol (napropamide). Sumimax (flumioxazin) as an alternative winter treatment damaged quite a few evergreen subjects and some deciduous. There were however a number of species identified that would be safe to treat with this herbicide.

A specific study was carried out on liverwort control with 15 treatments (including herbicides, biocides, physical acting and commodity substances) tested for contact and residual action when applied either in Summer or Winter. The outstanding treatment for contact effect was the commodity substance Sodium Bicarbonate.

Seven herbicide treatments were tested for crop safety on field-grown 2/0 hawthorn seedlings (grown for two seasons without undercutting) as dormant season treatments. The new herbicides Successor (pethoxamid), and HDC H24 proved to be safe, as did Samson 6%.

GROWER SUMMARY

Hardy Nursery Stock Trials

Headline

- New herbicide programmes including pethoxamid (Successor) and HDC H25, were effective for container-grown hardy nursery stock.
- Effective pre-emergence treatment have been identified for liverwort control. Sodium bicarbonate was particularly effective for post-emergence control.
- Pethoxamid (Successor) and HDC H24 were effective and crop safe on established field-grown *Crataegus.*

Background

The loss of oxadiazon (Ronstar 2G) and further restrictions on straight metazachlor products (e.g. Butisan S) have left very few options for growers for controlling weeds after potting and during the growing season. The industry is now virtually dependent on isoxaben (Flexidor 500) for summer herbicide applications, however Flexidor 500 does have its limitations.

All herbicides tested in 2014, including HDC H25, proved to be safe for use on the range of nursery stock subjects that they were tested on (Atwood *et al*., 2014). One of the aims this year (2015-2016) was to develop herbicide programmes based on new herbicide HDC H25. The follow up treatments should ensure continued weed control throughout the autumn, winter and the following spring period. Another problem facing the ornamentals industry is the control of liverwort. In the past, quinoclamine (Mogeton) could be used on non-cropped surfaces, however this is no longer permitted. The recent introduction of Mosskade (composed of natural substances) has helped ease the situation, however growers have found it less effective during the summer and have also found it to be relatively short lasting and expensive. Previous AHDB projects have found promising results from a range of substances. There are also a number of new herbicides that have not yet been fully assessed for their potential control of liverwort such as pethoxamid (Successor), HDC H25 and metazachlor combined with dimethenamid-p (Springbok). The objective of this piece of work was to test 23 new herbicide treatments for liverwort control, for contact and residual action, when applied in summer and winter.

Control of annual weeds in field-grown production has become more difficult following the loss of active ingredients outlined above and restrictions placed on some of the remaining actives (e.g. metazachlor). There are a number of new herbicides that have not been fully assessed for their potential for control of annual weeds in the field, such as pethoxamid

(Successor), HDC H24 and metazachlor combined with dimethenamid-p (Springbok). The objective of this piece of work was to test seven herbicide treatments for crop safety and weed control efficacy on field-grown *Crataegus* (402 provenence) seedlings prior to the second season of production as dormant season treatments.

Summary

HNS container trials (Norfolk and Herefordshire)

The nursery stock container trials were set up on two nurseries; Darby Nursery Stock in Norfolk and Wyevale Containers in Herefordshire. Both trials tested the same six herbicide programmes (**Table 1**) on a total of 41 species. A list of active ingredients and approval statuses of products can be found in **Table 2**. Both trials were set up as randomised split block designs with three replicated blocks. Treatments were applied on three occasions; 26 May 2015, 25 August 2015 and 2 December 2015 for the Norfolk trial and 28 May 2015, 20 August 2015 and 16 December for the Hereford trial. Treatments were applied at a water volume of 1000 L/ha using an OPS sprayer with a boom with three 03/F110 nozzles (02F110 nozzles were used in the Norfolk trial) delivering a medium spray at 1000 L/ha.

Phytotoxicity and weed assessments were undertaken throughout the trial period to monitor the crops for any signs of herbicide damage and to determine the effectiveness of weed control. Assessments were made approximately 2, 6 and 12 weeks after each treatment application had been made.

Table 1. Treatment list and timings for the hardy nursery stock container trials 2015-2016 (Norfolk and Herefordshire)

Trt.	May	Rate (kg/L/ha)	August	Rate (kg/L per ha)	December	Rate (kg/L per ha)
1	Untreated control	N/A	Untreated control	N/A	Untreated control	N/A
2	HCD H25	x	Springbok	1.6	Devrinol	9.0
3	HDC H25	x	Successor	2.0	Devrinol	9.0
4	HDC H25	x	Springbok + Successor	1.6 + 2.0	Devrinol	9.0
5	HDC H25	x	Springbok + Successor	1.6 + 2.0	Sumimax	0.1
6.	Flexidor 500 + Dual Gold	0.5 +0.78	Flexidor 500 + Devrinol*	0.5 + 9.0	Sumimax	0.1
7.	Flexidor 500 + Dual Gold	0.5 + 0.78	Flexidor 500	0.5	Devrinol	9.0

(x) Undisclosed

Table 2. List of active ingredients tested in the hardy nursery stock container trials and their approval status (Norfolk and Herefordshire - 2015)

Treatment	Active ingredient	Approval status
Untreated	-	-
HDC H25	undisclosed	Not authorised
Flexidor 500	isoxaben (500 g/L)	Label
Dual Gold	s-metolachlor (960 g/l)	EAMU 0501/12
Springbok	dimethenamid-p (200 g/L) + metazachlor (200 g/L)	EAMU 2108/15
Successor	pethoxamid	Label
Devrinol	napropamide (450 g/L)	Label
Sumimax	flumioxazin (300 g/L)	EAMU 2881/08

The majority of the treatments that were tested in this trial caused no significant damage to any of the HNS subjects, however there were a few treatments that certain species were found to be sensitive to.

Flexidor 500 + Dual Gold applied after potting in May 2015 caused some slight damage to *Buddleja*, *Clematis*, *Cotoneaster, Escallonia, Euonymus, Forsythia, Hydrangea, Ligustrum* and *Prunus*; however these species all fully recovered. More severe scorching was seen on *Sambucus* after being treated with Flexidor 500 + Dual Gold, however this species was considered saleable by April 2016.

Flexidor 500 + Devrinol applied in late August caused severe scorching to *Santolina*. *Ligustrum* and *Olearia* were considered moderately susceptible to this treatment and were very slightly damaged but still commercially acceptable by 12 weeks after treatment (WAT).

Flexidor 500 in late August resulted in slight damage on *Hydrangea, Olearia* and *Osmanthus,* however plants grew away by 12 WAT. *Cotoneaster* and *Ligustrum* were moderately susceptible to damage.

Springbok in late August resulted in damage to *Olearia.* All other subjects were considered commercially acceptable by 6 WAT.

Successor in late August resulted in damage to *Olearia* and *Hydrangea.* All other subjects were considered commercially acceptable by 6 WAT.

Springbok + Successor in late August resulted in damage to *Olearia* and *Hydrangea.* All other subjects were considered commercially acceptable by 6 WAT.

A winter application of Devrinol resulted in some phytotoxic damage on *Hydrangea, Olearia*, *Santolina, Osmanthus x burkwoodii.* All species were considered to be commercially acceptable with the exception of *Olearia, Osmanthus* and *Santolina* in the trial at Wyevale containers. The application of Devrinol in winter caused some slight damage to the *Santolina* in Norfolk but the damage was not as severe as the damage caused by the summer application to this species.

A winter application of Sumimax caused severe defoliation on *Abelia* and *Azalea* and severe leaf scorch on *Buxus, Hebe, Ligustrum*, *Prunus* and *Viburnum tinus.* These species did not recover from this damage. Necrotic spotting on *Phormium* was also caused by this treatment which had not recovered by the time the trial came to an end. The December application of Sumimax also caused some slight scorching to *Buddleja, Escallonia, Euonymus, Hydrangea, Hypericum* and *Pyracantha;* however all of these species recovered and were considered saleable.

Table 3 provides a summary of all the subjects assessed, showing the plants which are tolerant (T), moderately susceptible (MS) or susceptible (S) to the herbicide applications. MS plants may have shown some initial damage caused by the herbicide but they grew on to be saleable plants. The majority of the subjects tested showed little or no damage or growth defects caused by the different treatments.

Table 3. Tolerance of HNS subjects to applications of HDC H25, Flexidor 500 + Dual Gold, Springbok, Successor, Springbok + Successor, Flexidor 500 + Devrinol, Flexidor 500, Devrinol and Sumimax (tolerant – T, moderately susceptible – MS, susceptible – S)

Varieties	H25	Flexidor 500 + Dual Gold	Springbok	Successor	Springbok + Successor	Flexidor 500 + Devrinol	Flexidor 500	Devrinol	Sumimax
Abelia x *grandiflora*	T	T	T	T	T	T	T	T	S
Azalea 'Hino Crimson'	T	T	T	T	T	T	T	T	S
Berberis darwinii	T	T	T	T	T	T	T	T	T
Brachyglotis 'Sunshine'	T	T	T	T	T	T	T	T	T
Buddleja davidii 'Empire Blue'	T	MS	T	T	T	T	T	T	MS
Buxus sempervirens	T	T	T	T	T	T	T	T	MS
Camellia japonica 'Lady Campbell'	T	T	T	T	T	T	T	T	T
Caryopteris x clandonensis 'Heavenly Blue'	T	T	T	T	T	T	T	T	T
Chamaecyparis 'Elwoods Gold'	T	T	T	T	T	T	T	T	T
Choisya dewitteana Goldfingers = 'Limo'	T	T	T	T	T	T	T	T	T
Cistus x *purpureus*	T	T	T	T	T	T	T	T	T
Clematis montana var. rubens 'Tetrarose '	T	MS	T	T	T	T	T	T	T
Cotoneaster horizontalis	T	T	T	T	T	T	T	T	T
Escallonia 'Iveyi'	T	T	T	T	T	T	T	T	MS
Euonymus Green Rocket	T	T	T	T	T	T	T	T	MS
Forsythia intermedia Lynwood	T	T	T	T	T	T	T	T	T
Hebe 'Margret'	T	T	T	T	T	T	T	T	S
Hydrangea macrophylla	T	T	T	MS	T	T	T	T	MS
Hypericum x moserianum	T	T	T	T	T	T	T	T	MS

Varieties	H25	Flexidor 500 + Dual Gold	Springbok	Successor	Springbok + Successor	Flexidor 500 + Devrinol	Flexidor 500	Devrinol	Sumimax
Jasminum officinale	T	T	T	T	T	T	T	T	T
Lavender angustifolia 'Munstead'	T	T	T	T	T	T	T	T	T
Ligustrum ovalifolium	T	T	T	T	T	T	T	T	S
Ligustrum ovalifolium 'Argenteum'	T	MS	T	T	T	T	T	T	S
Olearia macrodonta 'Major'	T	T	S	S	S	T	S	S	S
Osmanthus x burkwoodii	T	T	T	T	T	T	T	S	S
Philadelphus 'Beauclark'	T	T	T	T	T	T	T	T	T
Phormium tenax	T	T	T	T	T	T	T	T	S
Potentilla fruticosa Primrose Beauty	T	T	T	T	T	T	T	T	T
Prunus laurocerasus	T	T	T	T	T	T	T	T	S
Pyracantha 'Red Column'	T	T	T	T	T	T	T	T	MS
Rhododendron 'Scarlet Wonder'	T	T	T	T	T	T	T	T	T
Rosa rugosa	T	T	T	T	T	T	T	T	T
Sambucus nigra f. *porphyrophylla* 'Black Lace'	T	MS	T	T	T	T	T	T	T
Santolina chamaecyparissus	T	T	T	T	T	S	T	MS	T
Spiraea japonica 'Golden princess'	T	T	T	T	T	T	T	T	T
Thuja occidentalis 'Rheingold'	T	T	T	T	T	T	T	T	T
Viburnum tinus 'Gwenllian'	T	T	T	T	T	T	T	T	S
Viburnum x bodnantense 'Dawn'	T	T	T	T	T	T	T	T	T
Vinca minor	T	T	T	T	T	T	T	T	T
Weigelia 'Bristol Ruby'	T	T	T	T	T	T	T	T	T

Liverwort

The liverwort trial was set up in a poly tunnel at ADAS Boxworth. The aim of this trial was to test 15 treatments for liverwort control when applied either in summer or winter (**Table 4**). **Table 5** lists the active ingredients of the treatments and their approval status.

In the summer trial pre-emergence treatments were applied on 31 July 2015, immediately before placing the infector plant (a pot filled with peat-based compost with 100% liverwort cover) in the middle of each plot containing 20 smaller pots filled with compost. For the post-emergence treatments, one pot with 100% liverwort cover was treated as a plot. The post-emergence treatments were applied to the plots in the summer trial on 3 September 2015. The treatments were applied using an air-assisted knapsack sprayer at a water volume of 1000 L/ha. However, HDC H25 (a granular formulation) and Sodium bicarbonate (a powder) were applied by calculating the appropriate weight of granules and powder for the surface area of the pot. These two treatments were then applied using a shaker pot.

Assessments were carried out every two weeks, for a period of 12 weeks, to determine the control of liverwort.

In the winter trial the pre-emergence treatments were applied on 16 December 2015 and the post-emergence treatments were applied on 6 January 2016. Assessments were carried out every two weeks for 12 weeks.

Table 4. Treatments, applied either pre or post-emergence, in the liverwort trials 2015-2016

Treatment no.	Treatment	Rate (kg/L/ha)	Timing of application
1	UTC	N/A	N/A
2	Chikara	0.15	Pre-emergence
3	Finalsan plus	166.0	Pre-emergence
4	Successor	2.0	Pre-emergence
5	Springbok	1.66	Pre-emergence
6	HDC H25		Pre-emergence
7	Sumimax	0.1	Pre-emergence
8	Venzar	5.0	Pre-emergence
9	Wing-p	3.5	Pre-emergence
10	Chikara	0.15	Post-emergence
11	New Way weed Spray	250.0	Post-emergence
12	Finalsan plus	220.0	Post-emergence
13	Quickdown	0.8	Post-emergence

Treatment no.	Treatment	Rate (kg/L/ha)	Timing of application
14	Reglone	2.0	Post-emergence
15	Successor	2.0	Post-emergence
16	Springbok	1.66	Post-emergence
17	HDC H25	220.0 as granule	Post-emergence
18	Sumimax	0.1	Post-emergence
19	Venzar	5.0	Post-emergence
20	Wing-p	3.5	Post-emergence
21	MMC Pro	200.0	Post-emergence
22	MMC Pro + Reglone	200.0 + 2.0	Post-emergence
23	Mosskade	100.0	Post-emergence
24	Sodium bicarbonate	As powder to cover	Post-emergence

Table 5. Active ingredients for the liverwort trial and their approval status 2015-2016

Treatment	Active ingredient	Potential use A = approved N = not approved
Chikara	flazasulfuron	Paths and beds outdoors (A)
Finalsan plus	pelargonic acid + maleic hydrazide	Paths and beds outdoors (A)
Successor	pethoxamid	Paths, beds & crops outdoors (N)
Springbok	metazachlor + dimethenamid-p	Paths, beds & crops outdoors (A)
HDC H25	undisclosed	Crops outdoors (N)
Sumimax	flumioxazine	Paths, beds & crops outdoors (A)
Venzar	lenacil	Paths & crops outdoors (A)
Wing-P	pendimethalin + dimethenamid-p	Paths and beds outdoors (A)
New Way Weed Spray	acetic acid	Paths and beds outdoors (A)
Quickdown	pyraflufen ethyl	Paths and beds outdoors (N)
Reglone	diquat	Paths and beds out and indoors (N*)
MMC Pro Moss Killer	didecyl dimethyl ammonium chloride	Paths and beds outdoors (A)
Mosskade	natural substances	Paths, beds & crops out & indoors (A)
Sodium bicarbonate	salt	Crops out & indoors (N)

* Other diquat products can be used on non-crop areas

The pre-emergence treatments that performed the best in terms of preventing liverwort spread from the infector pot to the smaller pots in summer were: Springbok, HDC H25, Venzar and Wing-P.

In summer the best post-emergence treatment was Sodium bicarbonate which remained at very low levels of liverwort (2.5% cover) throughout the trial period.

In the winter trial, 8 weeks after the pre-emergence treatments had been applied the untreated plots had significantly more liverwort cover than any of the treated plots (**Figure 1**). By the end of the trial liverwort had increased to 65% cover in the untreated plots (**Figure 2**) and remained as being significantly higher compared to all the other treatments. Springbok, HDC H25 and Wing-P were particularly effective for residual control over 10% liverwort cover. Springbok, HDC H25 and Wing-P were particularly effective for residual control.

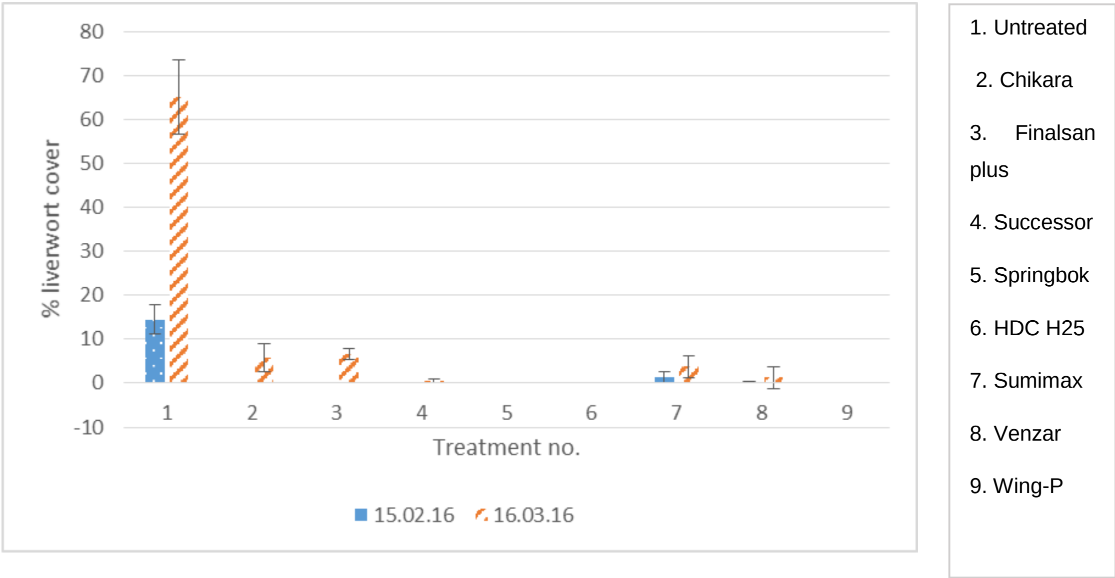


Figure 1. Percentage liverwort cover on 15 February 2016 and 16 March 2016 for pre-emergence treatments (winter trial)

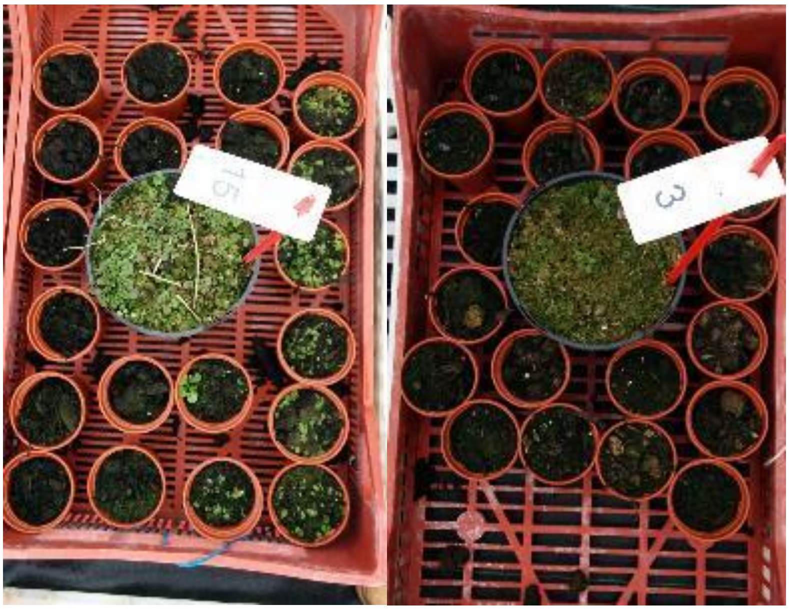


Figure 2. Untreated liverwort plot (left) and Springbok treated plot (right) on 16 March 2016 (pre-emergence winter trial)

Twelve weeks after post-emergence treatments were applied to the winter liverwort trial ; New Way Weed Spray, Finalsan plus, Reglone, Sumimax, Venzar, MMC Pro, MMC Pro + Reglone and Sodium bicarbonate (**Figure 3**) treated plots had significantly lower liverwort cover than the untreated control plots. MMC Pro, MMC Pro + Reglone and Sodium bicarbonate each had no liverwort cover, whereas New Way Weed Spray treated plots had 3.8% liverwort cover.

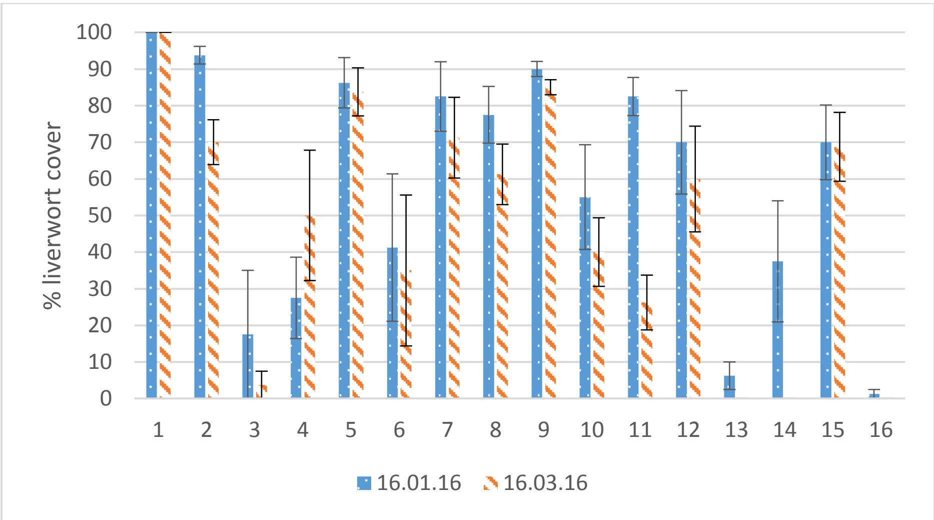


Figure 2. Percentage liverwort cover on 16 January 2016 and 16 March 2016 for post-emergence treatments (winter trial)

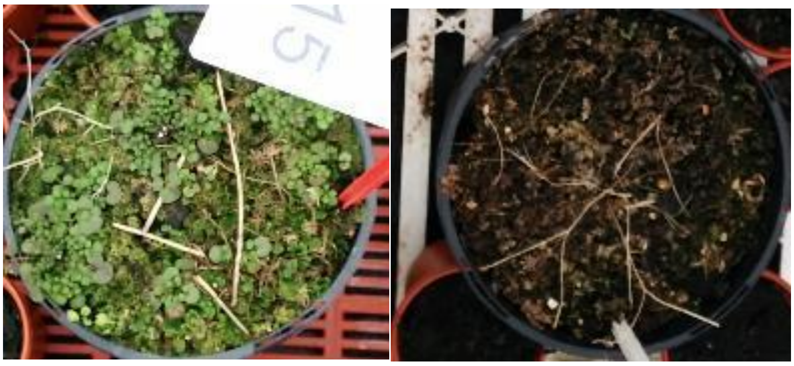


Figure 3. Untreated plot (left) and Sodium bicarbonate treated plot (right) on 16 March 2016 (post-emergence winter trial)

Crataegus

The aim was to test seven residual herbicide treatments for crop safety and weed control efficacy. The trial commenced in spring 2015 investigating weed control in field-grown *Crataegus* (402 provenance) at J & A Growers Ltd, Warwick, with treatments applied pre-bud burst in February.

There were subtle differences in the weed control between the various treatments due to the competitive nature of the crop in its second year of growth. When recorded 10 WAT, the untreated control treatment had weed cover of 1.6%. The best treatments for weed control were Stomp Aqua + Gamit 36 CS + Springbok, and Flexidor 500 both of which had 0% weed cover. The best additional treatments were Flexidor 500 + HDC H24, Nirvana high rate and Samson Extra 6% all of which had weed cover of 0.3%. **Table 6** below shows mean percentage weed cover 10 WAT for all treatments.

Nirvana at the maximum rate (high rate treatment 7) was the most damaging treatment and was considered commercially unacceptable. The lower rate of Nirvana also proved to be quite damaging. Although the *Crataegus* had started to grow away from the damage they were not classed as commercially acceptable until 16 WAT. Slight phytotoxic effects were noted on some of the other treatments, however all were considered commercially acceptable by 10 WAT.

Table 6. *Crataegus* tolerance to herbicides applications at 7, 10 and 16 weeks after treatment (WAT) (tolerant – T, moderately susceptible – MS, susceptible – S). Phytotoxicity was recorded on a 0 – 9 Scale with 0 representing plant death, 7 commercially acceptable damage and 9 being comparable with controls

Treatment number	Product name	7 WAT	10 WAT	16 WAT
1	Untreated control	9.0 (T)	9.0 (T)	9.0 (T)
2	Stomp Aqua + Gamit 36 CS*	8.3 (T)	9.0 (T)	8.6 (T)
3	Stomp Aqua + Gamit 36 CS* Springbok	7.0 (MS)	8.3 (T)	8.3 (T)
4	Flexidor 500 + HDC SUCCESSOR	9.0 (T)	9.0 (T)	9.0 (T)
5	Flexidor 500 + HDC H24	9.0 (T)	9.0 (T)	9.0 (T)
6	Nirvana Low rate	9.0 (T)	6.0 (S)	7.0 (MS)
7	Nirvana High rate	6.0 (S)	2.0 (S)	5.6 (S)
8	Samson Extra 6%	9.0 (T)	9.0 (T)	9.0 (T)

** Nursery standard*

Table 7 lists treatments and approval status and **Table 8** summarises percentage weed cover.

Table 7. Approval status of herbicides used in *Crataegus* trial

Treatment number	Product name	Active ingredients	Rate kg/l/ha	Authorisation status
1	Untreated control	-	-	-
2	Stomp Aqua + Gamit 36 CS*	pendimethalin + clomazone	2.9 l/ha 0.25 l/ha	EAMU 2919/09 + EAMU 1108/14
3	Stomp Aqua + Gamit 36 CS* Springbok	pendimethalin + clomazone + dimethenamid-p + metazachlor	2.9 l/ha 0.25 l/ha 1.66 l/ha	EAMU 2919/09 + EAMU 1108/14 + EAMU 2108/15
4	Flexidor 500 + HDC SUCCESSOR	isoxaben + pethoxamid	0.5 l/ha 2.0 l/ha	Label
5	Flexidor 500 + HDC H24	isoxaben + undisclosed	0.5 l/ha 4.0 l/ha	Label + undisclosed
6	Nirvana Low rate	imazamox + pendimethalin	3.0 l/ha	EAMU 2894/09
7	Nirvana High rate	imazamox + pendimethalin	4.5 l/ha	EAMU 2894/09
8	Samson Extra 6%	nicosulfuron	0.75 l/ha	EAMU 1054/14

* Nursery standard

Table 8. Mean percentage weed cover 10 weeks after treatment in the *Crataegus* trial

Treatment number	Product name	Percentage weed cover
1	Untreated control	1.6%
2	Stomp Aqua + Gamit 36 CS*	0.6%
3	Stomp Aqua + Gamit 36 CS* Springbok	0.0%
4	Flexidor 500 + Successor	0.0%
5	Flexidor 500 + HDC H24	0.3%
6	Nirvana Low rate	1.0%
7	Nirvana High rate	0.3%
8	Samson Extra 6%	0.3%

Financial Benefits

Hand weeding is estimated to cost up to £43,000 per hectare per year, which includes three weeding sessions and a clean-up when it comes to dispatch. Any reduction in hand weeding that can be achieved via chemicals will help reduce this cost. An effective herbicide programme including liverwort control could mean that hand weeding sessions could be reduced which would significantly reduce this cost for all container hardy nursery stock growers. For example, the chemical cost for one application of Springbok (1.6 L/ha), a successful summer application from the HNS container trials, would cost approximately £56 per hectare. Pre-emergence applications of Springbok or Wing-P were the stand out treatments in the liverwort trial and an application of Wing-P (3.5 L/ha) is estimated to cost £70 per hectare. Reglone was an effective post-emergence treatments in the liverwort trials and costs approximately £22 per hectare when applied at a rate of 2 L/ha. Please note that these costs do not include the labour time required to apply the herbicides.

Hand weeding field-grown crops three times during the growing season is estimated to cost in the region of £30,000 per hectare. Samson Extra + Flexidor 500 worked well in the *Crataegus* trial and it is estimated that one application of Samson Extra (0.75 L/ha) would cost £27 per hectare and Flexidor 500 (0.5 L per hectare) would cost approximately £161 per hectare. Any reduction in hand weeding or reduction in direct contact herbicide applications that can be achieved with residual herbicides will help to reduce this cost significantly, contributing to grower profitability.

Action Points

- New herbicide HDC H25 will be for use after potting for hardy nursery stock species and it has a very good weed control spectrum. It is anticipated that HDC H25 will be available as a commercial product with a label approval for outdoor ornamental plant production during 2017.
- Springbok would be a suitable follow up treatment to be applied as a summer treatment. Springbok has an EAMU for use in ornamental plant production although there are some restrictions relating to its use.
- Successor is now authorised on Maize in the UK and could be a useful summer herbicide for growers providing an EAMU could be obtained.
- HDC H25, Springbok and Wing-P all prevented the spread of liverwort for the entire period of the trials when applied as pre-emergences in the liverwort trials. The latter two could be useful as bed and path treatments outdoors.
- Sodium bicarbonate provided excellent quick and long lasting control of liverwort when applied post-emergence. It is currently authorised as a commodity substance for disease control and an application has been made to extend this to use as a herbicide for liverwort control.
- MMC Pro and MMC Pro + Reglone both showed promising results, when applied as post-emergence applications, in both the summer and winter liverwort trials.
- Samson Extra + Flexidor 500 was crop safe and resulted in good weed control in *Crataegus*, both products are authorised for use so can be used by growers
- Flexidor 500 + HDC H24 and Flexidor 500 + Successor proved to be crop safe and resulted in good weed control in *Crataegus*. These combinations are useful herbicides providing that an EAMU for HDC H24 and Successor can be obtained.

GROWER SUMMARY CUT FLOWER TRIALS

Headline

Herbicide trials carried out on China Aster, Larkspur, Sweet Williams, Peony and Wallflowers have indicated a number of herbicide treatments including combinations of Stomp Aqua, Goltix 70SC or Gamit 36 CS that can be used safely in these crops. Safe rates of use have been refined during the series of trials.

Background

There are few label recommended herbicides available for ornamental growers, which in many cases mean growers have to rely on hand weeding and cultivation, which is expensive and difficult in wet conditions, or on off-label herbicide usage through EAMUs. With the loss of key herbicide active ingredients such as oxadiazon (Ronstar Liquid), chlorthal-dimethyl (Dacthal-w75) and propachlor (Ramrod), it is necessary to find more options for cut flower growers. The increasing demand for British-grown cut flowers provides a significant business development opportunity for UK growers. However, the lack of technical information for the wide diversity of traditional and novel species being grown is a major factor limiting expansion of the sector. With improved knowledge, either the cost of ineffective treatments would be saved, or treatments that were effective would result in labour saving (reduced hand weeding) and a better quality crop.

During 2014, a range of herbicides were tested for crop safety on four key cut flower crops and wallflowers grown at the Cut Flower Centre (CFC), Holbeach St. Johns, as part of AHDB funded project HNS PO 192. Results from the work highlighted some promising new treatments, and so these products were further tested in 2015, both at the CFC and on grower holdings, to refine the treatments, examine rates of use and to see how well they worked in combination with other products.

Summary

Work was carried out between April and November 2015 to test a range of herbicides, either alone or in combination, for crop safety on four drilled flower species at the Cut Flower Centre (CFC); China aster (*Callistephus chinensis*; Compositae), Larkspur (*Delphinium consolida*; Ranunculaceae), Sweet Williams (*Dianthus barbartus*; Caryophyllacae) and Wallflowers (*Erysimum cheiri*; Cruciferae). Each flower species had a dedicated trial at the CFC and consisted of a total of 10 treatments, including an untreated control, replicated three times.

In addition to the trials held at the CFC, trials were also carried out during this period on growers' sites for transplanted China aster, newly planted Peony (*Paeonia* Hybrids;

Paeonaciae) and drilled Sweet Williams. The purpose of these trials were to refine the rates of herbicides that had been tested at the CFC and to demonstrate promising treatments in larger plots. Two promising experimental treatments were compared with the growers' standard herbicide treatment in the China aster and Sweet Williams trials. In these trials the main treatments were applied post-drilling and Shark was applied post-emergence. In the Peony trial, there were 10 treatments, including an untreated control, with pre- and post-planting treatments.

The products used in the 2015 trial are listed in **Table 9,** along with their approval status.

Table 9. Products and rates used in the Cut Flower trials, 2015

			Rate kg/ha or L/ha				
Product	**Active**	**Approval status**	**China Aster**	**Larkspur**	**Peony**	**Sweet William**	**Wallflower**
Benfluralin	60% w/w benfluralin	Not approved	2	2	2	2	2
Butisan S	500 g/L metazachlor	Label[1]			1.5		1
Defy	800 g/L prosulfocarb	EAMU outdoor[2]		4		2 4	
Dual Gold	960 g/L s-metolachlor	EAMU outdoor[4]		0.78			
Flexidor 500	500 g/L isoxaben	Label[1]			0.5		
Gamit 36 CS	360 g/L clomazone	EAMU outdoor[3]	0.05 0.125 0.25	0.25	0.125		0.05 0.125 0.25 0.33
Goltix 70 SC	700 g/L metamitron	EAMU[2]				1.0 2.0	
HDC H24	confidential	Not approved		X	X		
Kerb Flo 400	400 g/L propyzamide	Not approved	3.75				
Nirvana	250 g/L pendimethalin + 16.7 g/L imazamox	EAMU outdoor	3 4.5				
Ronstar Liquid	25% oxadiazon	Not approved	4.0				
Shark	60 g/L carfentrazone ethyl	EAMU outdoor and protected	0.33 0.66			0.33 0.66	
Stomp Aqua	455 g/L pendimethalin	EAMU outdoor	2	2	2.9	1.0 1.5	2 2.9

			Rate kg/ha or L/ha				
Product	**Active**	**Approval status**	**China Aster**	**Larkspur**	**Peony**	**Sweet William**	**Wallflower**
						2.0	
Successor	600 g/L pethoxamid	Not approved		2.0	2.0		
Venzar Flowable	440 g/L lenacil	LTAEU Outdoor			3		
Wing-P	250 g/L pendimethalin + 212.5 g/L dimethenamid-p	EAMU outdoor[2]		1.75	3.5		1.75 3.5

[1]Label only covers use on outdoor trees and shrubs but other ornamentals may be treated outdoors at grower's risk. Other formations of metazachlor can be used under protection providing the label does not specifically exclude such use.

[2]Pre-emergence only

[3]Pre-emergence and early post-emergence only

[4]Use only permitted during May

X indicates an experimental treatment applied at an undisclosed rate

Trials were assessed for phytotoxic symptoms approximately 2, 6 and 10 weeks from sowing or transplanting. Drilled crops were also assessed for emergence and a weed assessment was carried out on each trial.

For each crop **Tables 10 – 17**, show the final phytotoxicity score for each treatment 10 weeks after treatment (WAT), the average number of emerged seedlings per plot for drilled crops, and the percentage weed cover, to give an overall summary for each treatment. NS = no significant differences between treatments ($P<0.05$), lsd is the least significant difference between treatments.

China aster (drilled)

For the drilled China aster crop (**Table 10**), Nirvana applied at a rate of 4.5 L/ha proved to be the most phytotoxic treatment, with yellowing to foliage and stunted plants. By 10 WAT, all other treatments were considered commercially acceptable for plant quality. When Shark was applied as a post-emergence treatment, this initially caused some damage to the crop, with leaf yellowing and scorching to leaf edges, but these plants were able to recover at both application rates, so Shark could be considered for use as a herbicide in this crop, applied at a rate of 0.33 L/ha.

Plants treated with Stomp Aqua at 2 L/ha + Gamit at varying rates of 0.05-0.25 L/ha looked healthy and were commercially acceptable, but there was little difference in weed control and there was a tendency for emergence to be reduced in plots treated with the highest rate of Gamit at 0.25 L/ha. Therefore, Stomp Aqua 2 L/ha + Gamit 0.125 L/ha could be a suitable treatment applied to a crop post-drilling.

Table 10. Drilled China aster – Mean scores for phytotoxicity 10 weeks after treatment (WAT) (1 WAT), number of emerged seedlings and% weed cover – 2015 (scale of 0 - 9 where 9 is healthy, 0 is dead and 7 is commercially acceptable)

Treatment (rate kg or L)	**Phytotoxicity 10 WAT**	**Emergence (No.)**	**% weed cover**
1. Untreated	9.0	76.0	6.3
2. Benfluralin (2) / Gamit 36 CS (0.125)	8.3	101.7	6.0
3. Unt / Kerb Flo 400 (3.75)	8.7	96.7	5.0
4. Unt / Nirvana (3)	8.3	79.3	3.7
5. Unt / Nirvana (4.5)	6.3	82.7	1.7
6. Unt / Stomp Aqua + Gamit 36 CS (2 + 0.05)	9.0	85.0	3.7
7. Unt / Stomp Aqua + Gamit 36 CS (2 + 0.125)	9.0	86.7	3.7
8. Unt / Stomp Aqua + Gamit 36 CS (2 + 0.25)	8.7	69.7	4.0
9. Unt / Shark (post-em) (0.33)	5.7	N/A	N/A
10. Unt / Shark (post-em) (0.66)	6.0	N/A	N/A
F pr.	<.001		0.064
l.s.d (18 d.f)	1.587	NS	2.914

Note: plots treated with Shark were omitted from the emergence and weed cover assessment as this treatment went on at a later date.

China aster (transplanted)

Shark caused initial scorching on the leaves of the China asters which had been treated with Stomp Aqua + Gamit 36 CS pre-planting and Shark post-planting (T1.b). However, 4 weeks after the Shark had been applied (10 weeks after the main treatments had been applied) the asters had fully recovered with the new growth coming through unaffected (**Table 11**). None of the main treatments (T1.a, T2 or T3) caused any phytotoxic damage to the China asters throughout the trial. The best weed control was achieved by using Stomp Aqua + Gamit 36 CS. The Stomp Aqua + Dual Gold treatment was less effective.

Table 11. Transplanted China aster - Mean scores for phytotoxicity 10 weeks after treatment (WAT) and% weed cover – 2015 (scale of 0 - 9 where 9 is healthy, 0 is dead and 7 is commercially acceptable)

Treatment (rate kg or L)	Phytotoxicity 10 WAT	% weed cover
1.a Stomp Aqua (2) + Gamit 36 CS (0.25)	9.0	5.5
1.b Stomp Aqua (2) + Gamit 36 CS (0.25) / Shark (0.33) (post-emergence)	9.0	7.0
2. Stomp Aqua (2) + Dual Gold (0.78)	9.0	**16.0**
3. Ronstar Liquid (4)	9.0	11.7

Figures in **bold** show statistical significance at the 95% level compared with the grower's standard treatment of Ronstar Liquid.

Larkspur

Emergence of the Larkspur was still variable 11 WAT (**Table 12**) and some phytotoxicity was seen throughout the trial in the form of stunting and distortion to foliage.The variable emergence made it difficult to draw firm conclusions, but some treatments were identified with potential for further investigation, and some that can be ruled out. Stomp 2 L/ha + Dual Gold 0.78 L/ha, Wing-P 1.75 L/ha and Successor 2 L/ha all appear to be particularly phytotoxic to the crop, with the latter two treatments also tending to reduce emergence. Stomp Aqua 2 L/ha + Defy 4 L/ha was less phytotoxic but appeared to affect emergence. Overall, Stomp 2 L/ha + Gamit 0.25 L/ha appears to have the best potential both for weed control and crop safety.

Table 12. Drilled Larkspur – Mean scores for phytotoxicity 11 weeks after treatment (WAT), number of emerged seedlings and% weed cover - 2015 (scale of 0 - 9 where 9 is healthy, 0 is dead and 7 is commercially acceptable)

Treatment (rate kg or L)	**Phytotoxicity 11 WAT**	**Emergence (No.)**	**% weed cover**
1. Untreated	9.0	46.0	21.7
2. Benfluralin (2) / Defy (4)	6.0	58.7	18.3
3. Benfluralin (4) / Gamit 36 CS (0.25)	5.7	36.3	15.0
4. Unt / Stomp Aqua (2) + Gamit 36 CS (0.25)	6.3	50.3	6.7
5. Unt / Stomp Aqua (2) + Defy (4)	6.7	29.3	20.0
6. Unt / Stomp Aqua (2) + Dual Gold (0.78)	4.0	39.0	11.7
7. Unt / Wing-P (1.75)	5.3	30.7	10.0
8. Unt / Dual Gold (0.78) + Gamit 36 CS (0.25)	8.0	46.0	16.7
9. Unt / Successor (2)	4.0	31.3	13.3
10. Unt / H24	6.0	51.3	18.3
F pr.	0.008		
l.s.d (18 d.f)	2.394	NS	NS

Sweet Williams (CFC)

In the Sweet Williams trial (**Table 13**) Defy at a higher rate of 2 L/ha was unsafe when mixed with Stomp Aqua. Although crop emergence was not reduced, the seedlings that did come through showed some chlorosis and were scored down for phytotoxicity at 10 WAT. When used at the lower rate 1 L/ha and mixed with Stomp Aqua at 0.75 L/ha, plants showed little sign of phytotoxicity.

Goltix either on its own at 2 L/ha or tank mixed with Stomp Aqua showed little phytotoxicity. However, when Goltix was applied at the higher 2 L/ha rate mixed with Stomp Aqua, crop emergence appeared slightly reduced although it was not significantly different from the untreated control.

Benfluralin incorporated followed by Defy caused little phytotoxicity, but crop emergence was reduced. Weed control was also rather poor with this treatment.

Shark applied as a post-emergence treatment did cause some severe scorch and bleaching to leaves on the plants initially. However, the plants did recover from this and five weeks after treatment there was no damage to the new growth. Weed control was also much better with this treatment compared with the pre-emergence treatments.

Table 13. Drilled Sweet Williams - Mean scores for phytotoxicity 10 weeks after treatment (WAT) (5 WAT for Shark), number of emerged seedlings and% weed cover – 2015 (scale of 0 - 9 where 9 is healthy, 0 is dead and 7 is commercially acceptable)

Treatment (kg or L)	Phytotoxicity 10 WAT	Emergence (No.)	% weed cover
1. Untreated	9.0	283	65.0
2. Benfluralin (2) / Defy (2)	8.0	176	60.0
3. Unt / Stomp Aqua + Goltix (0.75 + 1)	8.3	343	36.7
4. Unt / Stomp Aqua + Goltix (0.75 + 2)	8.0	291	11.7
5. Unt / Stomp Aqua + Defy (0.75 + 1)	8.0	231	45.0
6. Unt / Stomp Aqua + Defy (0.75 + 2)	6.0	182	46.7
7. Unt / Stomp Aqua + Defy (1 + 1)	6.7	227	36.7
8. Unt / Stomp Aqua + Defy (1 + 2)	6.3	314	43.3
9. Unt / Goltix (2)	8.0	343	43.3
10. Unt / Shark (0.33)(post-em)	9.0	N/A	23.3
F pr.	0.072	0.021	
l.s.d (18 d.f)	2.098	118.4	NS

Note: plots treated with Shark were omitted from the emergence assessment as this treatment went on at a later date

Sweet Williams (Grower sites)

The rates of Stomp Aqua and Defy that were tested in the first Sweet Williams grower trial were too high with both of the treatments resulting in poor crop emergence (**Table 14**). All treatments, except the grower's standard treatment of Ronstar (T3), caused phytotoxic damage to the Sweet Williams which was seen as scorched leaves. Both rates of Stomp Aqua and Defy provided better weed control than the grower's standard treatment of Ronstar, however due to the poor crop emergence, were considered unacceptable.

Table 14. Sweet Williams – Mean scores for phytotoxicity 8 weeks after treatment (WAT), crop emergence and% weed cover– 2015 (grower site in Norfolk)

Treatment (rate kg or L)	Crop emergence per m² 8 WAT	Phytotoxicity 8 WAT	% weed cover
1.a Stomp Aqua (1.5) + Defy (2)	**2.3**	**7.8**	**4.5**
1.b Stomp Aqua (1.5) + Defy (2) / Shark (0.33)(post-em)	**2.7**	**6.5**	**4.0**
2.a Stomp Aqua (1) + Defy (2)	**7.4**	**7.8**	**6.3**

Treatment (rate kg or L)	Crop emergence per m² 8 WAT	Phytotoxicity 8 WAT	% weed cover
2.b Stomp Aqua (1) + Defy 2) / Shark (0.33)(post-em)	**7.0**	**6.5**	**5.0**
3. Ronstar Liquid (3)	28.0	9.0	12.5

Figures in **bold** show statistical significance at the 95% level compared with the grower's standard treatment of Ronstar.

A second Sweet Williams trial was carried out to test reduced rates of herbicides compared with the first grower site trial, and the opportunity was taken to test an alternative treatment of Stomp Aqua + Goltix. Crop emergence was poor across the whole trial, including the untreated plots (**Table 15**). Some initial slight herbicide damage was seen throughout the entire trial in the form of chlorotic spots on the Sweet Williams' leaves, even in the untreated plots. It is thought that this damage was caused from a herbicide that had been applied to a previous crop in the field. However, the only trial treatment to cause significant phytotoxic damage was the post-emergence application of Shark (T2.b and T3.b). Shark caused scorching to the leaves of the Sweet Williams, however the Sweet Williams had almost fully recovered by the final assessment that was carried out 12 weeks after the main treatments had been applied (3 weeks after the Shark was applied). Weed coverage of plots was lowest in the plots that had received an application of Stomp Aqua + Goltix with a post emergence application of Shark (T3.b).

Table 15. Sweet William – Mean scores for phytotoxicity 12 weeks after treatment (WAT), crop emergence and% weed cover– 2015 (grower site in Lincolnshire) (scale of 0 - 9 where 9 is healthy, 0 is dead and 7 is commercially acceptable)

Treatment	Crop emergence per m² 12 WAT	Phytotoxicity 12 WAT	% weed cover
1.Untreated	4.4	9.0	77.0
2.a Stomp Aqua (0.75) + Defy (1)	**1.0**	**8.5**	**38.1**
2.b Stomp Aqua (0.75) + Defy (1) / Shark (0.33) (post-em)	**6.0**	**8.0**	**18.8**
3.a Stomp Aqua (0.75) + Goltix (1)	**8.0**	8.8	50.6
3.b Stomp Aqua (0.75) + Goltix (1) / Shark (0.33) (post-em)	**14.0**	**8.0**	**6.3**

Figures in **bold** show statistical significance at the 95% level compared with the untreated control.

Wallflower

In the drilled Wallflower crop (**Table 16**), all treatments were safe in terms of foliar phytotoxicity. However, there was a tendency for emergence to be slightly reduced by some of the treatments, notably Stomp Aqua + Gamit 36 CS at both 2 L/ha + 0.25 L/ha and 2.9 L/ha + 0.33 L/ha (T5 and T6), Wing-P 3.5 L/ha (T8) and Wing-P 3.5 L/ha + Gamit 36 CS 0.125 L/ha (T10).

Benfluralin as a pre-drilling treatment followed by Gamit 36 CS (T4), Wing-P 1.75 L/ha (T7) and Wing-P 1.75 L/ha + Gamit 36 CS 0.125 L/ha (T9), all had good emergence.

In terms of weed control, all products achieved sufficient weed control, although Benfluralin / Gamit 36 CS (T4) was slightly poorer. There was little difference between T7 and T9, Wing-P 1.75 L/ha and Wing-P 1.75 L/ha + Gamit 36 CS 0.125 L/ha, which suggests that for the weed population at this site there was no benefit to mixing Wing-P with Gamit.

Table 16. Drilled Wallflowers - Mean scores for phytotoxicity 10 weeks after treatment (WAT), number of emerged seedlings and% weed cover – 2015 (scale of 0 - 9 where 9 is healthy, 0 is dead and 7 is commercially acceptable)

Treatment	**Phytotoxicity 10 WAT**	**Emergence (No. per m²)**	**% weed cover**
1. Untreated	9.0	108.0	50.0
2. Benfluralin / Butisan S	8.0	95.3	5.7
3. Benfluralin / Butisan S + Gamit 36 CS	8.0	110.7	13.3
4. Benfluralin / Gamit 36 CS	8.0	102.7	20.0
5. Unt / Stomp Aqua + Gamit (2 + 0.25)	8.0	84.0	13.3
6. Unt / Stomp Aqua + Gamit (2.9 + 0.33)	8.0	87.3	8.3
7. Unt / Wing-P (1.75)	8.0	110.0	8.3
8. Unt / Wing-P (3.5)	8.0	86.0	13.3
9. Unt / Wing-P + Gamit (1.75 + 0.125)	8.0	112.7	10.0
10. Unt / Wing-P + Gamit (3.5 + 0.125)	8.3	72.0	5.0
F pr.	<.001	NS	0.002
l.s.d (18 d.f)	0.313	NS	17.24

Peony

Very little phytotoxicity was seen in the Peony herbicide trial except for a slight effect of Wing-P (3.5 L/ha) + Gamit 36 CS (0.125 L/ha) applied pre-planting (**Table 17**). This treatment combination initially stunted the crop but the plants recovered by the assessment that was carried out 10 WAT. Tank mixtures of Stomp Aqua (2.9 L/ha) with either HDC H24 or Butisan S (1.5 L/ha) gave the best weed control.

Table 17. Peony – Mean scores for phytotoxicity 10 weeks after treatment (WAT) and% weed cover– 2015 (grower site in Lincolnshire) (scale of 0 - 9 where 9 is healthy, 0 is dead and 7 is commercially acceptable)

Treatment	Phytotoxicity 10 WAT	% weed cover
1. Untreated	9.0	100.0
2. Benfluralin* / Butisan S + Flexidor 500	9.0	**21.7**
3. Unt / Stomp Aqua + Butisan S + Flexidor 500	9.0	**6.7**
4. Unt / Successor	9.0	93.3
5. Unt / Successor + Stomp Aqua	9.0	76.7
6. Unt / Successor + Flexidor 500	9.0	76.7
7.Unt / HDC H24 + Venzar Flowable	9.0	**8.3**
8. Unt / HDC H24 + Stomp Aqua	9.0	**5.0**
9. Unt / HDC H24 + Flexidor 500	9.0	78.3
10. Unt / Wing-P + Gamit 36 CS**	9.0	83.3

* Pre-planting treatment to be sprayed then incorporated into the soil using a rake

** Pre-planting treatment to be sprayed but not incorporated into soil

Figures in **bold** show statistical significance at the 95% level compared with the untreated control.

Financial Benefits

Hand or mechanical weeding costs are currently estimated at around £2000 per hectare, therefore an increase in the options available for weed control will allow growers to produce outdoor cut flowers at a lower cost. For example, an application of Stomp Aqua (2.9 L/ha) would cost approximately £28 per hectare. Gamit 36 CS at a rate of 0.25 L/ha would cost approximately £37 per hectare and an application of Goltix at a rate of 1 L/ha would cost approximately £23 per hectare. However, experience from the grower trial sites indicates that some hand weeding would still be required unless more persistent treatments can be found or follow up treatments applied. It is not currently commercial practice for growers to produce a crop from drilled China asters, however if there were herbicides available that allowed growers to grow in this way then this could save growers a considerable amount of money compared to producing a transplanted crop. Having more herbicides available for weed control would be beneficial to all cut flower growers as weed control is a continual hindrance across this industry.

Action Points

- Stomp Aqua + Gamit 36 CS was safe and provided the best weed control when applied pre-planting to transplanted China aster. Both Stomp Aqua and Gamit 36 CS have EAMUs that allow them to be used by growers in this way. However follow up herbicides will be desirable to prolong weed control.
- Stomp Aqua + Goltix was the safest treatment combination for Sweet Williams regarding crop emergence and also provided the best weed control when followed by a post-emergence application of Shark. Stomp Aqua, Goltix and Shark all have EAMUs for outdoor ornamental plant production and so can be adopted up by growers immediately.
- Tank mixtures of Stomp Aqua with either HDC H24 or Butisan S gave the best weed control and were safe to use on a crop of newly planted Peony. Stomp Aqua can be used as an EAMU on Peony and Butisan S has an on-label approval. HDC H24 is not yet available for use.
- For wallflowers, Wing-P with or without Gamit 36 SC as a tank mix gave the best results. The benefit from the addition of Gamit 36 SC would depend on the weed spectrum of the site.

SCIENCE SECTION

Hardy Nursery Stock Trials

Introduction

Due to changes in legislation, many herbicides are no longer available to hardy nursery stock growers for the control of troublesome weeds. With the restrictions in place on the use of straight metazachlor products such as Butisan S, and the loss of Ronstar 2G (oxadiazon), the industry has been left virtually dependent on Flexidor 500 (isoxaben) for summer herbicide treatments. However, the continuous use of one active ingredient increases the risk of weeds becoming resistant to that particular chemistry, making weed control more difficult. Flexidor 500 also has limited efficacy against groundsel (*Senecio vulgaris*), willowherb (*Epilobium* species), grasses (various species) and also pearlwort (*Sagina* species); all of which are challenging weeds in nursery stock production. In addition, there are also some shrub and herbaceous species that are sensitive to Flexidor 500 meaning it is not a sensible option for use on these particular species.

All of these problems highlight the importance of developing an effective herbicide programme for the use on hardy nursery stock species. This herbicide programme would need to alternate different types of chemistry with different modes of actions to deliver substantial weed control.

Work carried out last year found new herbicide HDC H25 to be effective and safe to use on a range of nursery stock species, therefore the objective for this year's hardy nursery stock container project was to build on last year's work to establish a safe and effective herbicide programme that includes HDC H25. This project tested six different herbicide programmes which, in addition to testing HDC H25, included Successor (previously referred to as HDC H22); Flexidor 500; Dual Gold; Devrinol; Springbok and Sumimax.

The specific aim of this part of the project was to test six herbicide programmes for crop safety over a range of container grown hardy nursery stock species that are widely grown on commercial nurseries in the UK.

Further to the difficulty of controlling the weeds highlighted above, liverwort control is also a longstanding problem for the nursery stock container industry. In the past, Mogeton (quinoclamine) could be used on non-cropped surfaces, however this is no longer permitted. The recent introduction of physically acting Mosskade has helped to ease the situation, however growers have found Mosskade to be less effective during the summer and have also found it to be relatively short lasting. Mosskade is also an expensive treatment to use on a large scale which is particularly a problem when trying to control liverwort on paths and beds on a nursery. For these reasons, further treatments are required to complement the use of Mosskade, offering more persistent and economical control of liverwort.

Previous AHDB projects (HNS 93, HNS 93a, HNS 93c, HNS 126 and HNS 175) have studied the control of liverwort and other projects (HNS 139 and CP 86) have indirectly studied liverwort control. Within these projects it was found that lenacil (Venzar), metazachlor (Butisan S), flumioxazine (Sumimax) and flazasulfuron (Chikara) all had potential for liverwort control. However, metazachlor can no longer be used at the higher rates and the other herbicides have limited situations in which they can be used.

There are also a number of new herbicides which can be used selectively which have not yet been fully assessed for their potential control of liverwort (Successor, HDC H25 and Springbok). A further number of herbicides also exist which could be used non-selectively or pre-emergence on non-cropped areas including: pendimethalin + dimethenamid-p (Wing-P), acetic acid (various products), pyraflufen ethyl (Quickdown), pelargonic acid + maleic hydrazide (Finalsan plus), diquat (Reglone) and biocides or commodity substances. The aim of this part of the project was to test 15 treatments (including herbicides, biocides, physically acting and commodity substances) for liverwort control, for contact and residual activity, when applied either in summer or winter.

The loss of Ronstar liquid and restrictions on the use of herbicides such as metazachlor has made weed control more difficult in field-grown hardy nursery stock (HNS). There are a number of new herbicides that have not been fully assessed which can be applied when HNS crops are dormant to provide residual weed control in field situations. The aim of the field trial was to test seven herbicide treatments for crop safety and weed control efficacy on second year *Crataegus* seedlings as dormant season treatments.

Container trials

Materials and methods

The hardy nursery stock (HNS) container trials were set up on two commercial nurseries; Darby Nursery Stock in Norfolk and Wyevale Containers in Herefordshire. Species used were either supplied or sourced by these two nurseries and were chosen via the study director in discussion with the industry so that a wide range of popular HNS species were included. A total of 40 HNS subjects were used in this trial; 20 at Darby Nursery Stock and 20 at Wyevale Containers. Details of the potting mix, pesticide applications and irrigation can be found in Appendix 1.

There were two treatment factors (i) herbicide treatment (seven programmes including the untreated control) and (ii) crop species. The herbicide programmes consisted of seven different herbicides which were: Successor (pethoxamid), H25, Devrinol (napropamide), Dual Gold (s-metolachlor), Flexidor 500 (isoxaben), Springbok (metazachlor + dimethenamid-p) and Sumimax (flumioxazin); all of these herbicides were either used alone or in combination (Table 18). Treatment programmes also included an untreated control for comparison. Additional information for each treatment can be found in Table 19.

The trials were set up as a randomised split plot design at both locations, with each trial site having three replicated blocks. This meant that there were a total of 21 plots at each of the trial sites. Each plot contained five plants of each species and measured 1.5 m x 4 m at Darby Nursery Stock and 1.5 m x 4 m at Wyevale Containers. The treatments were applied to the plots at Darby Nursery Stock using an OPS sprayer and a 1 m boom with 02f110 nozzles to achieve a medium spray quality at a water volume of 1000 L/ha. Treatments at Wyevale Containers were applied to the plots using an OPS sprayer with a 1.5m boom with three 03/F110 nozzles delivering a medium spray at 1000 L/ha. However, HDC H25 is a granular treatment and so had to be applied using a pepper shaker pot. No attempt was made to brush off any granules that landed on the foliage.

The first application of treatments were applied to the Darby Nursery Stock trial on 26 May 2015, the second application were made on 25 August 2015 and the final application of herbicides was applied on 2 December 2015. Three treatments were applied to HNS species at Wyevale Containers, the first on 28 May 2015, the second on 20 August 2015 and the final application on 16 December.

Phytotoxicity was assessed approximately 2, 6 and 12 weeks after each of the herbicide applications were made. Additional assessments were made in April 2016 to check spring growth following the winter treatments. Phytotoxicity assessments involved comparing the treated plots to the untreated controls and awarding scores on a scale of 0 to 9 where 0 is dead, 7 is commercially acceptable and 9 is healthy and comparable with an untreated control. Assessments were also carried out at the same time as the phytotoxicity assessments for weed control. A percentage score was recorded for weeds found in each plot and weed species present were recorded.

Table 18. Details of herbicide programmes used for the hardy nursery stock container trials (Norfolk and Hereford - 2015)

Trt.	May	Rate (kg/L/ha)	August	Rate (kg/L per ha)	December	Rate (kg/L per ha)
1	Untreated control	N/A	Untreated control	N/A	Untreated control	N/A
2	HCD H25	x	Springbok	1.6	Devrinol	9.0
3	HDC H25	x	Successor	2.0	Devrinol	9.0
4	HDC H25	x	Springbok + Successor	1.6 + 2.0	Devrinol	9.0
5	HDC H25	x	Springbok + Successor	1.6 + 2.0	Sumimax	0.1
6.	Flexidor 500 + Dual Gold	0.5 +0.78	Flexidor 500 + Devrinol*	0.5 + 9.0	Sumimax	0.1
7.	Flexidor 500 + Dual Gold	0.5 + 0.78	Flexidor 500	0.5	Devrinol	9.0

(*) Irrigated in with 5 mm

(x) Undisclosed

Table 19. Active ingredients and status of approval for herbicides used in the container trials (Norfolk and Hereford)

Product	Active ingredient	Approvals status
HDC H25	undisclosed	Not approved
Flexidor 500	isoxaben	Label
Dual Gold	s-metolachlor	EAMU 0501/12
Springbok	metazachlor + dimethenamid-p	EAMU 2108/15
Successor	pethoxamid	Not approved
Devrinol	napropamide	Label
Sumimax	flumioxazin	EAMU 2881/08

Results

Results are detailed in Tables 20 to 28 for both the HNS container trials (Norfolk and Hereford). Results are summarised and combined below for each herbicide treatment from the trials in Norfolk and the trial in Hereford.

Treatment application at potting, May 2015

HDC H25 was safe on all of the hardy nursery stock species that it was tested on when applied in May 2015. No significant phytotoxicity was seen on any of the species tested at either nursery, assessments were carried out 2, 6 or 12 weeks after HDC H25 was applied.

Flexidor 500 + Dual Gold caused some initial damage to several of the species in the trial; *Berberis davidii, Buddleja davidii* 'Empire Blue', *Clematis montana* var. rubens 'Tetrarose' *Cotoneaster horizontalis*, *Escallonia* 'Iveyi', *Euonymus* Green Rocket, *Forsythia intermedia* 'Lynwood', *Hydrangea macrophylla, Ligustrum ovalifolium* 'Argenteum', *Prunus laurocerasus* and *Sambucus nigra* f. porphyrophylla 'Black Lace'. Most of the damage was on the growing tips which were soft and thus susceptible to slight damage at the time of application. Out of these species the *Berberis, Cotoneaster, Escallonia, Euonymous, Forsythia*, *Hydrangea*, *Ligustrum* and *Prunus* (all $p<0.001$) scored phytotoxicity scores of 6, meaning at this stage (2 WAT) the treatments were considered commercially unacceptable. However, for the remainder of the species listed above, no scores were significantly different to the untreated plots and the mean score for each species was above the commercially acceptable score of 7 (Table 3). Phytotoxic effects were also seen on *Sambucus* 2 WAT. At this assessment scorching could be seen on the leaves of *Sambucus* and at this point some of the plants of this species were considered commercially unacceptable (Figure 4). However, the mean phytotoxicity score was above 7, meaning that the majority of the plants remained commercially acceptable. By 6 weeks some phytotoxic damage could still be seen on the *Sambucus,* however the new growth was unaffected meaning the plants were scoring higher phytotoxicity scores (Table 20) and the same was true for the *Sambucus* at the assessment carried out 12 WAT (Table 21). *Olearia* (a species with known sensitivity to herbicides) was the most severely affected species within the trial, scoring a phytotoxicity score of 4 at 2 WAT ($p=<0.001$). *Olearia* treated with Flexidor 500 + Dual Gold was considered to be commercially acceptable by 12 WAT.

Figure 4. *Sambucus* two weeks after treatment of Flexidor 500 + Dual Gold (left) and on 24 October 2015 (right)

Table 20. Mean phytotoxicity scores for container nursery stock species, 2 weeks after treatments were applied in May 2015 – Norfolk and Herefordshire (scale of 0 - 9 where 9 is healthy, 0 is dead and 7 is commercially acceptable)

Species	Trt 1 (Untreated control)	Trt 2 (HDC H25)	Trt 3 (Dual Gold + Flexidor 500)	P value	LSD (df 16)
Abelia x *grandiflora*	9.0	9.0	9.0	NS	*
Azalea 'Hino Crimson'	9.0	9.0	8.8	NS	*
Berberis darwinii	9.0	9.0	6.0	<0.001	0
Brachyglottis 'Sunshine'	9.0	9.0	9.0	NS	0
Buddleja davidii 'Empire Blue'	9.0	8.9	7.2	NS	*
Buxus sempervirens	9.0	8.0	8.0	<0.001	0
Camellia japonica 'Lady Campbell'	9.0	9.0	9.0	NS	*
Caryopteris x clandonensis 'Heavenly Blue'	9.0	9.0	8.7	NS	*
Chamaecyparis 'Elwoods Gold'	9.0	9.0	9.0	NS	*
Choisya dewitteana Goldfingers = 'Limo'	9.0	9.0	9.0	NS	*
Cistus x *purpureus*	9.0	9.0	9.0	NS	*
Clematis montana var. rubens 'Tetrarose '	9.0	9.0	7.8	NS	*
Cotoneaster horizontalis	9.0	9.0	6.0	<0.001	0
Escallonia 'Iveyi'	9.0	9.0	6.0	<0.001	0
Euonymus 'Green Rocket'	9.0	9.0	6.0	<0.001	0
Forsythia intermedia 'Lynwood'	9.0	9.0	6.0	<0.001	0
Hebe 'Margret'	9.0	9.0	8.8	NS	*
Hydrangea macrophylla	9.0	9.0	6.0	<0.001	0
Hypericum x moserianum	9.0	9.0	9.0	NS	*
Jasminum officinale	9.0	9.0	8.7	NS	*
Lavender angustifolia 'Munstead'	9.0	9.0	8.8	NS	*
Ligustrum ovalifolium	9.0	9.0	6.0	<0.001	0
Ligustrum ovalifolium 'Argenteum'	9.0	9.0	7.7	NS	*
Olearia macrodonta 'Major'	9.0	9.0	4.0	<0.001	0
Osmanthus x burkwoodii	9.0	9.0	9.0	NS	*
Philadelphus 'Beauclark'	9.0	9.0	9.0	NS	*
Phormium tenax	9.0	9.0	9.0	NS	*
Potentilla fruticosa Primrose Beauty	9.0	9.0	8.0	<0.001	0
Prunus laurocerasus	9.0	9.0	6.0	<0.001	0
Pyracantha 'Red Column'	9.0	9.0	8.0	<0.001	0
Rhododendron 'Scarlet Wonder'	9.0	9.0	9.0	NS	*
Rosa rugosa	9.0	9.0	9.0	NS	*
Sambucus nigra f. *porphyrophylla* 'Black Lace'	9.0	9.0	7.2	NS	*
Santolina chamaecyparissus	9.0	9.0	8.8	NS	*
Spiraea japonica 'Golden princess'	9.0	9.0	8.7	NS	*
Thuja occidentalis 'Rheingold'	9.0	9.0	9.0	NS	*
Viburnum tinus 'Gwenllian'	9.0	9.0	9.0	NS	*
Viburnum x bodnantense 'Dawn'	9.0	9.0	9.0	NS	*
Vinca minor	9.0	9.0	9.0	NS	*
Weigelia 'Bristol Ruby'	9.0	9.0	8.3	NS	*

(*) Data not presented as results were not significant

Table 21. Mean phytotoxicity scores for container nursery stock species, 6 weeks after May 2015 treatments were applied – Norfolk and Herefordshire (scale of 0-9 where 9 is healthy, 0 is dead and 7 is commercially acceptable)

Species	Trt 1 (Untreated control)	Trt 2 (HDC H25)	Trt 3 (Dual Gold + Flexidor 500)	P value	LSD (df 16)
Abelia x *grandiflora*	9.0	9.0	9.0	NS	*
Azalea 'Hino Crimson'	9.0	9.0	8.5	NS	*
Berberis darwinii	9.0	9.0	9.0	NS	*
Brachyglottis 'Sunshine'	9.0	9.0	9.0	NS	*
Buddleja davidii 'Empire Blue'	9.0	9.0	8.7	NS	*
Buxus sempervirens	9.0	9.0	9.0	NS	*
Camellia japonica 'Lady Campbell'	9.0	9.0	9.0	NS	*
Caryopteris x clandonensis 'Heavenly Blue'	9.0	9.0	9.0	NS	*
Chamaecyparis 'Elwoods Gold'	9.0	9.0	9.0	NS	*
Choisya dewitteana Goldfingers = 'Limo'	9.0	9.0	9.0	NS	*
Cistus x *purpureus*	9.0	9.0	9.0	NS	*
Clematis montana var. rubens 'Tetrarose '	9.0	9.0	8.8	NS	*
Cotoneaster horizontalis	9.0	9.0	6.0	<0.001	0
Escallonia 'Iveyi'	9.0	9.0	9.0	NS	*
Euonymus 'Green Rocket'	9.0	9.0	9.0	NS	*
Forsythia intermedia 'Lynwood'	9.0	9.0	7.1	<0.001	0.2939
Hebe 'Margret'	9.0	9.0	8.3	NS	*
Hydrangea macrophylla	9.0	9.0	9.0	NS	*
Hypericum x moserianum	9.0	9.0	9.0	NS	*
Jasminum officinale	9.0	9.0	8.7	NS	*
Lavender angustifolia 'Munstead'	9.0	9.0	9.0	NS	*
Ligustrum ovalifolium	9.0	9.0	6.0	<0.001	0.2939
Ligustrum ovalifolium 'Argenteum'	9.0	9.0	8.7	NS	*
Olearia macrodonta 'Major'	9.0	9.0	6.0	<0.001	0.883
Osmanthus x burkwoodii	9.0	9.0	8.8	NS	*
Philadelphus 'Beauclark'	9.0	9.0	9.0	NS	*
Phormium tenax	9.0	9.0	9.0	NS	*
Potentilla fruticosa Primrose Beauty	9.0	9.0	9.0	NS	*
Prunus laurocerasus	9.0	9.0	7.0	<0.001	0.2939
Pyracantha 'Red Column'	9.0	9.0	7.6	<0.001	0.3807
Rhododendron 'Scarlet Wonder'	9.0	9.0	9.0	NS	*
Rosa rugosa	9.0	9.0	9.0	NS	*
Sambucus nigra f. *porphyrophylla* 'Black Lace'	9.0	9.0	7.2	<0.001	1.060
Santolina chamaecyparissus	9.0	9.0	9.0	NS	*
Spiraea japonica 'Golden princess'	9.0	9.0	9.0	NS	*
Thuja occidentalis 'Rheingold'	9.0	9.0	9.0	NS	*
Viburnum tinus 'Gwenllian'	9.0	9.0	8.8	NS	*
Viburnum x bodnantense 'Dawn'	9.0	9.0	9.0	NS	*
Vinca minor	9.0	9.0	9.0	NS	*
Weigelia 'Bristol Ruby'	9.0	9.0	9.0	NS	*

(*) Data not presented as results not significant

Table 22. Mean phytotoxicity scores for the container nursery stock species 12 weeks after May 2015 treatments were applied – Norfolk and Herefordshire (scale of 0-9 where 9 is healthy, 0 is dead and 7 is commercially acceptable)

Species	Trt 1 (Untreated control)	Trt 2 (HDC H25)	Trt 3 (Dual Gold + Flexidor 500)	P value	LSD (df 16)
Abelia x *grandiflora*	9.0	9.0	9.0	NS	*
Azalea 'Hino Crimson'	9.0	9.0	9.0	NS	*
Berberis darwinii	9.0	9.0	9.0	NS	*
Brachyglottis 'Sunshine'	9.0	9.0	9.0	NS	*
Buddleja davidii 'Empire Blue'	9.0	9.0	9.0	NS	*
Buxus sempervirens	9.0	9.0	9.0	NS	*
Camellia japonica 'Lady Campbell'	9.0	9.0	9.0	NS	*
Caryopteris x clandonensis 'Heavenly Blue'	9.0	9.0	9.0	NS	*
Chamaecyparis 'Elwoods Gold'	9.0	9.0	9.0	NS	*
Choisya dewitteana Goldfingers = 'Limo'	9.0	9.0	9.0	NS	*
Cistus x *purpureus*	9.0	9.0	9.0	NS	*
Clematis montana var. rubens 'Tetrarose '	9.0	9.0	9.0	NS	*
Cotoneaster horizontalis	9.0	9.0	8.0	<0.001	0
Escallonia 'Iveyi'	9.0	9.0	9.0	NS	*
Euonymus 'Green Rocket'	9.0	9.0	9.0	NS	*
Forsythia intermedia 'Lynwood'	9.0	9.0	7.0	NS	*
Hebe 'Margret'	9.0	9.0	9.0	NS	*
Hydrangea macrophylla	9.0	9.0	9.0	NS	*
Hypericum x moserianum	9.0	9.0	9.0	NS	*
Jasminum officinale	9.0	9.0	9.0	NS	*
Lavender angustifolia 'Munstead'	9.0	9.0	9.0	NS	*
Ligustrum ovalifolium	9.0	9.0	9.0	NS	*
Ligustrum ovalifolium 'Argenteum'	9.0	9.0	9.0	NS	*
Olearia macrodonta 'Major'	9.0	9.0	8.0	<0.001	0
Osmanthus x burkwoodii	9.0	9.0	8.8	0.302	0.2939
Philadelphus 'Beauclark'	9.0	9.0	9.0	NS	*
Phormium tenax	9.0	9.0	9.0	NS	*
Potentilla fruticosa Primrose Beauty	9.0	9.0	9.0	NS	*
Prunus laurocerasus	9.0	9.0	9.0	NS	*
Pyracantha 'Red Column'	9.0	9.0	9.0	NS	*
Rhododendron 'Scarlet Wonder'	9.0	9.0	9.0	NS	*
Rosa rugosa	9.0	9.0	9.0	NS	*
Sambucus nigra f. *porphyrophylla* 'Black Lace'	9.0	9.0	**7.7**	**0.069**	**0.745**
Santolina chamaecyparissus	9.0	9.0	9.0	NS	*
Spiraea japonica 'Golden princess'	9.0	8.6	9.0	NS	*
Thuja occidentalis 'Rheingold'	9.0	9.0	9.0	NS	*
Viburnum tinus 'Gwenllian'	9.0	9.0	9.0	NS	*
Viburnum x bodnantense 'Dawn'	9.0	9.0	9.0	NS	*
Vinca minor	9.0	9.0	9.0	NS	*
Weigelia 'Bristol Ruby'	9.0	9.0	9.0	NS	*

(*) Data not presented as results were not significant

Summer treatment application in August 2015

Springbok caused significant damage on *Olearia macrodonta* 'Major' ($p<0.001$), a species with known susceptibility to a number of herbicides. No other species that it was tested on in the HNS container trials were damaged to the same extent (Table 23) This species scored 3.6 on the phytotoxicity scale 12 WAT.

Successor caused damage on *Hydrangea macrophylla,* which scored 5.6 at the assessment carried out 2 WAT (p=<0.001), however this species grew away from the damage. *Olearia macrodonta* 'Major' scored four on the phytotoxicity scale 2 WAT (p=<0.001), which was considered susceptible to damage. No significant damage was noted on any of the other species it was tested on in the HNS container trials.

Springbok + Successor caused damage on *Hydrangea macrophylla,* which grew away from the damage, and caused significant phytotoxic effects on *Olearia macrodonta* 'Major' in the container trials after being applied in August 2015 (p=<0.001), with a phytotoxicity score of 2 at the assessment carried out 2 WAT.

Flexidor 500 + Devrinol (irrigated in) appeared to have no significant effects on any of the species that it was tested on at Darby Nursery Stock when assessed 2, 6 and 12 weeks after the August treatments were applied. However, when the crops were re-assessed in December 2015, damage that had not been apparent earlier was noticeable on *Santolina chamaecyparissus* which scored 4.6 on the phytotoxicity scale (0=<0.001). The Devrinol component of the treatment caused severe leaf scorching on the *Santolina* which was noted in December (Figure 5) and was still obvious in April 2016.

While phytotoxic damage was clearly visible on *Hydrangea macrophylla, Ligustrum ovalifolium, Santolina chamaecyparissus* and *Olearia macrodonta* 'Major' (all p=<0.001) at 2 WAT in the trial at Wyevale containers, it was scorching on *Ligustrum ovalifolium* (Figure 6)*, Santolina chamaecyparissus* (Figure 7) and *Olearia macrodonta* 'Major' that persisted to 12 WAT. This was the least damaging of the summer treatments applied to *Olearia macrodonta* 'Major' which scored 7.6 on the phytotoxicity scale 12 WAT.

Flexidor 500 caused phytotoxic damage on *Cotoneaster horizontalis, Hydrangea macrophylla, Ligustrum ovalifolium, Olearia macrodonta* 'Major' and *Osmanthus x burkwoodii*. The initial damage was worst on *Osmanthus x burkwoodii*, scoring 5.3 at 2 WAT (p=<0.001), and *Olearia macrodonta* 'Major', scoring 6.7 at 2 WAT (p=<0.001), but *Osmanthus* recovered whilst *Olearia* did not and was considered susceptible 12 WAT.

Table 23. Phytotoxicity scores for container trials, 2 weeks after August treatments were applied in 2015 – Norfolk and Hereford (scale of 0 - 9 where 9 is healthy, 0 is dead and 7 is commercially acceptable)

Species	Trt 1 (Untreated control)	Trt 2 (Springbok)	Trt 3 (Successor)	Trt 4 (Springbok + Successor)	Trt 5 (Springbok + Successor)	Trt 6 (Flexidor 500 + Devrinol)	Trt 7 (Flexidor 500)	P value	LSD (df 16)
Abelia x *grandiflora*	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Azalea 'Hino Crimson'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Berberis darwinii	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Brachyglottis 'Sunshine'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Buddleja davidii 'Empire Blue'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Buxus sempervirens	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Camellia japonica 'Lady Campbell'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Caryopteris x clandonensis 'Heavenly Blue'	9.0	9.0	9.0	8.7	8.8	8.0	9.0	NS	*
Chamaecyparis 'Elwoods Gold'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Choisya dewitteana Goldfingers = 'Limo'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Cistus x *purpureus*	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Clematis montana var. rubens 'Tetrarose '	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Cotoneaster horizontalis	9.0	**8.3**	9.0	8.0	8.0	9.0	6.6	NS	*
Escallonia 'Iveyi'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Euonymus 'Green Rocket'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*

Species	Trt 1 (Untreated control)	Trt 2 (Springbok)	Trt 3 (Successor)	Trt 4 (Springbok + Successor)	Trt 5 (Springbok + Successor)	Trt 6 (Flexidor 500 + Devrinol)	Trt 7 (Flexidor 500)	P value	LSD (df 16)
Forsythia intermedia 'Lynwood'	9.0	9.0	8.3	9.0	9.0	9.0	9.0	0.323	**0.6405**
Hebe 'Margret'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Hydrangea macrophylla	9.0	7.0	**5.6**	**6.6**	**6.0**	6.0	6.0	**<0.001**	**1.102**
Hypericum x moserianum	9.0	8.7	8.3	8.9	8.9	9.0	9.0	NS	*
Jasminum officinale	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Lavender angustifolia 'Munstead'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Ligustrum ovalifolium	9.0	8.0	**8.3**	**8.0**	**8.0**	6.6	6.0	**<0.001**	**0.4337**
Ligustrum ovalifolium 'Argenteum'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Olearia macrodonta 'Major'	9.0	4.0	**4.0**	**2.0**	**3.3**	7.6	6.7	**<0.001**	**1.798**
Osmanthus x burkwoodii	9.0	**6.6**	**7.6**	**7.3**	**7.6**	7.6	5.3	**<0.001**	**1.160**
Philadelphus 'Beauclark'	9.0	9.0	**9.0**	**8.0**	**8.0**	9.0	9.0	**<0.001**	**0**
Phormium tenax	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Potentilla fruticosa Primrose Beauty	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Prunus laurocerasus	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Pyracantha 'Red Column'	9.0	9.0	9.0	9.0	9.0	8.6	8.3	0.048	**0.4337**
Rhododendron 'Scarlet Wonder'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Rosa rugosa	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Sambucus nigra f. *porphyrophylla* 'Black Lace'	9.0	9.0	9.0	8.7	8.7	8.7	8.7	NS	*
Santolina chamaecyparissus	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*

Species	Trt 1 (Untreated control)	Trt 2 (Springbok)	Trt 3 (Successor)	Trt 4 (Springbok + Successor)	Trt 5 (Springbok + Successor)	Trt 6 (Flexidor 500 + Devrinol)	Trt 7 (Flexidor 500)	P value	LSD (df 16)
Spiraea japonica 'Golden princess'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Thuja occidentalis 'Rheingold'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Viburnum tinus 'Gwenllian'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Viburnum x bodnantense 'Dawn'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Vinca minor	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Weigelia 'Bristol Ruby'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*

(*) Data not presented as results were not significant

Table 24. Phytotoxicity scores for the container trials 6 weeks after August 2015 treatments were applied – Norfolk and Herefordshire (scale of 0- 9 where 9 is healthy, 0 is dead and 7 is commercially acceptable)

Species	Trt 1 (Untreated control)	Trt 2 (Springbok)	Trt 3 (Successor)	Trt 4 (Springbok + Successor)	Trt 5 (Springbok + Successor)	Trt 6 (Flexidor 500 + Devrinol)	Trt 7 (Flexidor 500)	P value	LSD (df 16)
Abelia x *grandiflora*	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Azalea 'Hino Crimson'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Berberis darwinii	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Brachyglottis 'Sunshine'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Buddleja davidii 'Empire Blue'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Buxus sempervirens	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Camellia japonica 'Lady Campbell'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Caryopteris x clandonensis 'Heavenly Blue'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Chamaecyparis 'Elwoods Gold'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Choisya dewitteana Goldfingers = 'Limo'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Cistus x *purpureus*	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Clematis montana var. rubens 'Tetrarose '	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Cotoneaster horizontalis	9.0	8.0	8.6	8.0	8.0	8.3	7.0	<0.001	**0.6271**
Escallonia 'Iveyi'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Euonymus 'Green Rocket'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Forsythia intermedia 'Lynwood'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Hebe 'Margret'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*

Species	Trt 1 (Untreated control)	Trt 2 (Springbok)	Trt 3 (Successor)	Trt 4 (Springbok + Successor)	Trt 5 (Springbok + Successor)	Trt 6 (Flexidor 500 + Devrinol)	Trt 7 (Flexidor 500)	P value	LSD (df 16)
Hypericum x moserianum	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Jasminum officinale	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Lavender angustifolia 'Munstead'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Ligustrum ovalifolium	9.0	9.0	9.0	9.0	9.0	6.0	6.0	<0.001	0
Ligustrum ovalifolium 'Argenteum'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Olearia macrodonta 'Major'	9.0	3.6	4.0	2.0	**3.3**	**7.6**	**5.3**	<0.001	**1.213**
Osmanthus x burkwoodii	9.0	8.6	9.0	9.0	**8.6**	**8.6**	9.0	0.78	**0.6326**
Philadelphus 'Beauclark'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Phormium tenax	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Potentilla fruticosa Primrose Beauty	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Prunus laurocerasus	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Pyracantha 'Red Column'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Rhododendron 'Scarlet Wonder'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Rosa rugosa	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Sambucus nigra f. *porphyrophylla* 'Black Lace'	8.3	9.0	9.0	8.2	8.4	9.0	8.7	NS	*
Santolina chamaecyparissus	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Spiraea japonica 'Golden princess'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Thuja occidentalis 'Rheingold'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*

Species	Trt 1 (Untreated control)	Trt 2 (Springbok)	Trt 3 (Successor)	Trt 4 (Springbok + Successor)	Trt 5 (Springbok + Successor)	Trt 6 (Flexidor 500 + Devrinol)	Trt 7 (Flexidor 500)	P value	LSD (df 16)
Viburnum x bodnantense 'Dawn'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Vinca minor	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Weigelia 'Bristol Ruby'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*

(*) Data not presented as results were not significant

Table 25. Phytotoxicity scores for the HNS container trials 12 weeks after August 2015 treatments were applied – Norfolk and Herefordshire (scale of 0-9 where 9 is healthy, 0 is dead and 7 is commercially acceptable)

Species	Trt 1 (Untreated control)	Trt 2 (Springbok)	Trt 3 (Successor)	Trt 4 (Springbok + Successor)	Trt 5 (Springbok + Successor)	Trt 6 (Flexidor 500 + Devrinol)	Trt 7 (Flexidor 500)	P value	LSD (df 16)
Abelia x *grandiflora*	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Azalea 'Hino Crimson'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Berberis darwinii	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Brachyglottis 'Sunshine'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Buddleja davidii 'Empire Blue'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Buxus sempervirens	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Camellia japonica 'Lady Campbell'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Caryopteris x clandonensis 'Heavenly Blue'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Chamaecyparis 'Elwoods Gold'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Choisya dewitteana Goldfingers = 'Limo'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Cistus x *purpureus*	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Clematis montana var. rubens 'Tetrarose '	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Cotoneaster horizontalis	9.0	8.0	8.6	8.0	8.0	**8.3**	7.0	**0.009**	**0.704**
Escallonia 'Iveyi'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Euonymus 'Green Rocket'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Forsythia intermedia 'Lynwood'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Hebe 'Margret'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Hydrangea macrophylla	9.0	9.0	7.3	8.3	8.0	**8.0**	8.0	**0.014**	**0.814**
Hypericum x moserianum	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Jasminum officinale	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Lavender angustifolia 'Munstead'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Ligustrum ovalifolium	9.0	9.0	9.0	9.0	9.0	**7.0**	7.0	**<0.001**	**0**
Ligustrum ovalifolium 'Argenteum'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*

Species	Trt 1 (Untreated control)	Trt 2 (Springbok)	Trt 3 (Successor)	Trt 4 (Springbok + Successor)	Trt 5 (Springbok + Successor)	Trt 6 (Flexidor 500 + Devrinol)	Trt 7 (Flexidor 500)	P value	LSD (df 16)
Abelia x *grandiflora*	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Azalea 'Hino Crimson'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Berberis darwinii	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Brachyglottis 'Sunshine'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Buddleja davidii 'Empire Blue'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Buxus sempervirens	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Camellia japonica 'Lady Campbell'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Caryopteris x clandonensis 'Heavenly Blue'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Olearia macrodonta 'Major'	9.0	3.6	**4.0**	**2.3**	**3.3**	**7.6**	**5.3**	**<0.001**	**1.123**
Osmanthus x burkwoodii	9.0	8.6	9.0	9.0	8.6	**8.6**	9.0	**0.781**	**0.6236**
Philadelphus 'Beauclark'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Phormium tenax	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Potentilla fruticosa Primrose Beauty	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Prunus laurocerasus	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Pyracantha 'Red Column'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Rhododendron 'Scarlet Wonder'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Rosa rugosa	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Sambucus nigra f. *porphyrophylla* 'Black Lace'	9.0	9.0	9.0	7.7	8.0	8.7	8.7	NS	*
Santolina chamaecyparissus	9.0	9.0	9.0	9.0	9.0	**4.6**	9.0	<0.001	1.027
Spiraea japonica 'Golden princess'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Thuja occidentalis 'Rheingold'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Viburnum tinus 'Gwenllian'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Viburnum x bodnantense 'Dawn'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Vinca minor	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*

Species	Trt 1 (Untreated control)	Trt 2 (Springbok)	Trt 3 (Successor)	Trt 4 (Springbok + Successor)	Trt 5 (Springbok + Successor)	Trt 6 (Flexidor 500 + Devrinol)	Trt 7 (Flexidor 500)	P value	LSD (df 16)
Abelia x *grandiflora*	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Azalea 'Hino Crimson'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Berberis darwinii	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Brachyglottis 'Sunshine'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Buddleja davidii 'Empire Blue'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Buxus sempervirens	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Camellia japonica 'Lady Campbell'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Caryopteris x clandonensis 'Heavenly Blue'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Weigelia 'Bristol Ruby'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*

(*) Data not presented as results were not significant

Figure 5. *Santolina* treated with Flexidor 500 + Devrinol in August 2015 (Norfolk trial, December 2015)

Figure 6. *Ligustrum* treated with Flexidor 500 + Devrinol in August 2015 (April 2016)

Figure 7. *Santolina* 12 weeks after treatment of Flexidor 500 + Devrinol

Treatments applied in December 2015

Devrinol was applied in winter 2015, and appeared to have no significant phytotoxic effects on any of the species it was tested on at the follow up assessments carried out (2, 6 and 12 weeks) (Table 26) at Darby Nursery Stock after the December treatments were applied. However, when the plots were revisited in spring 2016 some leaf scorch was noticeable on *Santolina* but this was assessed as average score eight meaning it was still considered commercially acceptable.

Significant phytotoxic damage from Devrinol was clearly visible on *Hydrangea macrophylla* which scored 6 on the phytotoxicity scale (p=<0.001), and *Olearia macrodonta* 'Major' which scored 4 (p=<0.001) 2 WAT. Slight, but commercially acceptable damage was recorded on *Osmanthus x burkwoodii* 2 WAT which was still noticeable 6 WAT in the trial at Wyevale containers.

Sumimax applied in winter 2015 appeared to have no significant effects on any of the species assessments made 2, 6 and 12 weeks after the December treatment had been applied at Darby Nursery Stock. However, because of the cold spring, phytotoxicity took some time to become apparent and when the trial was re-assessed in early spring 2016 a number of effects were noted. There was obvious leaf loss seen on *Abelia grandiflora* and also on *Azalea* 'Hino Crimson' (Figure 8) that had been caused by the Sumimax, however no statistics were performed on this data as the assessment was an additional informal assessment carried out to determine damage levels once plants were breaking out of dormancy. The *Abelia* had started shooting away from the base when they were re-assessed in April 2016, however the *Azalea* did not recover. Some leaf scorching could be seen on *Buddleja* when the trial was visited again in early March 2016, however these plants had fully recovered when the trial was re-visited at the beginning of April 2016. In April 2016, scorching could also be seen on *Hebe* 'Margret' (Figure 9) which was not previously obvious. *Hebe* scored a 5 on the phytotoxicity scale for the scorch and also for some loss of leaves. Some leaf scorching could be seen on *Hypericum x moserianum* when the trial was visited again in early March 2016, however these plants had fully recovered when the trial was re-visited at the beginning of April 2016.

Phytotoxicity damage was noted earlier at Wyevale containers and was clearly visible on a number of species by 2 WAT; the most severe damage was noted on *Prunus laurocerasus* (, Figure 10) and *Viburnum tinus* 'Gwenllian' (Figure 11), with both species scoring a phytotoxicity score of 4 ($p<0.001$). Slight, but significant damage was also noted on the following species: *Buxus sempervirens, Escallonia* 'Iveyi', *Euonymus* 'Green Rocket', *Hydrangea macrophylla, Prunus laurocerasus* and *Pyracantha* Red Column ($p<0.001$). *Prunus laurocerasus* was classed as severely damaged, scoring a phytotoxicity score of 2 ($p<0.001$), and *Viburnum tinus* Gwenllian (both $p<0.001$) as damaged, scoring 4, at 6 WAT; phytotoxic damage had worsened by 6 WAT and the plants had not recovered by 18 WAT (late April). *Phormium tenax* ($p=<0.001$, Figure 12) had developed phytotoxic damage (as necrotic spotting) by 6 WAT which the crop did not grow away from. *Ligustrum ovalifolium* ($p=<0.001$) and *Buxus sempervirens* ($p=<0.001$) were also showing additional phytotoxic symptoms by 6 WAT, with the *Ligustrum* scoring 6 and the *Buxus* scoring 4 on the phytotoxicity scale. *Buxus* had started to grow away from damage by 14 WAT. Whilst damage recorded at 6 WAT had got worse on the aforementioned species, some species (including *Hydrangea macrophylla, Euonymus* 'Green Rocket' and *Pyracantha* 'Red Column') were starting to grow away from phytotoxic damage. With the exception of *Berberis darwinii,* and *Brachyglottis* 'Sunshine,' all of the evergreen subjects in the Wyevale trial were still showing some phytotoxic damage by late April.

Table 26. Phytotoxicity scores for the HNS container trials 2 weeks after December treatments were applied – Norfolk and Herefordshire 2015 (scale of 0 - 9 where 9 is healthy, 0 is dead and 7 is commercially acceptable)

Species	Trt 1 (Untreated control)	Trt 2 (Devrinol)	Trt 3 (Devrinol)	Trt 4 (Devrinol)	Trt 5 (Sumimax)	Trt 6 (Sumimax)	Trt 7 (Devrinol)	P value	LSD (df 16)
Abelia x *grandiflora*	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*
Azalea 'Hino Crimson'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*
Berberis darwinii	9.0	9.0	9.0	9.0	8.0	7.6	9.0	<0.001	**0.2939**
Brachyglottis 'Sunshine'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Buddleja davidii 'Empire Blue'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*
Buxus sempervirens	9.0	9.0	9.0	9.0	6.0	6.0	9.0	<0.001	**0**
Camellia japonica 'Lady Campbell'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*
Caryopteris x clandonensis 'Heavenly Blue'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*
Chamaecyparis 'Elwoods Gold'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*
Choisya dewitteana Goldfingers = 'Limo'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*
Cistus x *purpureus*	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*
Clematis montana var. rubens 'Tetrarose '	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*
Cotoneaster horizontalis	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*
Escallonia 'Iveyi'	9.0	9.0	9.0	9.0	6.0	6.0	9.0	<0.001	**0**
Euonymus 'Green Rocket'	9.0	8.0	8.0	8.0	6.0	6.0	8.0	<0.001	**0**
Forsythia intermedia 'Lynwood'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*
Hebe 'Margret'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*
Hydrangea macrophylla	6.0	6.0	6.0	6.0	6.0	6.0	**6.0**	<0.001	**0**
Hypericum x moserianum	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*
Jasminum officinale	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*
Lavender angustifolia 'Munstead'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*
Ligustrum ovalifolium	9.0	8.0	8.0	8.0	7.0	7.0	8.0	<0.001	**0**
Ligustrum ovalifolium 'Argenteum'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*
Olearia macrodonta 'Major'	9.0	4.0	4.0	4.0	3.6	6.0	4.0	<0.001	**1.011**
Osmanthus x burkwoodii	9.0	8.0	8.0	8.0	6.0	6.0	8.0	<0.001	**0**
Philadelphus 'Beauclark'	9.0	9.0	9.0	9.0	8.0	8.0	9.0	<0.001	**0**
Phormium tenax	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*
Potentilla fruticosa Primrose Beauty	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*

Species	Trt 1 (Untreated control)	Trt 2 (Devrinol)	Trt 3 (Devrinol)	Trt 4 (Devrinol)	Trt 5 (Sumimax)	Trt 6 (Sumimax)	Trt 7 (Devrinol)	P value	LSD (df 16)
Prunus laurocerasus	**9.0**	**9.0**	**9.0**	**9.0**	**4.0**	**4.0**	**9.0**	<0.001	**0**
Pyracantha 'Red Column'	**9.0**	**9.0**	**9.0**	**9.0**	**6.6**	**6.0**	**9.0**	**<0.001**	**0.3807**
Rhododendron 'Scarlet Wonder'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Rosa rugosa	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Sambucus nigra f. *porphyrophylla* 'Black Lace'	9.0	9.0	9.0	9.0	9.0	9.0	9.0	NS	*
Santolina chamaecyparissus	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**4.6**	**9.0**	**<0.001**	**1.027**
Spiraea japonica 'Golden princess'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Thuja occidentalis 'Rheingold'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Viburnum tinus 'Gwenllian'	**9.0**	**9.0**	**9.0**	**9.0**	**4.0**	**4.0**	**9.0**	**<0.001**	**0**
Viburnum x bodnantense 'Dawn'	**9.0**	**9.0**	**9.0**	**9.0**	**8.0**	**8.0**	**9.0**	**<0.001**	**0**
Vinca minor	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Weigelia 'Bristol Ruby'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****

Table 27. Phytotoxicity scores for the HNS container trials 6 weeks after December treatments were applied – Norfolk and Hereford 2015 (scale of 0 - 9 where 9 is healthy, 0 is dead and 7 is commercially acceptable)

Species	Trt 1 (Untreated control)	Trt 2 (Devrinol)	Trt 3 (Devrinol)	Trt 4 (Devrinol)	Trt 5 (Sumimax)	Trt 6 (Sumimax)	Trt 7 (Devrinol)	P value	LSD (df 16)
Abelia x *grandiflora*	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Azalea 'Hino Crimson'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Berberis darwinii	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Brachyglottis 'Sunshine'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Buddleja davidii 'Empire Blue'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Buxus sempervirens	**9.0**	**9.0**	**9.0**	**9.0**	**4.0**	**4.0**	**9.0**	**<0.001**	**0**
Camellia japonica 'Lady Campbell'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Caryopteris x clandonensis 'Heavenly Blue'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Chamaecyparis 'Elwoods Gold'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Choisya dewitteana Goldfingers = 'Limo'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Cistus x *purpureus*	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Clematis montana var. rubens 'Tetrarose '	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Cotoneaster horizontalis	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Escallonia 'Iveyi'	**9.0**	**9.0**	**9.0**	**9.0**	**6.6**	**6.6**	**9.0**	**<0.001**	**0.3339**
Euonymus 'Green Rocket'	**9.0**	**9.0**	**8.3**	**9.0**	**8.0**	**7.6**	**8.8**	**0.001**	**0.653**
Forsythia intermedia 'Lynwood'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Hebe 'Margret'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Hydrangea macrophylla	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Hypericum x moserianum	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Jasminum officinale	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Lavender angustifolia 'Munstead'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Ligustrum ovalifolium	**9.0**	**9.0**	**9.0**	**9.0**	**6.0**	**6.3**	**9.0**	**<0.001**	**0.2939**
Ligustrum ovalifolium 'Argenteum'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Olearia macrodonta 'Major'	**9.0**	**3.3**	**4.0**	**4.0**	**4.0**	**4.0**	**3.6**	**<0.001**	**0.6201**
Osmanthus x burkwoodii	**9.0**	**6.0**	**6.0**	**6.0**	**6.0**	**6.0**	**6.0**	**<0.001**	**0**
Philadelphus 'Beauclark'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Phormium tenax	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**<0.001**	**0.5878**
Potentilla fruticosa Primrose Beauty	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****

Species	Trt 1 (Untreated control)	Trt 2 (Devrinol)	Trt 3 (Devrinol)	Trt 4 (Devrinol)	Trt 5 (Sumimax)	Trt 6 (Sumimax)	Trt 7 (Devrinol)	P value	LSD (df 16)
Prunus laurocerasus	**9.0**	**9.0**	**9.0**	**9.0**	**2.0**	**2.0**	9.0	<0.001	0
Pyracantha 'Red Column'	**9.0**	**9.0**	**9.0**	**9.0**	**8.0**	**8.0**	9.0	<0.001	0
Rhododendron 'Scarlet Wonder'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*
Rosa rugosa	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*
Sambucus nigra f. *porphyrophylla* 'Black Lace'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*
Santolina chamaecyparissus	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**4.3**	9.0	<0.001	1.495
Spiraea japonica 'Golden princess'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*
Thuja occidentalis 'Rheingold'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*
Viburnum tinus 'Gwenllian'	**9.0**	**9.0**	**9.0**	**9.0**	**4.0**	**4.0**	**9.0**	<0.001	0
Viburnum x bodnantense 'Dawn'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*
Vinca minor	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*
Weigelia 'Bristol Ruby'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*

Table 28. Phytotoxicity scores for the HNS container trials at final assessment March (Hereford), April (Norfolk) following December treatments – Norfolk and Herefordshire 2015 (scale of 0-9 where 9 is healthy, 0 is dead and 7 is commercially acceptable)

Species	Trt 1 (Untreated control)	Trt 2 (Devrinol)	Trt 3 (Devrinol)	Trt 4 (Devrinol)	Trt 5 (Sumimax)	Trt 6 (Sumimax)	Trt 7 (Devrinol)	P value	LSD (df 16)
Abelia x *grandiflora*	9.0	9.0	7.3	9.0	**4.0**	**4.0**	9.0	-	-
Azalea 'Hino Crimson'	9.0	9.0	9.0	9.0	**5.0**	**5.0**	9.0	-	-
Berberis darwinii	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Brachyglottis 'Sunshine'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Buddleja davidii 'Empire Blue'	9.0	9.0	9.0	9.0	8.0	8.0	9.0	-	-
Buxus sempervirens	**9.0**	**9.0**	**9.0**	**9.0**	**6.0**	**6.0**	**9.0**	**<0.001**	**0**
Camellia japonica 'Lady Campbell'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Caryopteris x clandonensis 'Heavenly Blue'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Chamaecyparis 'Elwoods Gold'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Choisya dewitteana Goldfingers = 'Limo'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Cistus x *purpureus*	9.0	9.0	9.0	9.0	9.0	7.6	9.0	NS	*
Clematis montana var. rubens 'Tetrarose '	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Cotoneaster horizontalis	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Escallonia 'Iveyi'	9.0	9.0	9.0	9.0	**8.3**	**8.3**	9.0	-	-
Euonymus 'Green Rocket'	9.0	9.0	9.0	9.0	**7.0**	**7.0**	9.0	**<0.001**	**0**
Forsythia intermedia 'Lynwood'	9.0	9.0	9.0	9.0	8.0	8.0	9.0	NS	*
Hebe 'Margret'	9.0	9.0	9.0	9.0	**5.0**	**5.0**	9.0	-	-
Hydrangea macrophylla	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Hypericum x moserianum	9.0	9.0	9.0	9.0	8.0	8.0	9.0	NS	*
Jasminum officinale	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Lavender angustifolia 'Munstead'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Ligustrum ovalifolium	**9.0**	**9.0**	**9.0**	**9.0**	**6.0**	**6.0**	**9.0**	**<0.001**	**0**
Ligustrum ovalifolium 'Argenteum'	9.0	9.0	9.0	9.0	**6.0**	**6.0**	8.3	-	-
Olearia macrodonta 'Major'	9.0	5.0	5.0	5.0	**5.0**	**5.0**	5.0	-	-
Osmanthus x burkwoodii	9.0	6.0	6.0	6.0	**6.0**	**6.0**	6.0	<0.001	**0.930**
Philadelphus 'Beauclark'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Phormium tenax	**9.0**	**9.0**	**9.0**	**9.0**	**6.0**	**6.0**	**9.0**	**<0.001**	**0**
Potentilla fruticosa Primrose Beauty	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****

Species	Trt 1 (Untreated control)	Trt 2 (Devrinol)	Trt 3 (Devrinol)	Trt 4 (Devrinol)	Trt 5 (Sumimax)	Trt 6 (Sumimax)	Trt 7 (Devrinol)	P value	LSD (df 16)
Prunus laurocerasus	**9.0**	**9.0**	**9.0**	**9.0**	**2.0**	**2.0**	**9.0**	**<0.001**	**0**
Pyracantha 'Red Column'	**9.0**	**9.0**	**9.0**	**9.0**	**8.3**	**8.3**	**9.0**	-	-
Rhododendron 'Scarlet Wonder'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Rosa rugosa	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Sambucus nigra f. *porphyrophylla* 'Black Lace'	9.0	9.0	9.0	9.0	9.0	**6.0**	9.0	-	-
Santolina chamaecyparissus	9.0	8.0	9.0	9.0	9.0	**4.0**	9.0	<0.001	0.7643
Spiraea japonica 'Golden princess'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Thuja occidentalis 'Rheingold'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Viburnum tinus 'Gwenllian'	**9.0**	**9.0**	**9.0**	**9.0**	**4.0**	**4.0**	**9.0**	<0.001	0
Viburnum x bodnantense 'Dawn'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Vinca minor	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****
Weigelia 'Bristol Ruby'	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**NS**	*****

(-) No statistics were performed on the additional April assessment at Darby Nursery Stock as this was an overall assessment taking into account all plots of the same treatment.

Figure 8. *Azalea* in spring 2016 after receiving a December treatment of Sumimax

Figure 9. *Hebe* in spring 2016 after receiving a December treatment of Sumimax

Figure 10. *Prunus* 2 weeks after treatment - Sumimax

Figure 11. *Viburnum* 18 weeks after treatment - Sumimax

Figure 12. *Phormium* 18 weeks after treatment - Sumimax

Discussion

HDC H25 caused no significant phytotoxic effects to any of the species tested at either site when applied in May. Therefore, HDC H25 appears to be a very promising herbicide for nursery stock container growers once it gains a full label approval for use.

Flexidor 500 + Dual Gold caused some slight scorching to *Buddleja, Clematis* and *Ligustrum*, however all of these species recovered well. *Olearia* (a species with known sensitivity to herbicides) also recovered well.

Leaf scorching was seen on several *Sambucus* plants but these had recovered by the end of the trial period and would have been considered saleable. The damage that was seen on these species was most probably linked to the Dual Gold component of this treatment application. However, this treatment combination did prove to be safe on the vast majority of species that it was tested on, so this treatment combination could be used by nursery stock container growers, but it must be used with caution. It must also be noted that Dual Gold use is restricted between 1 and 31 May.

Springbok was safe to use on most of the species that it was tested on in the container trials (with the exception of *Olearia)*. Therefore, Springbok is a possible treatment to follow up with in late summer to extend the persistence of control from post potting treatments. However, there are restrictions in the EAMU on application methods and crop handling following its use.

Successor also proved to be a safe treatment (with the exception of *Olearia)* to all of the species of nursery stock that it was tested on in the HNS trials. It is hoped that an EAMU can be obtained for Successor for ornamental plant production so that growers can include this herbicide in their programme.

Flexidor 500 + Devrinol did cause some severe damage to *Santolina* when applied in August due to the Devrinol component of the treatment. The plants did not recover so it was concluded that a summer application of Devrinol is not safe for use on this species. Although some damage also occurred from a winter application it was not as severe. Leaf scorching on *Ligustrum ovalifolium* persisted throughout to 12 WAT so is unlikely to be a suitable summer treatment. *Hydrangea macrophylla* recovered so Flexidor 500 + Devrinol may be a suitable summer treatment, providing the crop has sufficient time to recover prior to marketing. It is likely that the 5 mm of irrigation applied post herbicide application to wash the Devrinol into the growing media (to prevent photo degradation) is why this was the least damaging of the summer treatments on *Olearia macrodonta* 'Major'.

Flexidor 500 caused phytotoxic damage on *Cotoneaster horizontalis* and *Hydrangea macrophylla* which recovered*,* however *Ligustrum ovalifolium* was classed as moderately susceptible, It is worth noting that damage does not occur when Flexidor is applied, it is the later, soft new growth that is damaged – this should not be a problem where commercial crops are treated straight after potting, particularly if they have been cut back. Damage on *Olearia macrodonta* 'Major' and *Osmanthus x burkwoodii* affected the growing tips, and the damage persisted therefore these species were both considered susceptible.

Devrinol was a fairly safe treatment, all species with the exception of *Olearia macrodonta* 'Major' and *Santolina chamaecyparissus* grew away from any damage. The weather prior to the winter application of Devrinol had been unseasonably mild. Plants were still in active growth at the time that Devrinol was applied which may help to explain why more damage resulted than was expected from a winter application.

Sumimax was found to be safe on the majority of species it was tested on in the Norfolk trial, but a few, particularly evergreens, suffered more severe damage. The species that were damaged were *Abelia, Hebe, Ligustrum* and *Azalea*. The Sumimax application caused scorch on *Hebe* and *Ligustrum* and defoliation on *Abelia* and *Azalea* and the plants were not commercially acceptable at the end of the trial, spring 2016. Some slight leaf scorch damage was also seen on *Buddleja* and *Hypericum* when the plants were re-assessed in March, however by April 2016 these species were both considered commercially acceptable. More damage occurred earlier in the Hereford trial when compared to the Norfolk trial. Plants were still in active growth at the time of Sumimax application; growth was still relatively soft for the time of year which is likely to have predisposed evergreens to crop damage, many of which were affected. The Sumimax caused leaf scorch on *Prunus laurocerasus* and leaf discoloration on *Viburnum tinus* 'Gwenllian' which rendered these plants unsaleable, therefore they should not be treated. Other evergreen species were affected to a lesser extent but slight damage was still visible 18 WAT (late April). Therefore it is unlikely that Sumimax will be a suitable treatment for *Ligustrum, Olearia, Osmanthus, Phormium* or *Santolina.* Sumimax did however prove to be a safe treatment on the deciduous species tested.

Liverwort trials

Materials and methods

In total 24 treatments, including an untreated control, were applied either pre- or post-emergence, or at both timings to test their efficacy for controlling liverwort (Table 29). The pre-emergence treatments were applied to pots immediately before placing an infector plant, a pot of peat-based compost with 100% liverwort cover, in the middle of each plot. The infector plant was surrounded by 20 pots filled with a peat-based compost and was placed in the center of each plot to determine how well the liverwort spread after the 20 pots had been treated. For the post-emergence treatments, one pot with 100% liverwort cover was treated as a plot and the post-emergence treatments were then applied to the individual pots so that the efficacy of the different treatments could be tested.

Both parts of the trial were set up as a randomised block design and were in a polytunnel at ADAS Boxworth. Treatments were replicated four times, giving a total of 96 plots. Pre-emergence plots measured 0.4 m long by 0.5 m wide and contained 20 unplanted 9 cm liner pots containing a peat growing media and one infector plant in a 2 litre pot. Post-emergence plots also measured 0.4 m by 0.5 m but the treated area consisted of a 2 litre pot. The trial was set up in summer 2015 and repeated in winter 2015-16.

For the summer trial, pre-emergence treatments were applied on 31 July 2015 and post-emergence treatments were applied on 3 September 2015. Plots were assessed every two weeks for a period of 12 weeks. Additional assessments were carried out to determine the period of liverwort control that could be achieved by the promising post-emergent treatments. Pre-emergence plots were assessed by calculating the percentage liverwort cover of the 20 pots and the post-emergence part of the trial was assessed by recording the percentage of green thallus cover of the plot.

For the winter trial the pre-emergence treatments were applied on 16 December 2015 and the post-emergence treatments were applied on 6 January 2016. The same assessments as before were carried out every two weeks over a 13 week period. The treatments were applied using an air assisted knapsack sprayer at a water volume of 1000 L/ha. However, HDC H25 (a granular formulation) and Sodium bicarbonate (a powder) were applied by calculating the appropriate weight of granules and powder for the surface area of the pot. These two treatments were then applied using a shaker pot.

Table 29. Treatments and timings of application for liverwort trial at ADAS Boxworth (UTC = untreated control)

Treatment no.	Treatment	Rate (kg/L/ha)	Timing of application
1	UTC	N/A	N/A
2	Chikara (flazasulfuron)	0.15	Pre-emergence
3	Finalsan plus (pelargonic acid + maleic hydrazide)	166.0	Pre-emergence
4	Successor (pethoxamid)	2.0	Pre-emergence
5	Springbok (metazachlor + dimethenamid-p)	1.66	Pre-emergence
6	HDC H25	220.0 as granule	Pre-emergence
7	Sumimax (flumioxazine)	0.1	Pre-emergence
8	Venzar (lenacil)	5.0	Pre-emergence
9	Wing-p (pendimethalin + dimethenamid-p)	3.5	Pre-emergence
10	Chikara (flazasulfuron)	0.15	Post-emergence
11	Acetic acid e.g. New Way weed Spray or OWK	250.0	Post-emergence
12	Finalsan plus (pelargonic acid + maleic hydrazide)	220.0	Post-emergence
13	Quickdown (pyraflufen ethyl)	0.8	Post-emergence
14	Reglone (diquat)	2.0	Post-emergence
15	Successor	2.0	Post-emergence

Treatment no.	Treatment	Rate (kg/L/ha)	Timing of application
16	Springbok (metazachlor + dimethenamid-p)	1.66	Post-emergence
17	HDC H25	220.0 as granule	Post-emergence
18	Sumimax (flumioxazine)	0.1	Post-emergence
19	Venzar (lenacil)	5.0	Post-emergence
20	Wing-p (pendimethalin + dimethenamid-p)	3.5	Post-emergence
21	MMC Pro (didecyl dimethyl ammonium chloride)	200.0	Post-emergence
22	MMC Pro (didecyl dimethyl ammonium chloride) + Reglone (diquat)	200.0 + 2.0	Post-emergence
23	Mosskade (natural substances)	100.0	Post-emergence
24	Sodium bicarbonate	As powder to cover	Post-emergence

Results

Summer trial

In the pre-emergence trial the liverwort was slow to establish, even in the untreated plots. Springbok, HDC H25, Venzar and Wing P, when applied as pre-emergence treatments, appeared to prevent the spread of liverwort throughout the entire period of the trial, 12 weeks (**Figure 13**). The untreated plots and plots treated with Chikara, Successor or Sumimax all had less than 5% liverwort cover at the assessment carried out on 25 September 2015, three and a half weeks after the pre-emergence treatments had been applied. At this assessment plots treated with Finalsan plus had the highest percentage of liverwort cover, 21%, significantly higher than all the other treatments (p=0.046, l.s.d. 13.02). None of the other treatments were significantly different on this date. A small amount of liverwort (less than 5% plot cover) was seen in the untreated plots and in plots treated by Chikara or Successor at this time.

After 12 weeks, on 21 October, the plots that had been treated with Finalsan plus had the highest percentage of liverwort (59%). This treatment was significantly different from all of the other treatments on this date (p<0.001, l.s.d.=10.65). On this date, liverwort cover had increased slightly in the untreated plots and the plots that had been treated with either Chikara, Successor or Sumimax. However, the greatest increase in liverwort was by 3% in the untreated plots. Plots treated with either Springbok, HDC H25, Venzar or Wing-P that had been liverwort free at 8 WAT, remained free from liverwort at the final assessment made 12 weeks after the pre-emergence treatments had been applied.

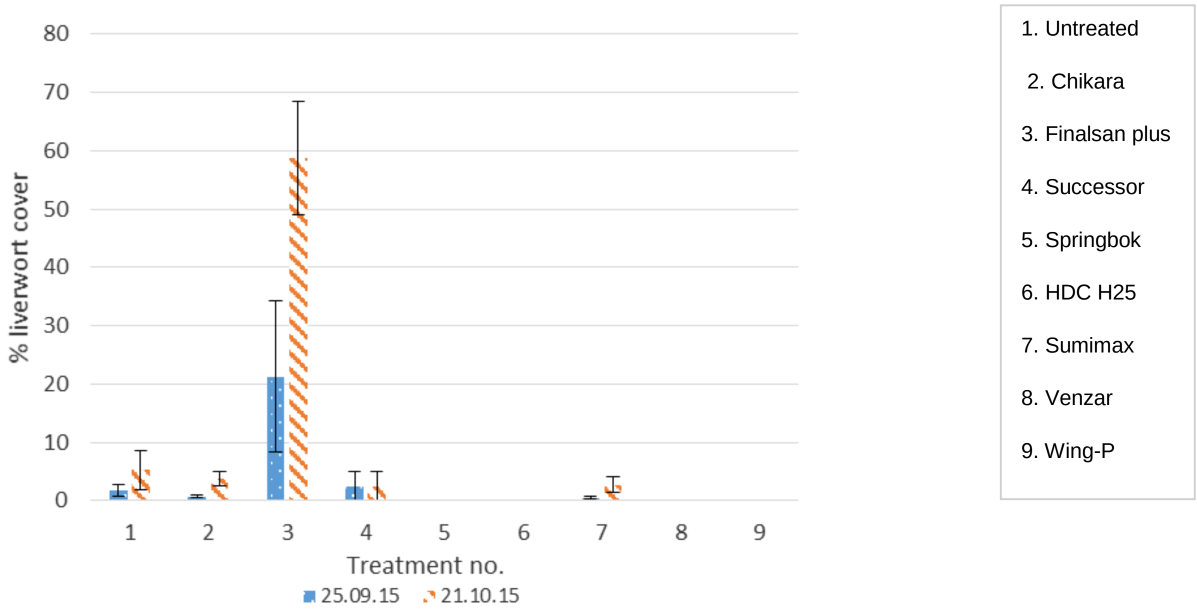


Figure 13. Percentage liverwort cover on 25 September 2015 and 21 October 2015 for pre-emergence treatments (summer trial)

All plots treated with post-emergence sprays started off with 100% liverwort (green thallus) cover (Figure 14). By 29 September 2015, 8 WAT, Finalsan plus, Reglone, MMC Pro + Reglone, Mosskade and Sodium bicarbonate had all reduced the percentage liverwort cover of plots (p=<0.001, l.s.d.=29.38). Sodium bicarbonate was the most effective treatment, when applied post-emergence, with a liverwort cover of 2.5% 8 WAT.

After 12 weeks MMC Pro, MMC Pro + Reglone, Mosskade and Sodium bicarbonate all had significantly lower percentage liverwort cover compared to the untreated control (p=<0.001, l.s.d.=17.74). On this date, 12 WAT, Sodium bicarbonate remained the best at controlling liverwort, when applied post-emergence. Liverwort cover in the sodium bicarbonate treated plots remained at 2.5% on this date (Figure 15).

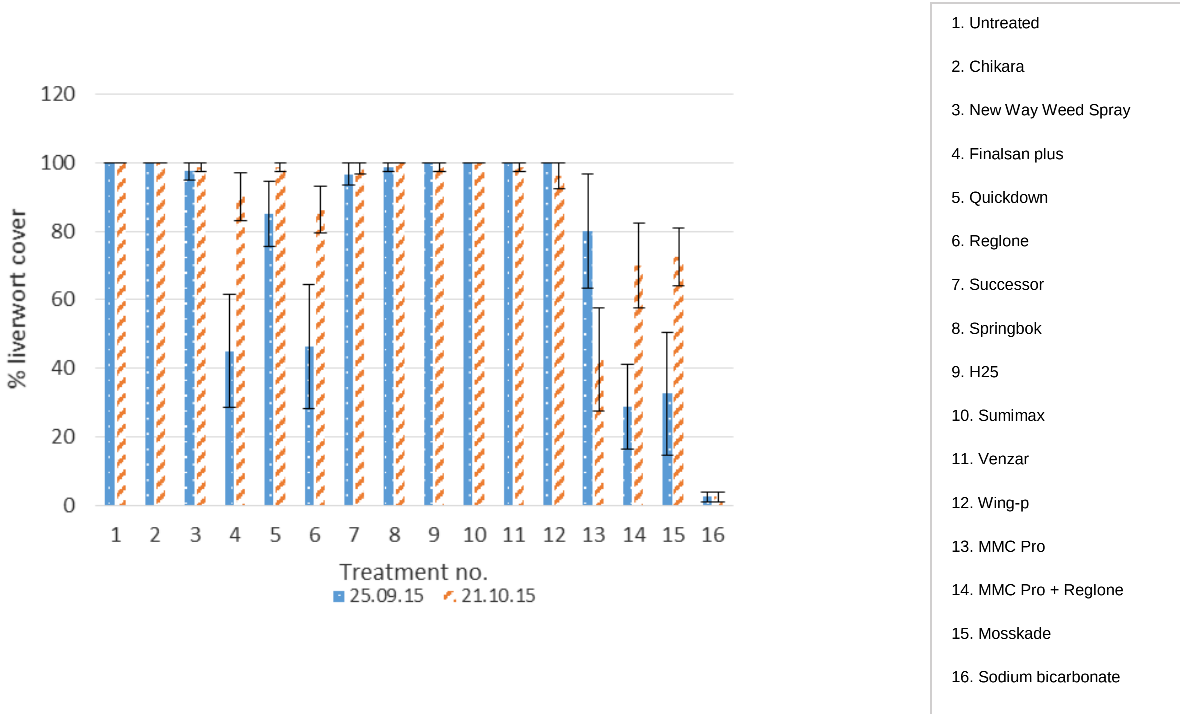


Figure 14. Percentage liverwort cover on 25 September 2015 and 21 October 2015 for post-emergence treatments (summer trial)

Figure 15. Liverwort treated with Sodium bicarbonate 2 weeks after treatment

Winter trial

In the pre-emergence part of the trial, liverwort did not spread from the infector plant into the smaller pots until eight weeks into the trial, even in the untreated plots (Figure 16). Eight weeks after the pre-emergence treatments had been applied, 15 February 2016, the untreated plots had significantly more liverwort cover than any of the treated plots with an average of 15% liverwort cover (p=<0.001, l.s.d. 9.59) (Figure 17). On this date the only plots that had any liverwort cover were the plots that had been treated with Sumimax and Venzar. Both of these treated plots had less than 5% liverwort cover. By the end of the trial, 12 weeks after the treatments had been applied, liverwort had increased to 65% cover in the untreated plots and remained as being significantly higher compared to all the other treatments. Some liverwort could be seen in plots that had received pre-emergence treatments of Chikara, Finalsan plus, Successor, Sumimax or Venzar; however none of these treatments had over 10% liverwort cover. At the end of the trial no liverwort had spread in plots that had been treated with Springbok (Figure 18), HDC H25 or Wing-P.

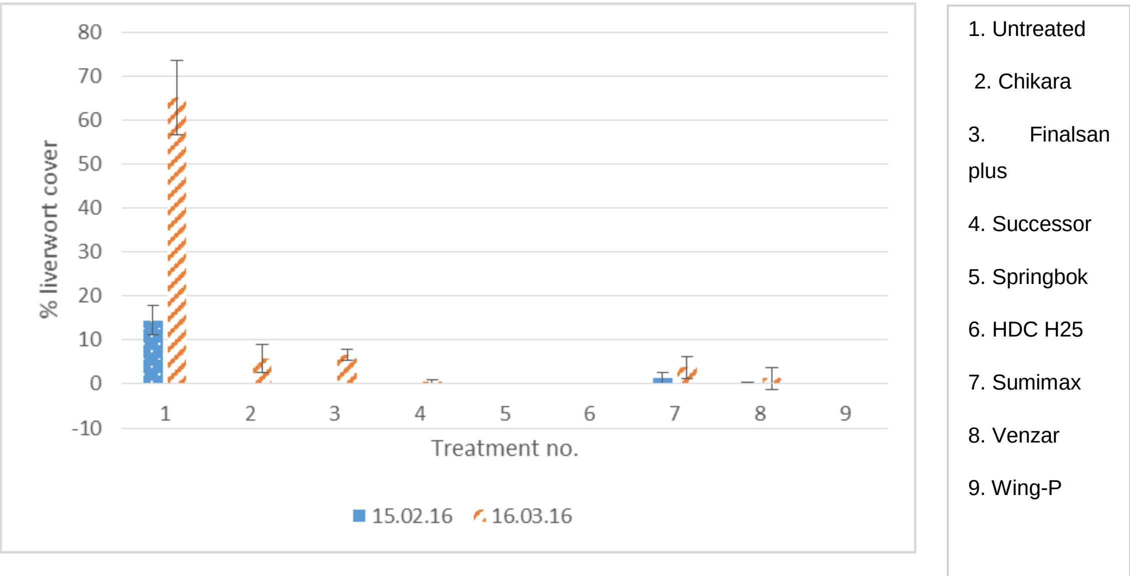


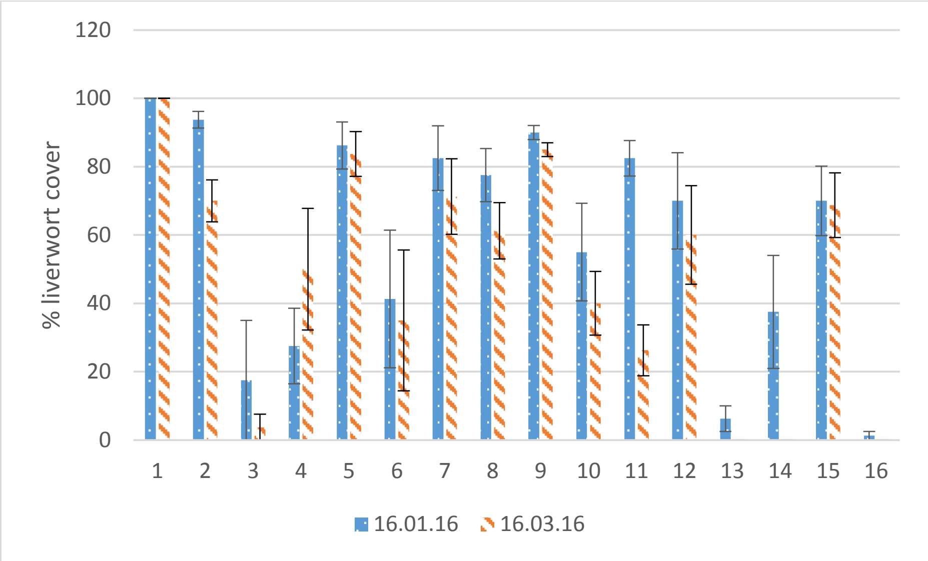
Figure 16. Percentage liverwort cover on 15 February 2016 and 16 March 2016 for pre-emergence treatments (winter trial)

Figure 17. Untreated liverwort 8 weeks after treatment

Figure 18. Pots that received a pre-emergence application of Springbok in the liverwort trial 12 weeks after treatment

Four weeks after post-emergence treatments were applied (16 January 2016,) New Way Weed Spray, Finalsan plus, Reglone, Sumimax, MMC Pro, MMC Pro + Reglone and Sodium bicarbonate all had significantly less liverwort cover than the untreated control ($p<0.001$, l.s.d.=30.80) (Figure 19). At this assessment Sodium bicarbonate had achieved the best liverwort control (1.2%) (Figure 20). The second best performing treatment was MMC Pro with 6.2% liverwort cover (Figure 21).

At the 12 week assessment, on 16 March 2016, New Way Weed Spray, Finalsan plus, Reglone, Sumimax, Venzar, MMC Pro, MMC Pro + Reglone and Sodium bicarbonate had significantly lower liverwort percentages than the untreated control plots. MMC Pro, MMC Pro + Reglone and Sodium bicarbonate each had zero percentage liverwort cover. New Way Weed Spray treated plots had 3.8% liverwort cover by the 12 WAT assessment.



1. Untreated
2. Chikara
3. New Way Weed Spray
4. Finalsan plus
5. Quickdown
6. Reglone
7. Successor
8. Springbok
9. H25
10. Sumimax
11. Venzar
12. Wing-P
13. MMC Pro
14. MMC Pro + Reglone
15. Mosskade
16. Sodium bicarbonate

Figure 19. Percentage liverwort cover on 16 January 2016 and 16 March 2016 for post-emergence treatments (winter trial)

Figure 20. Liverwort treated with Sodium bicarbonate 12 weeks after treatment

Figure 21. Liverwort treated with MMC Pro 12 weeks after treatment

Discussion

Due to poor liverwort establishment, the pre-emergence trial results from the summer trial should be taken with caution. In this trial Springbok, HDC H25, Venzar and Wing-P appeared to prevent the spread of liverwort throughout the entire period of the trial, a period of 12 weeks. In the pre-emergence part of the trial the highest infestation of liverwort was seen in plots treated with Finalsan plus. Finalsan plus is a contact acting herbicide and so it wouldn't be expected to have any residual activity against liverwort. However, this doesn't explain why plots treated with this herbicide had significantly higher liverwort cover than the untreated control plots. When the trial was repeated in winter, all of the pre-emergence treatments prevented the spread of liverwort compared to the untreated control, and plots that were treated with either Springbok, H25 or Wing–P prevented any liverwort from establishing throughout the entire 12 week period. The results from the winter trial are similar to the summer trial in that in both trials the pre-emergence treatments of Springbok, HDC H25 and Wing-P successfully controlled liverwort throughout the 12 week period. The only anomaly is the Finalsan plus, which did not cause the plots to have significantly higher coverages of liverwort, as was seen in the summer trial, when the trial was repeated in winter. The best liverwort control was achieved when Sodium bicarbonate was applied post-emergence. This treatment acted instantly when applied to liverwort and had killed most liverwort 1 week after the application was made in both the summer and winter trial. Eight weeks after the post-emergence treatments were applied MMC Pro + Reglone, Mosskade and Sodium bicarbonate looked the most promising in terms of liverwort control in the summer trial, however by 12 weeks MMC Pro + Reglone and Mosskade provided no further control and the liverwort started re-growing.

Similar results were seen in the winter trial with Sodium bicarbonate providing quick and long lasting control of the liverwort. This treatment gave the best results in both the summer and winter trial, showing that it would be a valuable treatment for warmer or colder temperatures. MMC Pro and MMC Pro + Reglone performed very well in both the summer and winter trials offering lost lasting control of liverwort. New Way weed spray, Finalsan plus, Reglone, Venzar and Sumimax all performed much better in terms of liverwort control in the winter trial compared to the summer trial indicating that these treatments would work best by applying them in winter. The Venzar did not provide immediate control of liverwort in the winter trial but after 12 weeks, the liverwort present in the Venzar plots had decreased significantly.

Crataegus trial

Materials and methods

The ornamentals herbicide trial was set up on a commercial nursery; J&A Growers Ltd, Warwick. The test species was a second year (1+1) crop of *Crataegus monogyna* (provenance 402) that had been sown into a pre-formed bed on 16 April 2014 and that was treated with Basamid in autumn 2013.

A fully randomised block design with eight treatments per bed, including an untreated control, replicated three times, giving a total of 24 plots. Within each bed, plots were 1.5 meters wide and 4 meters long. Further details can be found in Appendix 2.

The herbicide treatments (eight treatments including the untreated control) consisted of seven different herbicides: Stomp Aqua (pendimethalin), Gamit 36 CS (clomazone), Springbok (dimethenamid-p + metazachlor), Flexidor 500 (isoxaben), Successor (pethoxamid), HDC H24, Nirvana Low rate (imazamox + pendimethalin), Nirvana High rate (imazamox + pendimethalin) and Samson Extra 6% (nicosulfuron); all of these herbicides were either used alone or in combination (Table 30). Treatment programmes also included an untreated control for comparison. Additional information for each treatment can be found in Table 31.

The treatments were applied to the plots using an OPS sprayer with a boom with three 03/F110 nozzles delivering a medium spray at 200 L/ha. Some weeds were present when the trial was marked out so willowherb was removed by hand as glyphosate does not control this species well. An overspray of Clinic Ace (glyphosate) was applied over the top of all plots on

18 February 2015 to kill other existing weeds. The residual herbicides were applied on the same day.

Phytotoxicity was assessed later than usual (due to very cold weather and a late spring which resulted in the crop staying dormant until early April) at 7, 10 and 16 weeks after the herbicide applications were made. Phytotoxicity assessments involved comparing the treated plots to the untreated controls and awarding scores on a scale of 0 to 9 where 0 is dead, 7 is commercially acceptable and 9 is healthy and comparable with an untreated control. A weed cover assessment was carried out at ten weeks after treatment as there was so little weed cover. A percentage score was recorded for weeds found in each plot and weed species present were recorded.

Table 30. Details of the residual herbicides used for the Crataegus herbicide trials 2015

Treatment No.	**Product number**	**Rate (kg/L/ha)**
1	Untreated control	N/A
2	Stomp Aqua + Gamit 36 CS	2.9 l/ha + 250 ml/ha
3	Stomp Aqua + Gamit 36 CS Springbok	2.9 l/ha + 250 ml/ha 1.66 l/ha
4	Flexidor 500 + Successor	0.5 l/ha 2.0 l/ha
5	Flexidor 500 + HDC H24	0.5 l/ha + x
6.	Nirvana Low rate	3.0 l/ha
7.	Nirvana High rate	4.5 l/ha
8.	Samson Extra 6%	0.75 l/ha

(x) Undisclosed

Table 31. Details of the residual herbicides active ingredients for the Crataegus herbicide trials 2015

Product number	Active ingredient
Untreated control	N/A
Stomp Aqua +	Pendimethalin
Gamit 36 CS*	Clomazone
Springbok	dimethenamid-p + metazachlor
Flexidor 500 +	Isoxaben
Successor	Pethoxamid
HDC H24	*Undisclosed*
Nirvana	Imazamox + pendimethalin
Samson Extra 6%	Nicosulfuron

The heights of 10 plants within the central region of each plot were measured at the end of the growing season on 16 October 2015.

Results

Table 32. Details of percentage weed cover, assessed 10 weeks after treatment (WAT)

Treatment	Percentage weed cover 10 WAT	Weed species
1 (Untreated control)	1.7	*Cirsium arvensis, Cirsium vulgare, Capsella bursa – pastoris, Epilobium spp, Poa annua, Sonchus oleraceus, Stellaria media, Senecio vulgaris, Solanum nigrum, Viola arvensis.*
2 (Stomp Aqua + Gamit 36 CS)	0.7	*Epilobium spp., Solanum nigrum,*
3 (Stomp Aqua + Gamit 36 CS + Springbok)	0	
4 (Flexidor 500 + Successor)	0	
5 (Flexidor 500 + HDC H24)	0.3	*Poa annua.*
6 (Nirvana Low rate)	1.0	*Poa annua, Senecio vulgaris, Stellaria media, Viola arvensis*
7 (Nirvana High rate)	0	*Senecio vulgaris*
8 Samson Extra 6%)	0.3	*Sonchus oleraceus*

The second year *Crataegus* crop out competed annual weeds by the time residual herbicides applied in late winter were running out, as the crop canopy became dense by early summer.

Unsurprisingly the weed cover and number of weed species present was slightly higher in the untreated controls.

Stomp Aqua + Gamit 36 CS + Springbok resulted in slight initial damage which was considered commercially acceptable, and the *Crataegus* grew away from this damage. Nirvana was the most damaging treatment at both rates applied; the low rate resulted in initial stunting, and although the crop grew away from this, the damage was still visible by 16 WAT (weeks after treatment), and the statistics support this (Table 33, p,0.001, l.s.d=1.114). The high rate of Nirvana was more damaging, resulting in stunted and bleached growth that was still showing signs of damage by 16 WAT (Table 33).

Mean height was also measured, and *Crataegus* treated with Samson Extra 6% were found to be taller than the control (Table 34)

Table 33. Mean phytotoxicity scores for ornamental herbicide trial 6, 10 and 16 weeks after treatment (WAT) (Scale of 0-9 where 0 is dead and 7 is commercially acceptable)

Assessment date	**Trt 1 (Untreated control)**	**Trt 2 (Stomp Aqua + Gamit 36 CS)**	**Trt 3 (Stomp Aqua + Gamit 36 CS + Springbok)**	**Trt 4 (Flexidor 500 + Successor)**	**Trt 5 (Flexidor 500 + HDC H24)**	**Trt 6 (Nirvana Low rate)**	**Trt 7 (Nirvana High rate)**	**Trt 8 (Samson Extra 6%)**	**P value**	**LSD (df 14)**
7 WAT	9	8.3	7	9	9	9	6	9	<0.001	0.3575
10 WAT	9	9	8.3	9	9	6	2	9	<0.001	1.877
16 WAT	9	8.3	8.3	9	9	7	5.6	9	<0.001	1.114

Table 34. Mean height measurements by treatment, taken at the end of the growing season on 16 October 2015

Trt 1 (Untreated control)	**Trt 2 (Stomp Aqua + Gamit 36 CS)**	**Trt 3 (Stomp Aqua + Gamit 36 CS + Springbok)**	**Trt 4 (Flexidor 500 + Successor)**	**Trt 5 (Flexidor 500 + HDC H24)**	**Trt 6 (Nirvana Low rate)**	**Trt 7 (Nirvana High rate)**	**Trt 8 (Samson Extra 6%)**	**P value**	**LSD (df 14)**
81	82.3	76.2	77.7	75	73.2	76.9	83	0.782	16.54

Figure 22. *Crataegus* treated with the low rate of Nirvana (left) and high rate (right) both 10 weeks after treatment

Discussion

Nirvana applied at the high rate resulted in persistent crop damage and as a result was not considered a commercially acceptable treatment. The low rate Nirvana was less damaging but was still more damaging than any of the other treatments within this trial. All of the other treatments were crop safe and are suitable for use as residual herbicides on *Crataegus.* An EAMU will need to be sought to facilitate the use of HDC 24. There was little difference between the weed control of treatments due to the crop's age and ability to out compete weeds. Although there was a slightly significant difference between mean crop heights, the difference, in reality, was negligible. The Nirvana treatments resulted in slightly shorter crops but no excessive stunting occurred.

Conclusions

Container nursery stock herbicide trial

The most promising herbicide programmes for container nursery stock would start with a post-potting application of new herbicide HDC H25. In the interim before this herbicide is made available, a programme starting with Flexidor 500 + Dual Gold is possible for May potting but a few species suffered temporary phytotoxicity. Later in summer, follow up treatments of

Springbok or Successor were safe to most species as was the winter treatment of Devrinol. Most damage was caused by Sumimax as a winter treatment, particularly on evergreens.

Liverwort

Springbok, HDC H25 and Wing-P all prevented the spread of liverwort for the entire period of the trials when applied as pre-emergences in the liverwort trials. Sodium bicarbonate gave very promising results on liverwort control when applied as a post-emergence application to liverwort and remained effective for 12 weeks (the entire period of the trial). MMC Pro and MMC Pro + Reglone both showed very promising results, when applied as post-emergence applications, in both the summer and winter liverwort trials.

Crataegus trials

Stomp Aqua + Gamit 36 CS, Stomp Aqua + Gamit 36 CS + Springbok, Flexidor 500 + Successor, Flexidor 500 + HDC H24 and Samson Extra 6%, all proved to be crop safe when applied as late winter residual herbicides when the crop was still dormant. These new herbicide options will help growers to control weeds effectively in the future.

Knowledge and Technology Transfer

A news article was published in the May edition of the AHDB grower magazine, pages 11 - 13.

AHDB Herbicide workshops are taking place at Coles Nurseries, Leicestershire on 29/06/16 and at Hillier's Nurseries in Hampshire on 30/06/16.

References

Atwood, J. (2005). Protected container-grown nursery stock: Chemical and non-chemical screening for moss and liverwort control in liners. Horticultural Development Company Final report for project HNS 93c.

Atwood, J. (2013). Practical weed control for nursery stock (a grower guide, hardy nursery stock). Horticultural Development Company, revised 2013.

Atwood, J. (2015). Herbicide screening for ornamental plant production (nursery stock, cut flowers and wallflowers). Agriculture and Horticulture Development Board. Final report for project HNS/PO 192.

Scott, M., Hutchinson, H. and Williams, S. (2001). Nursery Stock Propagation: control of moss, liverwort and algae. Horticultural Development Company Final report for project HNS 93.

Appendices

Appendix 1. Container grown nursery stock residual herbicide programmes, Wyevale containers, Hereford.

All plants for this trial were propagated and produced on site with the exception of *Rosa rugosa* which was bought in. No liquid fertilisers or pesticides were applied to trial plants during the course of this trial.

Table 1. Key to growing media mixes

Species	**Growing media mix / specification**	**Potting Week 2015**
Berberis darwinii	Inside mix (Met)	8
Brachyglottis ‘Sunshine’	Short term mix	20
Buxus sempervirens	Long term mix	19
Cotoneaster horizontalis	Outside spring mix (Met)	21
Escallonia ‘Iveyi’	Outside spring mix (Met)	24
Euonymus ‘Green Rocket’	OS Outside spring mix (Met)	19
Forsythia intermedia ‘Lynwood’	OS Outside spring mix (Met)	18
Hydrangea macrophylla	Long term mix	27
Ligustrum ovalifolium	OS Outside spring mix (Met)	8
Olearia macrodonta ‘Major’	Inside mix (Met)	26
Osmanthus x burkwoodii	Inside mix (Met)	21
Philadelphus ‘Beauclark’	OS Outside spring mix (Met)	18
Phormium tenax	Long term mix	20
Potentilla fruticosa Primrose Beauty	OS Outside spring mix (Met)	16
Prunus laurocerasus	High Lime (Met)	8
Pyracantha ‘Red Column’	OS Outside spring mix (Met)	21
Rosa rugosa	OS Outside spring mix (Met)	6
Santolina chamaecyparissus	Short term mix	21
Viburnum tinus ‘Gwenllian’	Inside mix (Met)	13
Viburnum x bodnantense ‘Dawn’	OS Outside spring mix (Met)	21

Table 2. Inside mix recipe (target pH 5.30 pH (H^20):

Amount	**Ingredient details**
50%	White peat surface milled (0-25 mm)
25%	White sod peat (10-25 mm)
25%	GreenFibre coarse
0.75 kg/cubic metre	PG Mix 12/14/24
0.25 kg/ cubic metre	PG Micro mix (Trace elements)
4.5 kg/cubic metre	Osmocote Exact 8-9 Month
0.5 kg/cubic metre	MET52
0.5 kg/cubic metre	K Hydro-S (Wetting Agent)

Table 3. Short-term mix recipe (target pH 5.30 pH (H^20):

Amount	**Ingredient details**
50%	White peat surface milled (0-25 mm)
25%	White sod peat (10-25 mm)
25%	GreenFibre coarse
0.75 kg/cubic metre	PG Mix 12/14/24
0.25 kg/ cubic metre	PG Micro mix (Trace elements)
3.3 kg/cubic metre	Osmocote Exact 8-9 Month
0.5 kg/cubic metre	MET52
0.5 kg/cubic metre	K Hydro-S (Wetting Agent)

Table 4. Long-term mix recipe (target pH 5.30 pH ($H^{2}0$):

Amount	Ingredient details
50%	White peat surface milled (0-25 mm)
25%	White sod peat (10-25 mm)
25%	GreenFibre coarse
0.75 kg/cubic metre	PG Mix 12/14/24
0.25 kg/ cubic metre	PG Micro mix (Trace elements)
6.0 kg/cubic metre	Osmocote Exact 12-14 Month
0.5 kg/cubic metre	MET52
0.5 kg/cubic metre	K Hydro-S (Wetting Agent)

Table 5. Outside spring mix recipe (target pH 5.30 pH ($H^{2}0$):

Amount	Ingredient details
50%	White peat surface milled (0-25 mm)
25%	White sod peat (10-25 mm)
25%	GreenFibre coarse
0.75 kg/cubic metre	PG Mix 12/14/24
0.25 kg/ cubic metre	PG Micro mix (Trace elements)
2.25 kg/cubic metre	Osmocote Exact 8-9 Month
3.30 kg/cubic metre	Osmocote Exact 12-14 Month
0.5 kg/cubic metre	MET52
0.5 kg/cubic metre	K Hydro-S (Wetting Agent)

Table 6. High Lime mix recipe (target pH 6.20 pH ($H^{2}0$):

Amount	Ingredient details
50%	White peat surface milled (0-25 mm)
25%	White sod peat (10-25 mm)
25%	GreenFibre coarse
0.75 kg/cubic metre	PG Mix 12/14/24
0.25 kg/ cubic metre	PG Micro mix (Trace elements)
6.0 kg/cubic metre	Osmocote Exact 12-14 Month

Amount	Ingredient details
0.5 kg/cubic metre	MET52
0.5 kg/cubic metre	K Hydro-S (Wetting Agent)

Appendix 2. Crataegus trial, J & A Growers, Warwick.

Table 7. Crop history / inputs (insecticides, fungicides, herbicides and fertilisers):

Date	Product	Rate per Hectare l/kg
03/04/14	Hydro Complex	500
16/04/14	Seed sown	Seed rate worked out on seed viability.
22/04/14	Centium 360 CS (clomazone)	0.150
	Stomp Aqua (pendimethalin)	2.9
	Cropspray 11E	0.400
	Azural (glyphosate)	2.400
28/04/14	Azural (glyphosate)	2.400
01/06/14	Justice (proquinazid)	0.250
	Headland Sulphur	2.500
	Hallmark (lambda-cyhalothrin)	0.090
02/06/14	Aramo (tepraloxydim)	1.500
	Calcium Nitrate (Tropicoat 600kg)	250.000
03/06/14	Croplift	2.500
	P-Kursor	1.000
11/06/14	Azural (glyphosate)	3.500
	Shark (carfentrazone-ethyl)	0.330
12/06/14	Signum (boscalid + pyraclostrobin)	1.500
	Headland Sulphur	2.500
	Megafol	2.000
23/06/14	Megafol	2.000

Date	Product	Rate per Hectare l/kg
	Flexity (metrafenone)	0.500
	Headland Sulphur	2.500
	Hallmark (lambda-cyhalothrin)	0.090
25/06/14	Calcium Nitrate (Tropicoat 600kg)	250.000
	Croplift	2.500
	P-Kursor	1.000
02/07/14	Cosine (cyflufenamid)	0.500
	Headland Sulphur	2.500
	Megafol	2.000
10/07/14	Azural (glyphosate)	3.500
	Shark (carfentrazone-ethyl)	0.330
11/07/14	Justice (propquinazid)	0.250
	Headland Sulphur	2.500
	Hallmark (lambda-cyhalothrin)	0.090
	Megafol	2.000
22/07/14	Signum (boscalid + pyraclostrobin)	1.500
	Headland Sulphur	2.500
	Potassium bicarbonate	10.000
	Megafol	2.000
23/07/14	Calcium Nitrate (Tropicoat 600kg)	250.000
30/07/14	Flexity (metrafenone)	0.500
	Potassium bicarbonate	10.000
	Hallmark (lambda-cyhalothrin)	0.090
	Megafol	2.000
08/08/14	Cyflamid (cyflufenamid)	0.500
	Potassium bicarbonate	10.000

Date	Product	Rate per Hectare l/kg
	Megafol	2.000
18/08/14	Calcium Nitrate (Tropicoat 600kg)	211.765
	Calcium Nitrate (Tropicoat 25kg)	367.647
19/08/14	Talius (proquinazid)	0.250
	Potassium bicarbonate	10.000
	Hallmark (lambda-cyhalothrin)	0.090
	Megafol	2.000
02/09/14	Potassium bicarbonate	10.000
	Megafol	2.000
16/09/14	Flexity (metrafenone)	0.500
	Potassium bicarbonate	10.000
23/09/14	Leaf fall	5.500
	Slither	0.370
02/10/14	Leaf fall	5.500
	Slither	0.370

SCIENCE SECTION CUT FLOWER TRIALS

Introduction

The growing UK demand for cut flowers provides a significant business development opportunity for UK growers regarding the production of field-grown flowers. However, the lack of technical information for the wide diversity of traditional and novel species being grown is a major limiting factor behind the expansion of this sector. Included in this is the shortfall of information on herbicides. At present, there are no on-label herbicide recommendations for outdoor flower crops, as many agrochemical companies do not consider the relatively minor overall economic value of such specialist crops sufficient to justify the cost of the development and approval process of substances. As a consequence, growers rely on hand weeding and cultivation, which are both expensive and unreliable in wet conditions. The other option for growers in terms of weed control is the use of off-label herbicide usage through EAMUs (Extension of Authorisation for Minor Uses) or LTAEU (Long Term Arrangements for Extension of Use).

The ADHB has previously funded herbicide trials on outdoor cut flowers, with specific studies on the major crops; Sweet William (*Dianthus barbartus*), Chrysanthemum and Larkspur (*Delphinium consolida*) (BOF 29, 30 and 40 respectively). In 2003 to 2005, a multi-screen study was carried out on China aster (*Callistephus chinensis*), Cornflower (*Centaurea cyanus*), Zinnia, Larkspur, Love-in-a-mist (*Nigella damascena*), Delphinium, Bupleurum, Snapdragon (*Antirrhium*), Stocks (*Matthiola incana*) and Phlox (BOF 51). These herbicide trials followed an earlier Defra-funded project on tunnel-grown flowers (HH1528SPC). Projects BOF 51, BOF 58 and HH1528SPC provided information on a range of treatments that could be employed by growers at the time. However, following the loss of key herbicide active ingredients such as oxadiazon (Ronstar Liquid), chlorthal-dimethyl (Dacthal-w75) and propachlor (Ramrod) and the impeding loss of linuron, it is necessary to find more options for cut flower and wallflower growers. Recently, new herbicide actives such as benfluralin have been developed for the UK arable or vegetable market and appear to have promise for use on cut flower crops and wallflowers.

In 2014, trials on drilled China aster (HNS PO 192) showed treatments of propyzamide (Kerb Flo 400), imazamox plus pendimethalin (Nirvana) and pendimethalin plus clomazone (Stomp Aqua combined with Gamit 36 CS) to have potential for use by cut flower growers. However, further work was needed to refine the rates of use. In the same project, pendimethalin (Stomp Aqua) and prosulfocarb (Defy) was shown to have potential for use on Sweet Williams, but further work was needed to refine the rates of both products when combined in a tank mix. Wallflowers appeared to have tolerance to pendimethalin plus clomazone (Stomp Aqua plus

Gamit 36 CS), however this needed to be confirmed to give confidence in the results. All three drilled crops seemed to be tolerant to benfluralin but additional herbicides would be needed to provide control of a wide weed spectrum. Both Sweet Williams and China aster were shown to have some tolerance to carfentrazone-ethyl (Shark) as a selective contact herbicide.

Good information on weed control spectra is already available from the SCEPTRE project CP 077 vegetable herbicide screening for the herbicides to be tested on flower crops and from project BOF 73 which studied herbicides suitable for narcissus production.

The trials carried out in 2015 were focused on crop safety and were designed to build on the results found in 2014 at the Cut Flower Centre, Holbeach St. Johns, as part of project HNS PO 192. Overall, nine new herbicide treatments were tested either alone or in combinations, for crop safety on four drilled flower species grown outdoors (China aster, Larkspur, Sweet William and Wallflower) and one perennial flower species (Peony). Additionally, three promising herbicide treatments were tested in larger demonstration plots on growers' holdings for drilled Sweet Williams and transplanted China aster. A full treatment list can be found in **Table 35**, along with the current approval status.

Table 35. Products and rates used in the Cut Flower trials, 2015

			Rate kg/ha or L/ha				
Product	**Active**	**Approval status**	**China Aster**	**Larkspur**	**Peony**	**Sweet William**	**Wallflower**
Benfluralin	60% w/w benfluralin	Not approved	2	2	2	2	2
Butisan S	500 g/L metazachlor	Label[1]			1.5		1
Defy	800 g/L prosulfocarb	EAMU outdoor[2]		4		2 4	
Dual Gold	960 g/L s-metolachlor	EAMU outdoor[4]		0.78			
Flexidor 500	500 g/L isoxaben	Label[1]			0.5		
Gamit 36 CS	360 g/L clomazone	EAMU outdoor[3]	0.05 0.125 0.25	0.25	0.125		0.05 0.125 0.25 0.33
Goltix 70 SC	700 g/L metamitron	EAMU[2]				1.0 2.0	
HDC H24	confidential	Not approved		X	X		
Kerb Flo 400	400 g/L propyzamide	Not approved	3.75				

			Rate kg/ha or L/ha				
Product	**Active**	**Approval status**	**China Aster**	**Larkspur**	**Peony**	**Sweet William**	**Wallflower**
Nirvana	250 g/L pendimethalin + 16.7 g/L imazamox	EAMU outdoor	3 4.5				
Ronstar Liquid	250 g/L oxadiazon	Not approved	4.0				
Shark	60 g/L carfentrazone ethyl	EAMU outdoor and protected	0.33 0.66			0.33 0.66	
Stomp Aqua	455 g/L pendimethalin	EAMU outdoor	2	2	2.9	1.0 1.5 2.0	2 2.9
Successor	600 g/L pethoxamid	Not approved		2.0	2.0		
Venzar Flowable	440 g/L lenacil	LTAEU Outdoor			3		
Wing-P	250 g/L pendimethalin + 212.5 g/L dimethenamid-p	EAMU outdoor[2]		1.75	3.5		1.75 3.5

[1]Label only covers use on outdoor trees and shrubs but other ornamentals may be treated outdoors at grower's risk.

[2]Pre-emergence only

[3]Pre-emergence and early post-emergence only

[4]Use only permitted during May

Species 1: China aster (drilled)

Materials and methods

The drilled China aster trial, variety Matsumota, was carried out at the CFC between May and September 2015. The crop was grown on a Lincolnshire silt. The trial was a fully randomised block design with 10 treatments, including an untreated control (Table 36), replicated three times. Each plot was 3 m long and 1.2 m wide and consisted of four rows of plants.

Table 36. Detail of herbicide treatments applied pre or post-drilling to China aster seed - 2015

Trt no.	Pre – drilling	Rate kg/ha or L/ha	Post - drilling	Rate kg/ha or L/ha
1	Untreated	-	Untreated	-
2	Benfluralin (incorp)	2	Gamit 36 CS	0.125
3	Untreated	-	Kerb Flo 400	3.75
4	Untreated	-	Nirvana	3
5	Untreated	-	Nirvana	4.5
6	Untreated	-	Stomp Aqua + Gamit 36 CS	2 + 0.05
7	Untreated	-	Stomp Aqua + Gamit 36 CS	2 + 0.125
8	Untreated	-	Stomp Aqua + Gamit 36 CS	2 + 0.25
9	Untreated	-	Shark (post emergence)	0.33
10	Untreated	-	Shark (post emergence)	0.66

Prior to drilling, the site was marked out and the pre-drilling treatment was applied on 12 May. Benfluralin was tested because it is known to be relatively safe to Compositae species and the follow-up treatment Gamit was selected because the combination was thought likely to provide a broad weed control spectrum. Benfluralin was applied to the soil using an OPS sprayer and a 1.5 m boom with 02f110 nozzles, to achieve a medium spray quality at 200 L/ha. The treatment was then incorporated into the soil using a rake, and lightly irrigated.

The trial was drilled on the same day, and the post-drilling treatments were applied on 13 May. The same sprayer and boom were used, to achieve a medium spray quality at 200 L/ha. All treatments were lightly irrigated afterwards, and the trial was covered with clear polythene. The polythene was removed on 10 June, once plants had reached 1-2 true leaves.

Treatments 9 and 10, a contact acting herbicide, were applied on 14 July, 9 weeks post-drilling, once weeds had emerged and the crop was at four true leaves. The same spray equipment and water volume were used.

The trial was assessed at 4, 6 and 10 weeks after treatment (WAT), on the 10 June, 24 June and 21 July respectively. Plots treated with Shark were assessed 1, 2 and 10 WAT (21 July, 31 July and 21 September respectively). Phytotoxicity was assessed on each plot, using a scale of 0-9, whereby 9 showed no effect, 7 was commercially acceptable damage, 1 was a very severe effect and 0 was plant death. Plots were also assessed for the number of emerged asters on 10 June and 24 June, and percentage weed cover on 24 June. Plots were then hand weeded to prevent competition between weeds and the crop. Data was analysed using ANOVA.

Results

Nirvana applied at 4.5 L/ha post-drilling (T5) was the most phytotoxic treatment, significantly more so than the other treatment, with plants consistently scoring below the commercial standard of 7 (p=0.004, Appendix 3, Table 1). Typical symptoms consisted of yellowing to foliage and stunted growth. At the first assessment, 4 WAT, all treatments aside from T5 were commercially acceptable, with limited phytotoxicity symptoms (Figure 23).

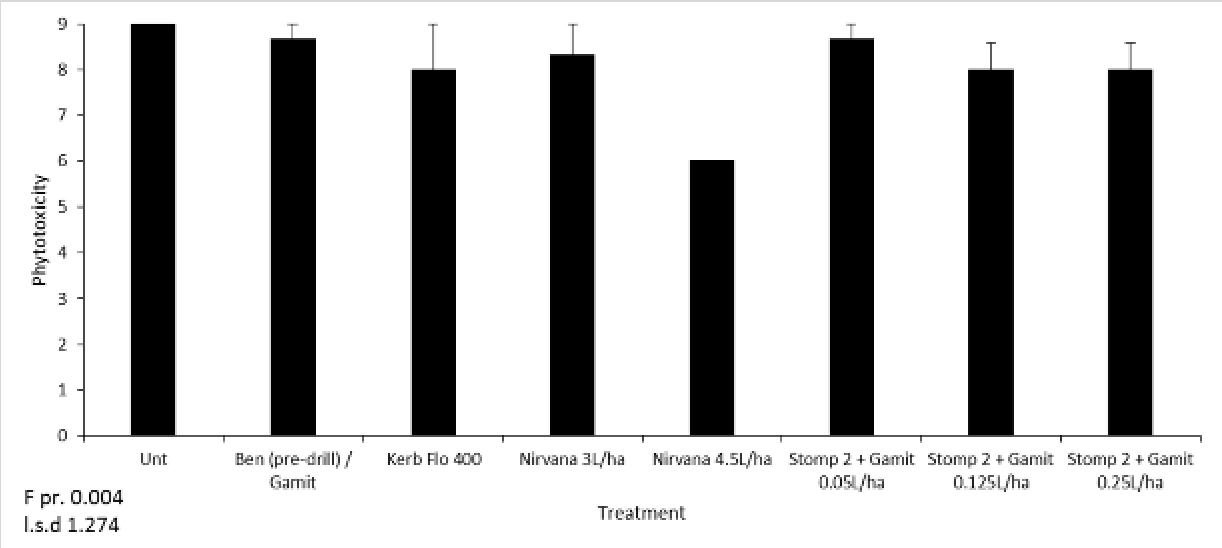


Figure 23. Phytotoxicity scores for each treatment 4 weeks after treatment– 10 June 2015 (scale of 0 - 9 where 9 is healthy, 0 is dead and 7 is commercially acceptable)

At the second assessment, 6 WAT, there was very little difference compared to the assessment 2 weeks previously, with plants treated with Nirvana at 4.5 L/ha (T5) still showing signs of phytotoxicity scoring 6.3.

Treatment 9 and 10, Shark, was applied on 14 July, and initially this had a significant impact on the plants, with yellowing of foliage, and some scorch and distortion to leaf edges seen one week after application (p<0.001).

At the final assessment on 21 July, 10 WAT, all treatments apart from Nirvana 4.5 L/ha were commercially acceptable, scoring 7 or above (Figure 24). Plots treated with Shark were monitored until 21 September, 10 WAT, and plants had fully recovered, with no signs of yellowing or distortion present (Figure 25).

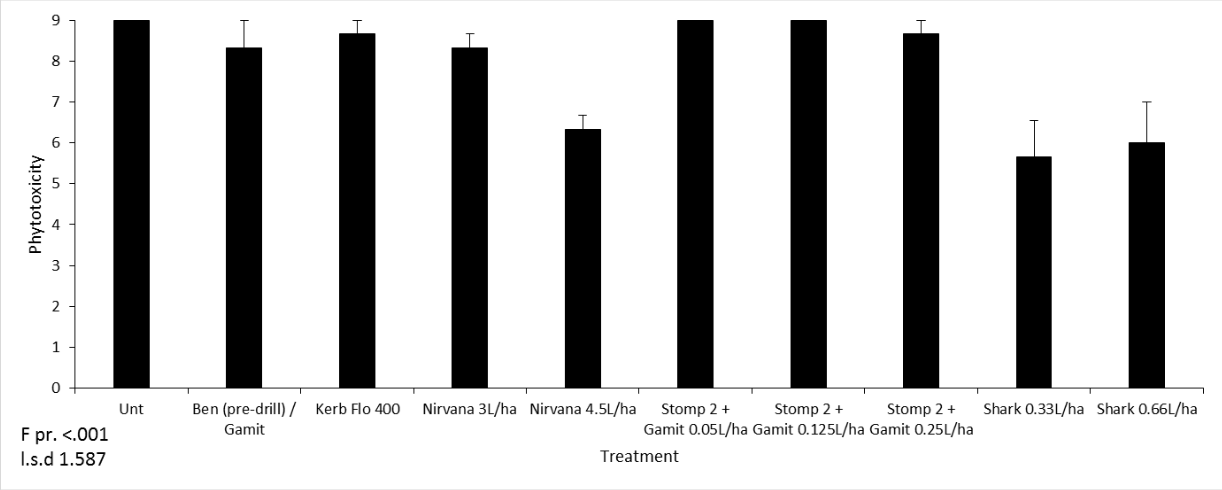


Figure 14. Phytotoxicity scores for each treatment 10 weeks after treatment and 1 week after treatment for Shark – 21 July 2015 (scale of 0 - 9 where 9 is healthy, 0 is dead and 7 is commercially acceptable)

Figure 25. Plants treated with Shark at 0.66 L/ha at 1 week after treatment and 10 weeks after treatment

Plant emergence was rather variable across the trial, and there were no significant differences between treatments. However, compared with the untreated plots, emergence was numerically slightly reduced in plots treated with Stomp Aqua 2 L/ha + Gamit at the higher rate of 0.25 L/ha (T8) with 69.7 emerged seedlings per plot compared to 76 in the untreated control (Figure 26). Treatment 9 and 10 were omitted from this assessment as the treatment went on at a later date.

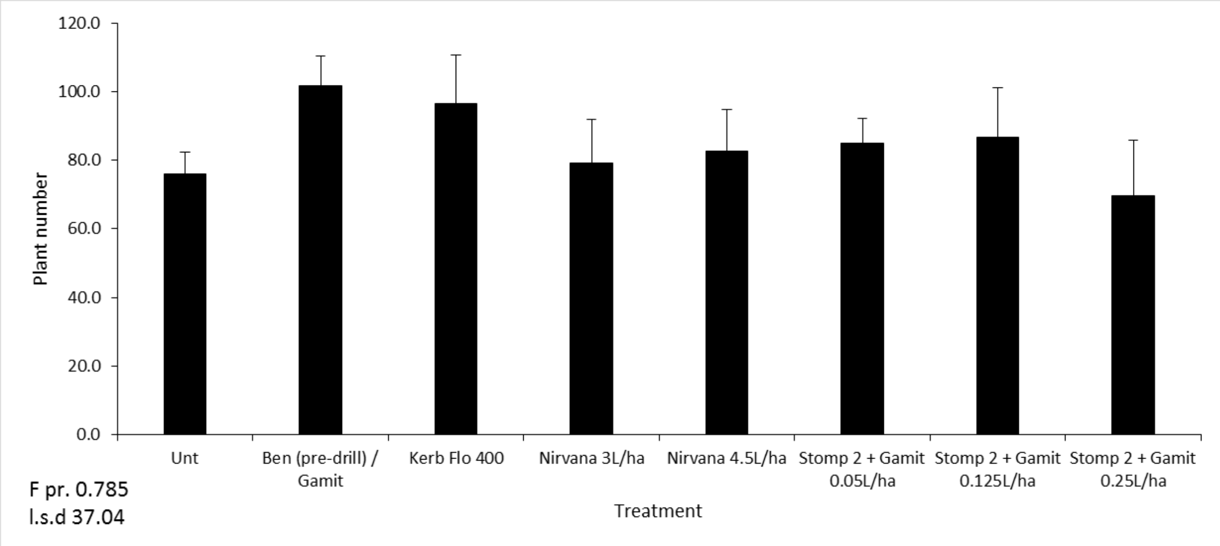


Figure 26. Average number of emerged China aster seedlings per plot for each treatment – 10 June 2015

A weed assessment was carried out on 24 June, and the results can be seen in (Figure 27). Again, treatment 9 and 10 have been omitted from this assessment. Weed emergence was relatively low, but compared to the untreated, all treatments gave some control, apart from Benfluralin 2 L/ha and Gamit 0.125 L/ha (T2) (p=0.064, Appendix 3, Table 2). Nirvana at 4.5 L/ha (T5) was the most effective with 1.7% weed cover, but this treatment had already proved to be phytotoxic. Nirvana at 3 L/ha (T4) gave slightly less control with 3.7% weed cover, and there was very little difference between the plots treated with Stomp Aqua 2 L/ha and the varying rates of Gamit (T6-T8).

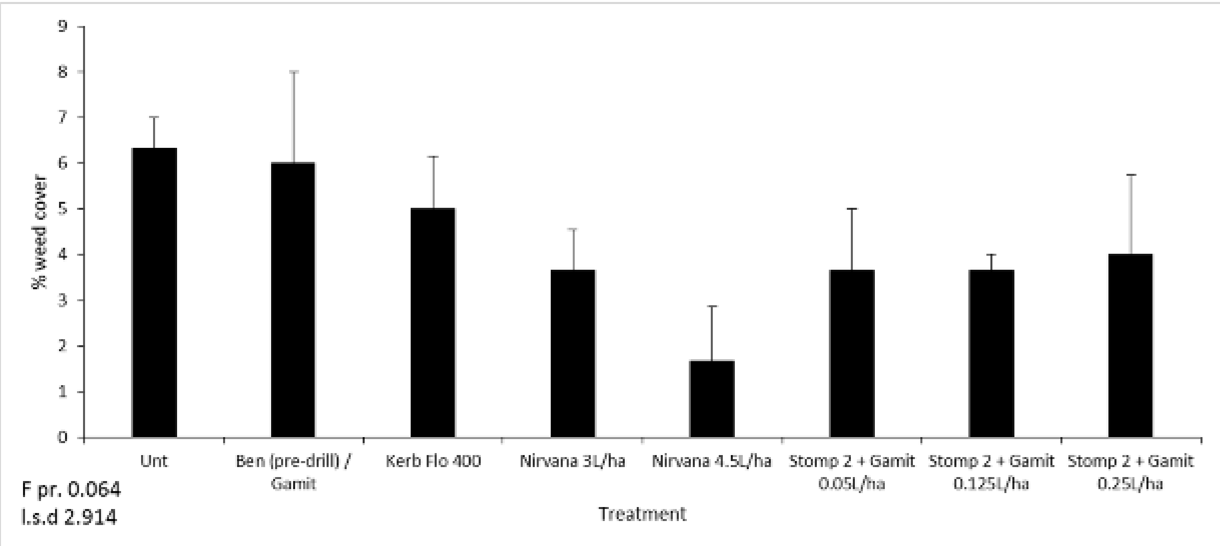


Figure 27. Average weed cover for each treatment – 24 June 2015

Discussion

In the drilled China aster trial, Nirvana applied at a rate of 4.5 L/ha proved to be the most phytotoxic treatment, with yellowing to foliage and stunted plants. By 10 WAT, all other treatments were considered commercially acceptable for plant quality. When Shark was applied as a post-emergence treatment, this initially caused some damage to the crop, with leaf yellowing and scorching to leaf edges, but these plants were able to recover at both application rates, so Shark could be considered for use as a herbicide in this crop, applied at a rate of 0.33 L/ha.

Plants treated with Stomp Aqua at 2 L/ha + Gamit at varying rates of 0.05-0.25 L/ha looked healthy and were commercially acceptable, but there was little difference in weed control and emergence was reduced in plots treated with the highest rate of Gamit at 0.25 L/ha. Therefore, Stomp Aqua 2 L/ha + Gamit 0.125 L/ha could be a suitable treatment applied to a crop post-drilling.

Crop emergence was highest in plots treated with Benfluralin 2 L/ha pre-drilling + Gamit 0.125 L/ha post-drilling, and Kerb Flo 400 post-drilling, and although these plants were commercially acceptable, weed control was not as good with these treatments.

Species 2: China aster (transplanted)

Materials and methods

The transplanted China aster trial was set up on a grower's holdings to demonstrate two promising herbicide treatments in larger demonstration plots. The trial treatments consisted of pre-planting treatments and post-emergence treatments and were compared with the growers' standard herbicide treatment (Table 37). The pre-planting treatment was applied immediately prior to planting on 8 May 2015, whereas the post-emergence treatment, Shark, was applied once the crop had reached six leaves on 19 June 2015. Pre-planting treatments were applied by the grower using farm-sprayers and the post-emergence treatment was applied by ADAS staff using an OPS knapsack sprayer with 02f110 nozzles and using a medium spray quality.

The trial was a fully randomised block design with three main treatments, including the grower's standard, which were replicated twice, giving a total of six main plots. Shark was only applied to sub-plots of treatment one. The main plots were 120 m^2 and the sub-plots measured 20 m^2. Phytotoxicity assessments were carried out 2, 6 and 10 weeks after each treatment application. Phytotoxicity was scored on a scale of 0-9, whereby 9 showed no effect, 7 was commercially acceptable damage, 1 was a very severe effect and 0 was plant death. Data were analysed using ANOVA.

Table 37. Treatment list for China aster herbicide trial on a grower's holdings in Norfolk

Species	Trt 1 (Untreated control)	Trt 2 (Springbok)	Trt 3 (Successor)	Trt 4 (Springbok + Successor)
1	Stomp Aqua + Gamit 36 CS	2.0 + 0.25	Shark	0.33
2	Stomp Aqua + Dual Gold	2.0 + 0.78	Untreated	-
3	Ronstar Liquid	4.0	Untreated	-

Results

No phytotoxic effects were seen from any of the main treatments (Stomp Aqua + Gamit 36 CS, Stomp Aqua + Dual Gold or Ronstar) throughout the trial (Table 38). However, 2 weeks after Shark had been applied to sub-plots there was obvious scorching to leaves of the China asters with the plants receiving an average score of 6.5 ($p<0.001$, Appendix 3, Table 3) (Figure 28). By the follow up assessment, 4 weeks after the Shark had been applied, the asters had fully recovered, with the new growth coming through unaffected scoring 9 on the phytotoxicity scale (Figure 29).

Table 38. Phytotoxicity scores for China aster at 2, 6 and 10 weeks after each treatment application (WAT) (scale of 0 - 9 where 9 is healthy, 0 is dead and 7 is commercially acceptable)

Treatment	2 WAT	6 WAT	10 WAT
1a) Stomp Aqua + Gamit 36 CS	9.0	9.0	9.0
1b) Stomp Aqua + Gamit 36 CS followed by Shark (post-emergence)	6.0	9.0	9.0
2. Stomp Aqua + Dual Gold	9.0	9.0	9.0
3. Ronstar	9.0	9.0	9.0

Figure 28. China asters treated with Shark 0.33 L/ha 1 week after treatment – 25 June 2015, Norfolk

Figure 29. China asters treated with Shark 0.33 L/ha 4 weeks after treatment – 2015, Norfolk

At the first assessment, 2 weeks after the main treatments had been applied on 22 May 2015, there were no weeds found in any of the quadrats sampled for each of the treatments. By 6 weeks after the main treatments had been applied, 2 weeks after Shark had been applied to sub-plots of Stomp Aqua + Gamit 36 CS, the lowest percentage weed cover was seen in the plots that had been treated with Stomp Aqua + Gamit 36 CS followed by Shark, 3% weed cover, (Figure 30). On this date the highest percentage of weeds were found in plots that had been treated with Stomp Aqua + Gamit 36 CS, 11% weed cover, and plots treated with Stomp Aqua + Dual Gold, 12.5% weed cover ($p=0.065$). At the final assessment that was carried out 10 weeks after the main treatments had been applied the lowest percentage of weeds were found in plots treated with either Stomp Aqua + Gamit 36 CS (5.5% weed cover) or Stomp Aqua + Gamit 36 CS followed by Shark (7% weed cover).

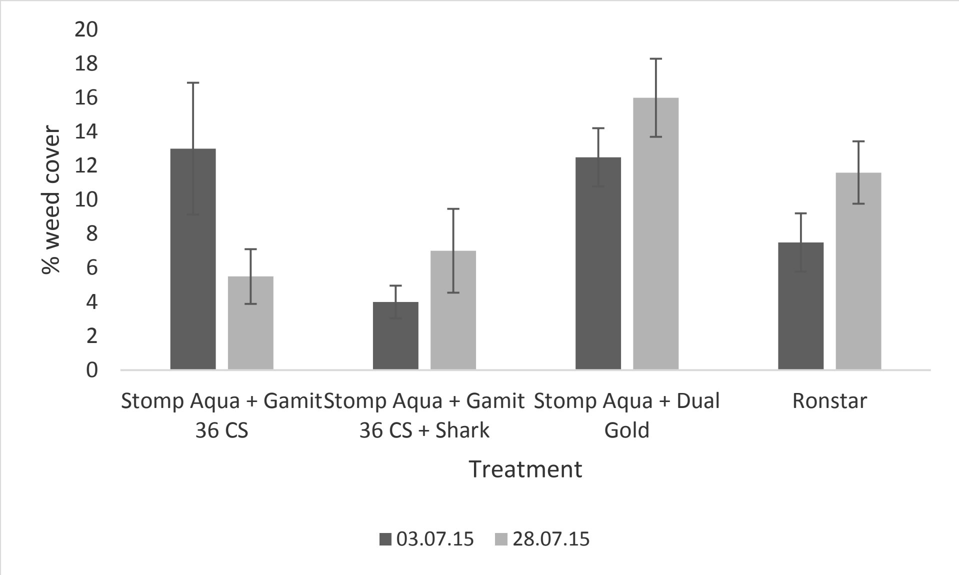


Figure 30. Average percentage weed cover per m² for the China aster trial at approximately 2 (22 May 2015), 6 (3 July 2015) and 10 weeks (28 July 2015) after main treatments had been applied – Norfolk. *Note that no weeds were present at the first assessment on 22 May 2015*

Discussion

Shark (0.33 L/ha) caused initial phytotoxic effects in the asters but they grew away by the final assessment, 5 weeks after the Shark had been applied. All other treatments were safe on China aster. Stomp Aqua (2 L/ha) with Gamit 36 CS (0.25 L/ha), followed by Shark (0.33 L/ha), gave the best weed control results. There was a lot of *Equisetum arvense* at this site which the Shark scorched but didn't take out completely.

Although the test treatment Stomp Aqua (2 L/ha) + Gamit 36 CS (0.25 L/ha) proved to be safe it was felt that the next step would be to develop a follow up residual herbicide treatment in order to maintain weed control up to harvest. This could be in combination with an early post-emergence application of Shark (0.33 L/ha).

Species 3: Larkspur

Materials and methods

The drilled Larkspur trial, variety Sublime Special Mixed, was carried out at the CFC between May and July 2015. The crop was grown on a Lincolnshire silt. The trial was a fully randomised block design with 10 treatments, including an untreated control (Table 39) replicated three times. Each plot was 3 m long and 1.2 m wide and consisted of four rows of plants.

Table 39. Detail of herbicide treatments applied pre or post-drilling to Larkspur seed - 2015

Trt no.	Pre – drilling	Rate kg/ha or L/ha	Post - drilling	Rate kg/ha or L/ha
1	Untreated	-	Untreated	-
2	Benfluralin (incorp)	2	Defy	4
3	Benfluralin (incorp)	2	Gamit 36 CS	0.25
4	Untreated	-	Stomp Aqua + Gamit 36 CS	2 + 0.25
5	Untreated	-	Stomp Aqua + Defy	2 + 4
6	Untreated	-	Stomp Aqua + Dual Gold	2 + 0.78
7	Untreated	-	Wing-P	1.75
8	Untreated	-	Dual Gold + Gamit 36 CS	0.78 + 0.25
9	Untreated	-	Successor	2
10	Untreated	-	HDC H24	confidential

Prior to drilling, the site was marked out and the pre-drilling treatments were applied on 12 May. The treatments were applied to the soil using an OPS sprayer and a 1.5 m boom with 02f110 nozzles, to achieve a medium spray quality at 200 L/ha. The treatments were then incorporated into the soil using a rake, and lightly irrigated.

The trial was drilled on the same day, and the post-drilling treatments were applied on 13 May. The same sprayer and boom were used, to achieve a medium spray quality at 200 L/ha. All treatments were lightly irrigated afterwards.

The trial was monitored weekly, and crop emergence and percentage weed cover was assessed 9 WAT (14 July). Phytotoxicity was assessed at 9 and 11 WAT (14 July and 31 July respectively). Phytotoxicity was assessed on each plot, using a scale of 0-9, whereby 9 showed no effect, 7 was commercially acceptable damage, 1 was a very severe effect and 0 was plant death. Data was analysed using ANOVA.

Results

In the drilled Larkspur trial, emergence was particularly slow, and when the trial was inspected at 6 WAT, emergence across all plots was quite variable, even in the untreated. Two phytotoxicity assessments were carried out at 9 WAT and 11 WAT, and although it was possible to pick out some potential treatment differences, due to the poor and protracted emergence and variability in crop height (plants varied from 2-3 cm tall, up to 12 cm), the results need to be treated with caution.

At the final assessment on 31 July, 11 WAT, plots treated with Stomp 2 L/ha + Dual Gold 0.78 L/ha (T6), Wing-P 1.75 L/ha (T7) and Successor 2 L/ha (T9) appear to have had a phytotoxic effect, receiving phytotoxicity scores of 4, 5.3 and 4 respectively (Figure 31).The foliage in these plots appeared quite yellow when compared to the untreated. However, all treatments apart from Dual Gold 0.78 L/ha + Gamit 0.25 L/ha (T8), which scored 8 for phytotoxicity, scored below the commercially acceptable score of 7 (p=0.008, Appendix 3, Table 4).

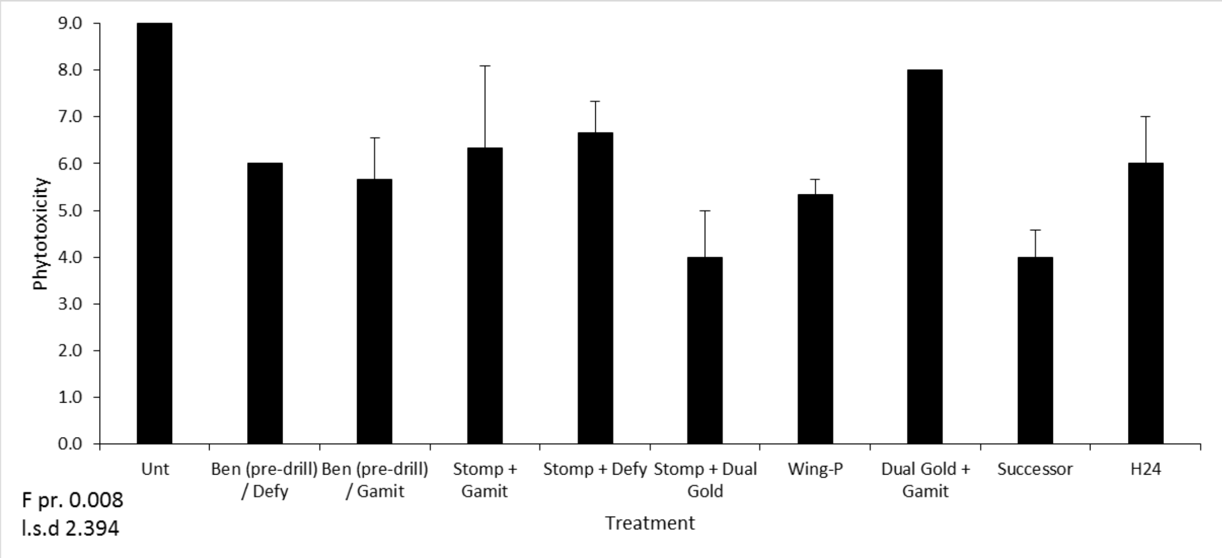


Figure 31. Phytotoxicity scores for each treatment 11 weeks after treatment – 31 July 2015 (scale of 0 - 9 where 9 is healthy, 0 is dead and 7 is commercially acceptable)

Emergence was patchy across the whole trial, including in the untreated, with plants taking a long time to germinate. Emergence was assessed 9 WAT and the results can be seen in Figure 32. Differences were not statistically significant but plots treated with Stomp 2 L/ha + Defy 4 L/ha (T5), Wing-P 1.75 L/ha (T7) and Successor 2 L/ha (T9) showed the lowest rate of emergence and this links in with the phytotoxicity seen in T7 and T9 11 WAT. Emergence appeared to be at least as good as the control for most of the other treatments but plots treated with Dual Gold 0.78 L/ha + Gamit 0.25 L/ha (T8), were the only treatment that scored within the commercially acceptable range for phytotoxicity.

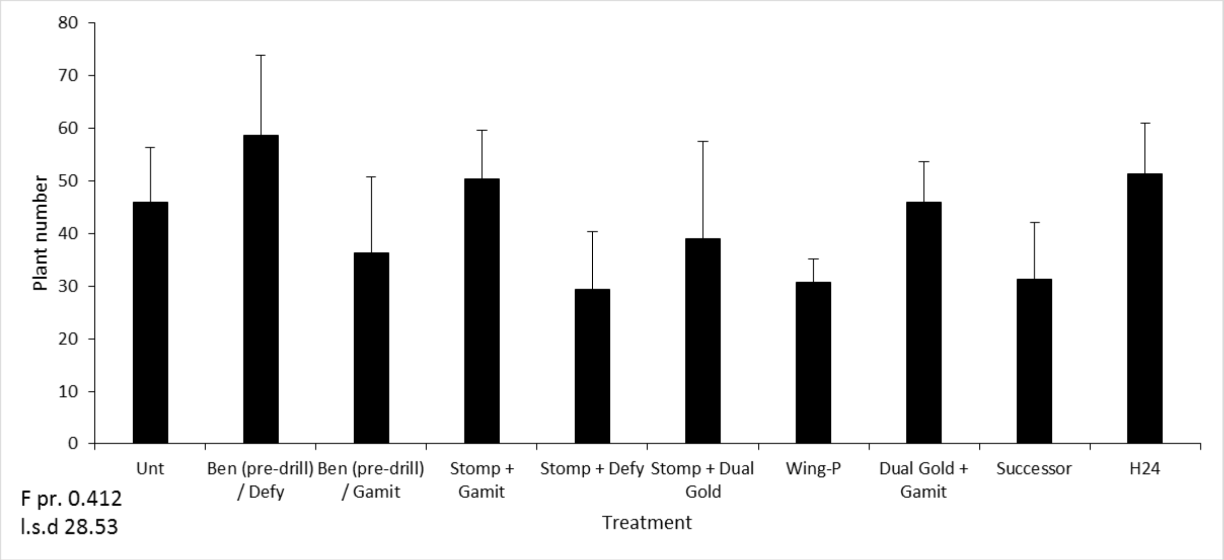


Figure 32. Average number of emerged seedlings per plot for each treatment – 14 July 2015 (Unt = untreated)

A weed assessment was carried out on 14 July, and the results can be seen in Figure 33. Weeds were much lower in some treatments compared with the untreated (21.7% weed cover), with Stomp 2 L/ha + Gamit 0.25 L/ha (T4) giving the best weed control (6.7% weed cover). Wing-P 1.75 L/ha (T7) gave good weed control (10% weed cover) but appeared to be phytotoxic. Stomp Aqua 2 L/ha + Defy 4 L/ha did not give particularly good weed control.

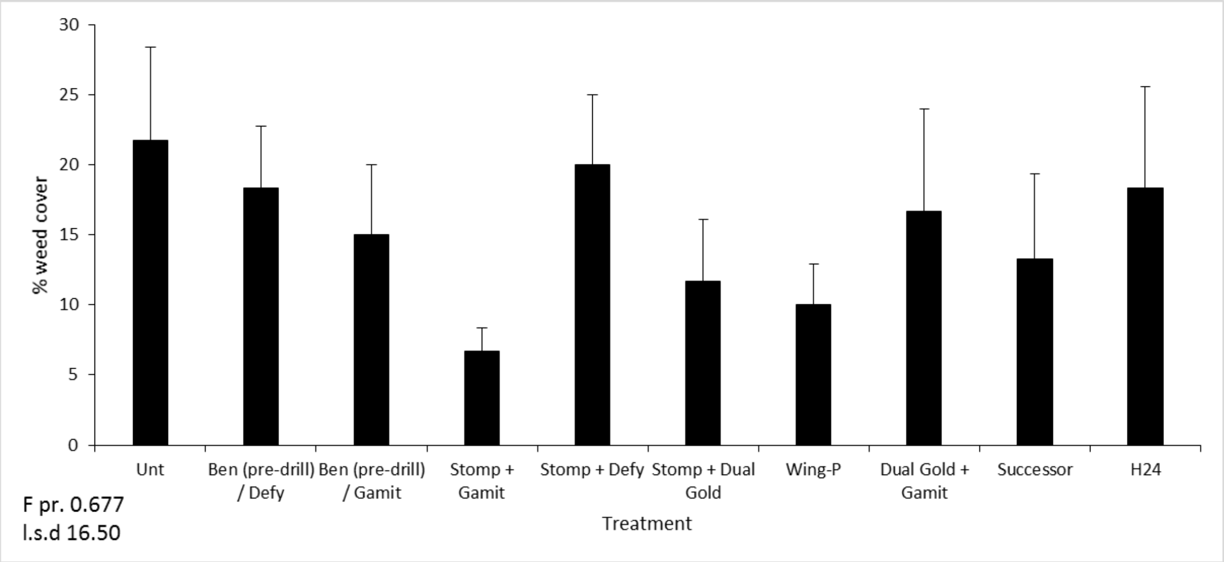


Figure 33. Average weed cover for each treatment – 14 July 2015

Discussion

Although emergence of the Larkspur was still variable 11 WAT, phytotoxicity was seen throughout the trial in the form of stunting and distortion to foliage. This was the case for many of the treatments but because of the variable emergence it wasn't easy to assess and draw firm conclusions. However, the trial did give some pointers for treatments to investigate further, and some that can be ruled out. Stomp 2 L/ha + Dual Gold 0.78 L/ha, Wing-P 1.75 L/ha and Successor 2 L/ha all appear to be particularly phytotoxic to the crop, with the latter two treatments also tending to reduce emergence. Stomp Aqua 2 L/ha + Defy 4 L/ha was less phytotoxic but also reduced emergence. Stomp 2 L/ha + Gamit 0.25 L/ha and Wing-P 1.75 L/ha gave the best weed control but Wing-P appeared to be phytotoxic.

Species 4: Sweet Williams (CFC trial)

Materials and methods

The drilled Sweet Williams trial at the CFC was carried out between July and September 2015. The crop was grown outdoors on a Lincolnshire silt. The trial was a fully randomised block design with 10 treatments, including an untreated control (Table 40), replicated three times. Each plot was 3 m long and 1.2 m wide and consisted of three rows of plants.

Table 40. Detail of herbicide treatments applied pre or post drilling to Sweet Williams seed – 2015

Trt no.	Pre – drilling	Rate kg/ha or L/ha	Post - drilling	Rate kg/ha or L/ha
1	Untreated	-	Untreated	-
2	Benfluralin (incorp)	2	Defy	2
3	Untreated	-	Stomp Aqua + Goltix 70 SC	0.75 + 1
4	Untreated	-	Stomp Aqua + Goltix 70 SC	0.75 + 2
5	Untreated	-	Stomp Aqua + Defy	0.75 + 1
6	Untreated	-	Stomp Aqua + Defy	0.75 + 2
7	Untreated	-	Stomp Aqua + Defy	1 + 1
8	Untreated	-	Stomp Aqua + Defy	1 + 2
9	Untreated	-	Goltix 70 SC	2
10	Untreated	-	Shark (post em of crop & weeds)	0.33

Prior to drilling, the site was marked out and the pre-drilling treatment was applied on 10 July. The treatments were applied to the soil using an OPS sprayer and a 1.5 m boom with 02f110 nozzles, to achieve a medium spray quality at 200 L/ha. The treatments were then incorporated into the soil using a rake, and lightly irrigated.

The trial was hand-sown with three rows of seed per plot on 12 July 2015 and the post-drilling treatments were applied the next day, using the same spray equipment to achieve a medium spray quality at 500 L/ha. The change in water rate from 200 L/ha for the pre-drilling treatment, to 500 L/ha for the post-drilling treatment, was due to the conditions stipulated in the Goltix 70 SC Extension of Authorisation for Minor Use (EAMU). In May 2015, Goltix 70 SC (MAPP number 16638) was granted an EAMU (1175/15) for use as an herbicide in protected and outdoor ornamental plant production. The EAMU states that if the product is to be applied using handheld equipment, then a minimum water volume of 500 L/ha must be observed. Therefore, for the Sweet Williams trial, all post-drilling treatments were applied in a water volume of 500 L/ha.

Treatment 10 (Shark), a contact-acting herbicide, was applied on 17 August, five weeks after drilling, when the crop had reached four true leaves and weeds had emerged.

The trial was assessed at 2, 6 and 10 WAT (28 July, 25 August and 21 September respectively). Treatment 10 was assessed 1 and 5 WAT. The trial plots were assessed for phytotoxicity using a scale of 0–9, whereby 9 showed no effect, 7 was commercially acceptable damage, 1 was a very severe effect and 0 was plant death. Plots were also assessed for the number of emerged Sweet Williams and percentage weed cover. Data was analysed using ANOVA.

Results

At 2 WAT, plants were at cotyledon stage, so any phytotoxic effects from the treatments were not clear at that time. However, at the second assessment 6 WAT, differences between treatments were much clearer ($p=0.015$, Appendix 3, Table 41). All treatments appeared safe, apart from Stomp Aqua 0.75 L/ha + Defy 2 L/ha (T6), where there was some distortion and slight yellowing visible on the leaves resulting in an average phytotoxicity score of 6.7 (Figure 34). Shark (T10), was applied one week before the 6 WAT assessment, when the plants were approximately four true leaves, and initially the effect of this treatment was clearly visible. Plants were severely scorched with bleaching to the leaves scoring an average score of 4.7 (Figure 35). However, at the final assessment 10 WAT and 5 WAT for Shark, the plants had fully recovered and there was no damage to any of the new growth.

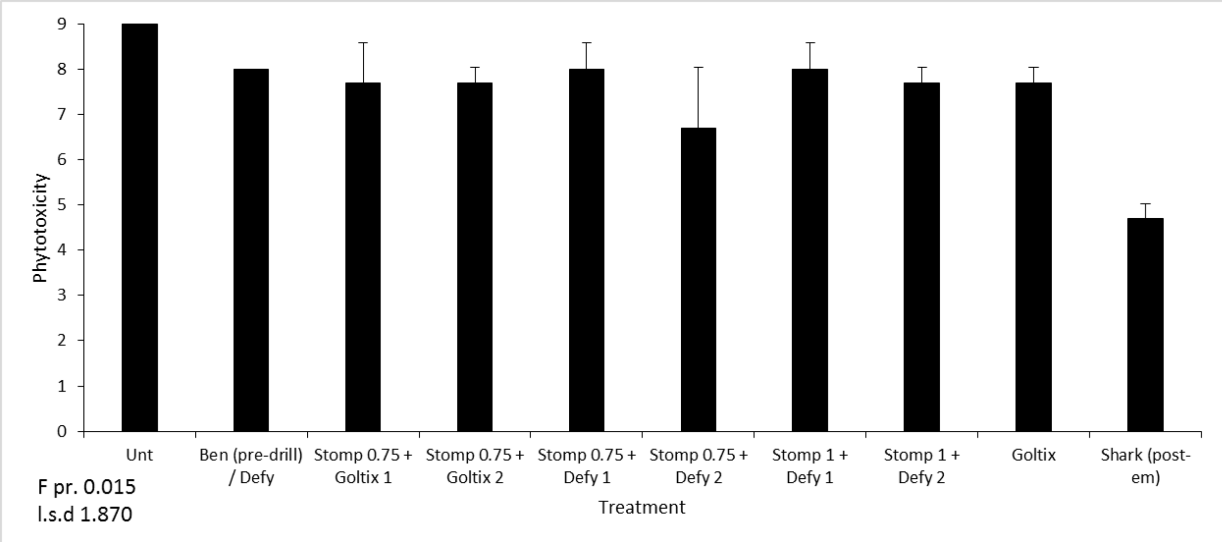


Figure 34. Phytotoxicity scores for each treatment 6 weeks after treatment and 1 week after treatment for Shark – 25 August 2015 (scale of 0 - 9 where 9 is healthy, 0 is dead and 7 is commercially acceptable)

Figure 35. Sweet Williams treated with Shark (T10) at 1 week after treatment (left) and 5 weeks after treatment (right)

At the final assessment 10 WAT, signs of phytotoxicity still remained in T6, with an average score of 6, and damage was now apparent in the plots treated with Stomp Aqua + Defy at both 1 L/ha + 1 L/ha and 1 L/ha + 2 L/ha (T7 and T8), which hadn't been visible earlier on in the trial, scoring phytotoxicity scores of 6.7 and 6.3 respectively (p=0.072) (Figure 36).

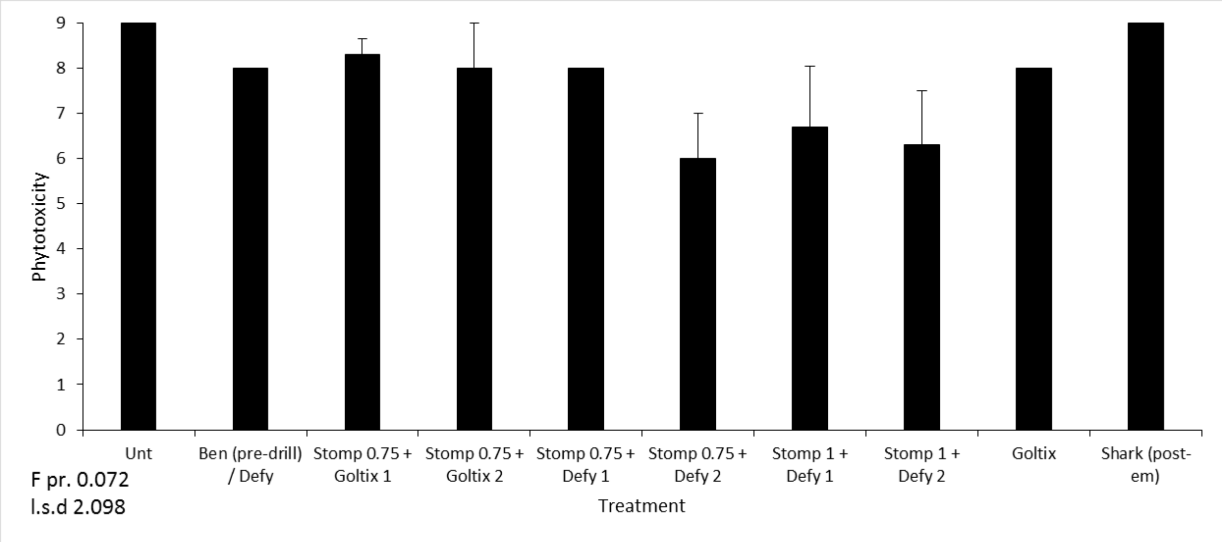


Figure 36. Phytotoxicity scores for each treatment 10 weeks after treatment and 5 weeks after treatment for Shark – 21 September 2015 (scale of 0 - 9 where 9 is healthy, 0 is dead and 7 is commercially acceptable)

The number of emerged plants per plot were assessed 2 WAT and there were significant differences noted between the treatments (p=0.021) (Figure 37). Treatment 10, Shark, was omitted from this assessment as the treatment was applied at a later date. Emergence in plots treated with Benfluralin followed by Defy (T2) was reduced compared with the best plots with an average of 176 seedlings per plot. Plots treated with Stomp Aqua 0.75 L/ha + Goltix 1 L/ha (T3) showed better emergence than plots treated with Stomp Aqua 0.75 L/ha plus the higher rate of Goltix 2 L/ha (T4), both with 343 seedlings per plot on average. There were no clear effects on emergence from the different rates of Stomp Aqua + Defy (T5-8) however only the lower rate Stomp Aqua 0.75 L/ha + Defy 1 L/ha (T5) had acceptable phytotoxicity scores; emergence was moderate.

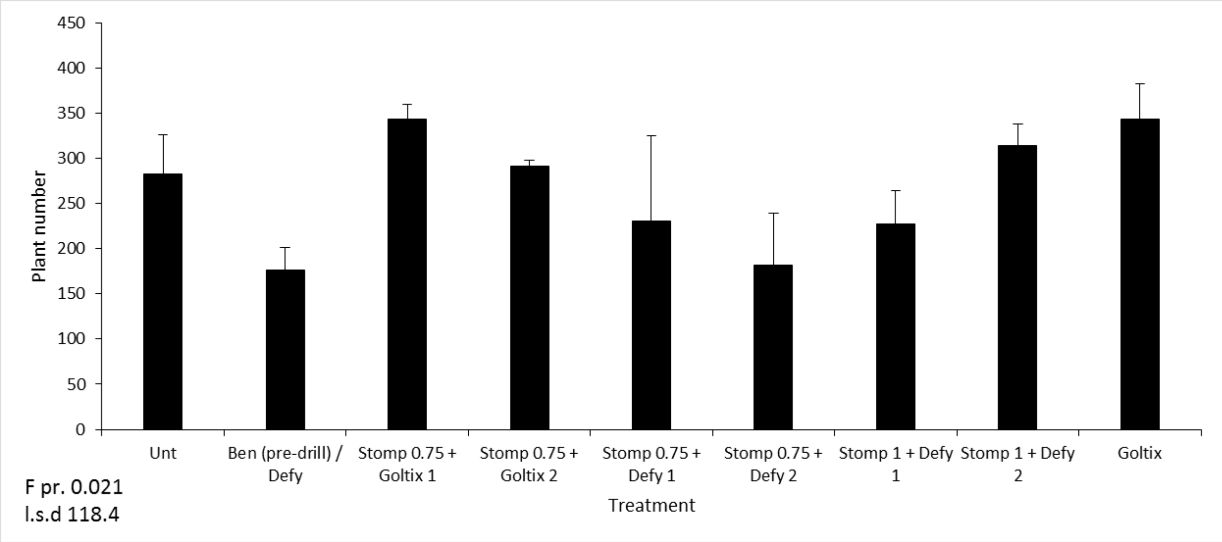


Figure 37. Average number of emerged seedlings per plot for each treatment – 28 July 2015

A weed assessment was carried out 6 WAT and the results can be seen in Figure 38. Weed control was very good in Stomp Aqua 0.75 L/ha + Goltix 2 L/ha (T4) with only 11% weed cover, however this treatment had some impact on crop emergence. Control was also good in plots which had been treated with Shark (T10) the previous week (23.3% weed cover) and plots treated with Stomp Aqua 0.75 L/ha + Goltix 1 L/ha (T3), (36.7% weed cover), although this was not significant. All other treatments showed moderate levels of control, apart from plots treated with Benfluralin followed by Defy, which showed high numbers of weeds 6 WAT, 60% weed cover.

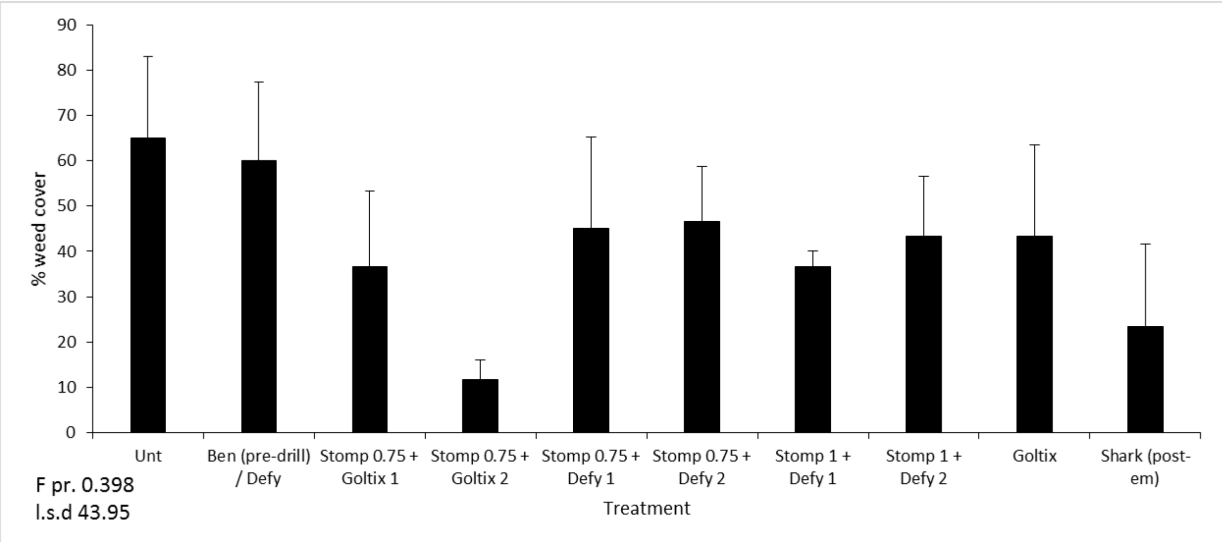


Figure 38. Average weed cover for each treatment – 25 August 2015

Discussion

Results suggest that for the Sweet Williams trial, Defy at a higher rate of 2 L/ha was unsafe when mixed with Stomp Aqua. Although crop emergence was not reduced in this trial, the seedlings that did come through showed some chlorosis and were scored down for phytotoxicity at 10 WAT. When used at the lower rate, 1 L/ha and mixed with Stomp Aqua at 0.75 L/ha, plants showed little sign of phytotoxicity.

Goltix either on its own at 2 L/ha or tank mixed with Stomp Aqua showed little phytotoxicity. However, when Goltix was applied at the higher 2 L/ha rate mixed with Stomp Aqua, crop emergence was slightly reduced, although it was not significantly different from the untreated control.

Benfluralin + Defy caused little phytotoxicity but crop emergence was reduced. Weed control was also rather poor with this treatment.

Shark applied as a post-emergence treatment did cause some severe scorch and bleaching to leaves on the plants initially. However, the plants recovered from this and five weeks after treatment there was no damage to the new growth. Weed control was also much better with this treatment compared with the pre-emergence treatments.

Species 5: Sweet Williams (Grower sites)

Materials and methods

The first of the grower trials was set up in Norfolk in May 2015 to demonstrate two promising herbicide programmes in larger demonstration plots on growers' holdings for Sweet Williams. The promising treatments were compared with the grower's standard herbicide treatment (Table 42). The two main test treatments were applied to 100 m² main plots, alongside the grower's standard treatment, post-drilling on 15 May 2015. Shark (0.33 L/ha) was used as a follow up treatment and was only applied to 20 m² sub-plots of treatments T1 and T2 when the Sweet Williams had reached the four leaf stage on 3 July 2015.

The trial was laid out as a randomised block design with two replications, giving a total of six main plots and four sub-plots. Main treatment applications that were made post-drilling were applied by the grower using farm-sprayers and the post-emergence treatment of Shark was applied by ADAS staff using an OPS knapsack sprayer with 02f110 nozzles and at a medium spray quality. Phytotoxicity assessments were carried out approximately 2, 6 and 10 weeks after each treatment application. Phytotoxicity was scored on a scale of 0-9, whereby 9 showed no effect, 7 was commercially acceptable damage, 1 was a very severe effect and 0 was plant death. Data were analysed using ANOVA.

Table 42. Details of test treatments for 1st Sweet Williams trial - Norfolk 2015

Trt no.	Post - drilling	Rate kg/ha or L/ha	Post – emergence	Rate kg/ha or L/ha
1	Stomp Aqua + Defy	1.5 + 2	Shark	0.33
2	Stomp Aqua + Defy	1 + 2	Shark	0.33
3	Ronstar liquid	3	Untreated	-

A second Sweet Williams trial was carried out to refine treatments from the first Sweet Williams trial, as the treatments used in the first trial had a severe effect on crop emergence. The opportunity was also taken to test a Stomp Aqua + Goltix 70 SC tank mix which had been promising in the CFC trials. Two test treatments were applied post-drilling to 100 m^2 main plots and compared to an untreated control (Table 43). Post-emergence treatments of Shark were applied to 20 m^2 sub-plots of treatments two and three once the Sweet Williams had reached the four leaf stage. The post-drilling treatments were applied on 14 August 2015 and the post-emergence treatments were applied on 14 October 2015. All treatments were applied by ADAS staff using an OPS knapsack sprayer with 02f110 nozzles and at a medium spray quality. The trial was set up as a randomised block design with a two-fold replication.

Phytotoxicity was assessed and analysed in the same way as in the first sweet williams trial.

Table 43. Details of test treatments for second Sweet Williams trial - Lincolnshire 2015

Trt no.	Post - drilling	Rate kg/ha or L/ha	Post – emergence	Rate kg/ha or L/ha
1	Untreated	-	Untreated	-
2	Stomp Aqua + Defy	0.75 + 1	Shark	0.33
3	Stomp Aqua + Goltix	0.75 + 1	Shark	0.33

Results

In the first Sweet Williams trial in Norfolk, both of the main test treatments (Stomp Aqua + Defy at both the higher and lower rate) significantly reduced the emergence of Sweet Williams, with 1.8 and 2.7 Sweet Williams per m^2 respectively ($p<0.001$, Appendix 3, Table 7) (Figure 39). Only the plots that were treated with the grower's standard treatment of Ronstar were commercially acceptable in terms of emergence, with 28 Sweet Williams per m^2.

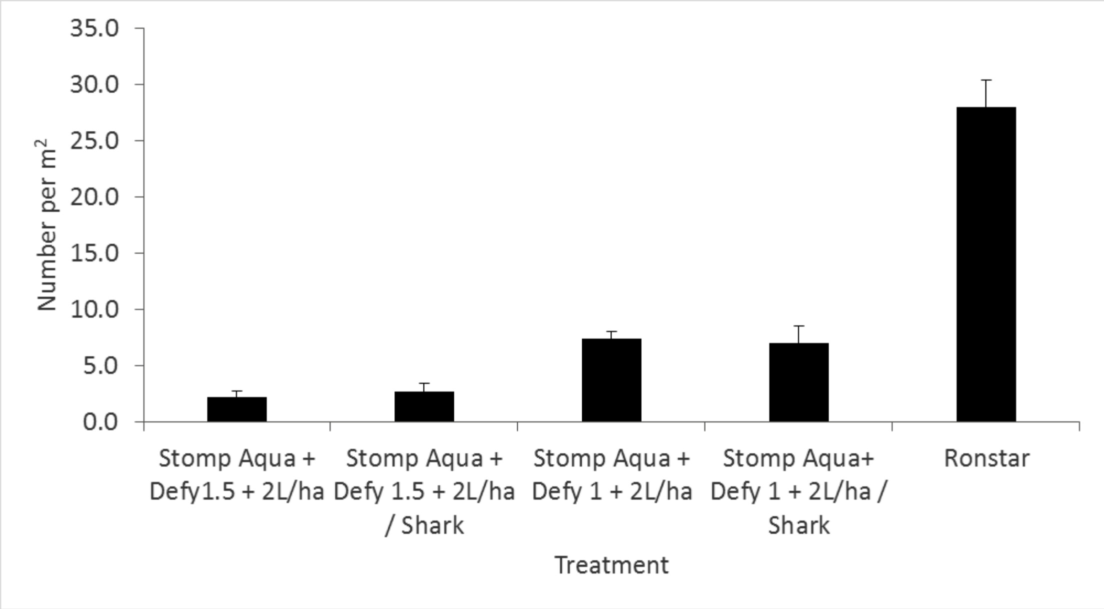


Figure 39. Average number of emerged Sweet Williams per m² as on 7 July, 8 weeks after treatment - Norfolk 2015

Some slight phytotoxic damage was seen on the Sweet Williams that had been treated with both rates of Stomp Aqua + Defy, however the most phytotoxic effects were found on the Sweet Williams that had received a post-emergence application of Shark (Figure 40). This damage was seen as scorching on the leaves of the Sweet Williams and resulted in phytotoxicity scores of 6.5. At this point the plants were not considered commercially acceptable but as this damage was found on the older leaves it was believed that the Sweet

Williams would grow out of the damage which is what was seen in the second trial.

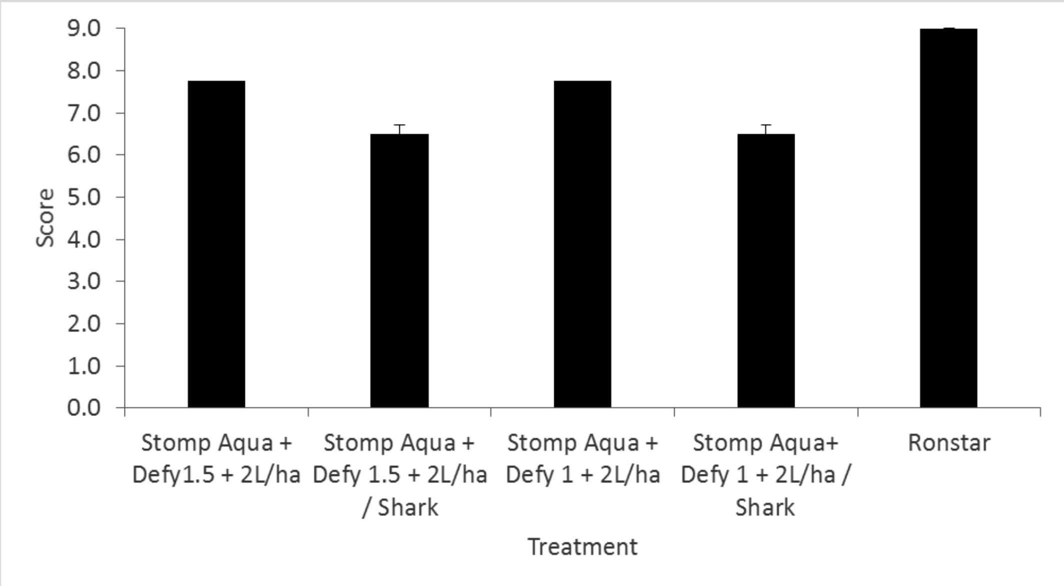


Figure 40. Average phytotoxicity score for Sweet Williams on 7 July 2015, 8 weeks after treatment– Norfolk 2015 (scale of 0 - 9 where 9 is healthy, 0 is dead and 7 is commercially acceptable)

All of the test treatments significantly reduced the percentage weed cover compared to the grower's commercial standard treatment of Ronstar (p=0.002). At the assessment carried out 8 WAT Stomp Aqua + Defy at the higher rate and followed by Shark had the lowest percentage weed cover with 4% weed cover in a quadrat, compared to 12.5% weed cover in the Ronstar treated plots (Figure 41).

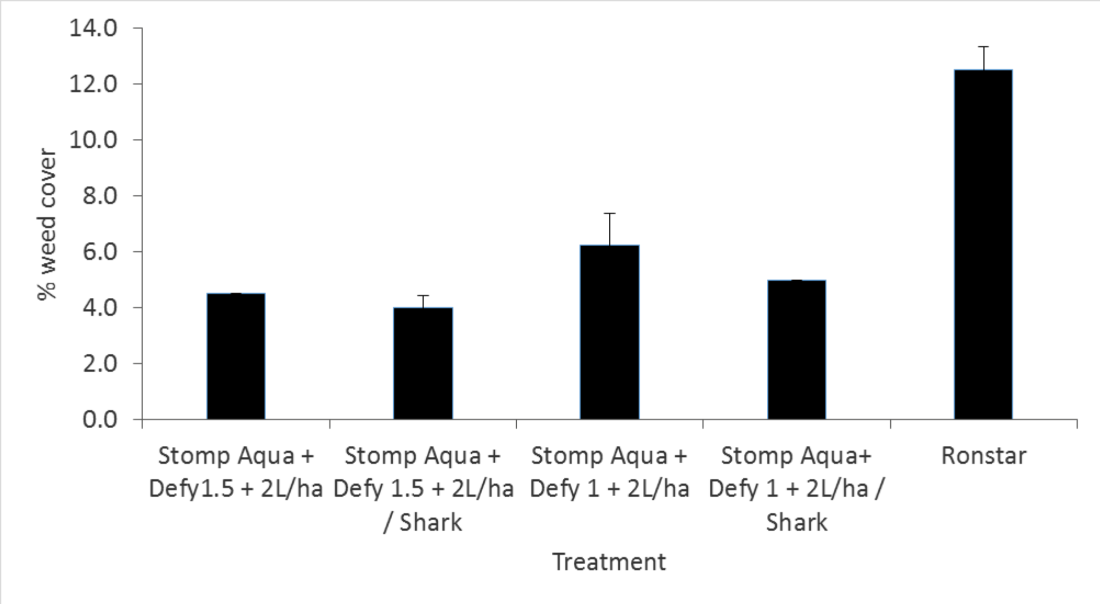


Figure 41.. Average percentage weed cover of Sweet William plots on 7 July 2015, 8 weeks after treatment – Norfolk 2015

In the second Sweet William trial germination was poor, even in the grower's commercial crop with a crop emergence of 4.4 plants per m² 12 WAT (Table 44). No Sweet Williams had germinated until the assessment carried out 6 weeks after the post-drilling treatments had been applied. By 12 WAT differences could be seen between treatments in terms of the number of Sweet Williams that had emerged ($p<0.001$). By the 12 WAT assessment, plots treated with Stomp Aqua + Defy or Stomp Aqua + Defy + Shark had significantly lower numbers of Sweet Williams present ($p<0.001$), 1 plant per m², compared with the highest number of Sweet Williams, which were were found in plots that had been treated with Stomp Aqua + Goltix + Shark, 14 plants per m². Some slight phytotoxicity was seen on the Sweet Williams throughout the trial, even in the untreated plots (Figure 42). This damage was seen as some slight scorching to the leaves of Sweet Williams. It is thought that this damage might have been the result of a previous herbicide that had been applied to a previous crop. The Shark that was applied post-emergence caused some scorching to the leaves of Sweet Williams, however the damage only affected the older leaves and so the Sweet Williams recovered well by 12 WAT, scoring an average of 8 on the phytotoxicity scale. None of the average scores of phytotoxicity dropped below the commercially acceptable score of 7 throughout the entire trial, meaning that the scorching caused by the treatments was not severe.

Table 44. Mean number of emerged seedlings per plot, phytotoxicity 12 weeks after treatment and% weed cover – Sweet William 2015 (grower's holdings Lincolnshire)

Treatment	Crop emergence per m² 12 WAT	Phytotoxicity 12 WAT	% weed cover
1. Untreated	4.4	9.0	77
2.a Stomp Aqua + Defy	1.0	8.5	38.1
2.b Stomp Aqua + Defy / Shark (post-emergence)	6.0	8.0	18.8
3.a Stomp Aqua + Goltix	8.0	8.8	50.6
3.b Stomp Aqua + Goltix / Shark (post-emergence)	14	8.0	6.3
F pr.	<0.001	<0.001	<0.001
l.s.d (25 d.f)	1.485	0.3619	26.33

Figure 42. Sweet Williams treated with Shark 0.33 L/ha 1 week after treatment (left) and 3 weeks after treatment (right) – Lincolnshire

All of the test treatments reduced weed cover compared to the untreated plots (Figure 43). Stomp Aqua + Defy and Stomp Aqua + Goltix both provided good weed control up to 6 WAT (Figure 44), however by the assessment carried out 10 weeks after these treatments had been applied the weeds had started to recover. At this point, the sub-plots that had received a post-emergence application of Shark had significantly less weeds than the plots that had just received the post-drilling treatments (p<0.001). Shark caused severe scorching to the predominant weeds fumitory and groundsel, however as expected it did not control any grasses.

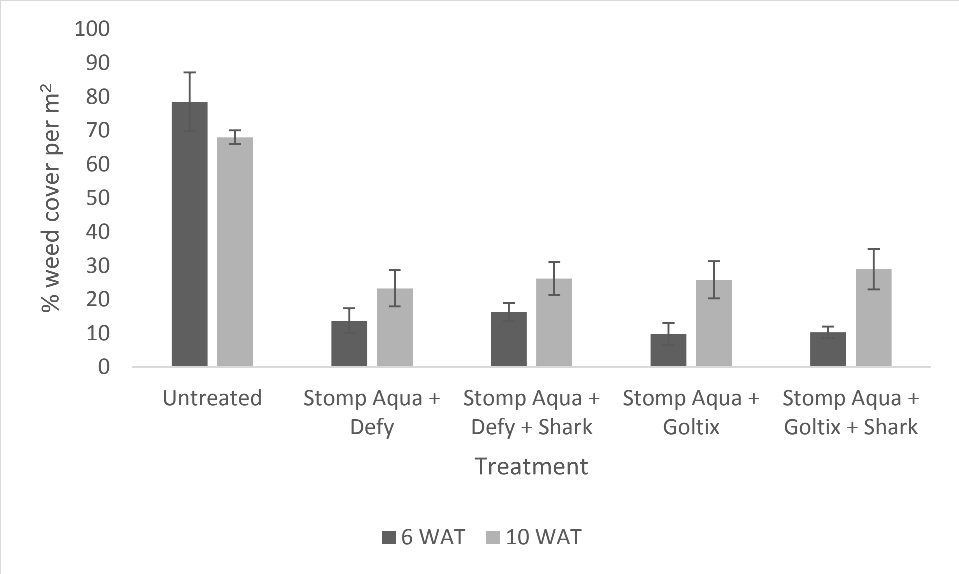


Figure 43. Percentage weed cover per m² for Sweet Williams – Lincolnshire 2015

Figure 44. Weed cover of Sweet Williams treated with Stomp Aqua + Goltix, left, and untreated, right, on 24 September (6 weeks after treatment) - Lincolnshire 2015

Discussion

At the first trial on Sweet Williams scorch was only noted on the plants in the sub-plots that had been treated with Shark (0.33 L/ha). However in this trial, the rates of Stomp Aqua and Defy were found to be too high, reducing emergence, even when the Stomp Aqua was applied at the lower rate. These results mirrored the results seen in the Sweet William trial at the CFC. For this reason the rates were reduced on the next Sweet William trial and Goltix 70 SC was trialled as an alternative to Defy.

The second Sweet Williams trial that was set up in Lincolnshire showed that, even at the lower 1 L/ha rate, Defy still seemed to affect emergence, although emergence was generally poor across the whole crop; even the grower's commercial crop. This was because the crop was late drilled and heavy rain caused the soil to cap, resulting in poor emergence. Stomp Aqua

(0.75 L/ha) + Goltix (1 L/ha) had a better emergence than the Stomp Aqua (0.75 L/ha) + Defy (1 L/ha).

Shark (0.33 L/ha) improved weed control over and above that achieved from the residuals alone. Stomp Aqua (0.75 L/ha) + Goltix (1 L/ha) was safer to the Sweet Williams and also gave better weed control than Stomp Aqua (0.75 L/ha) and Defy (1 L/ha). Shark (0.33 L/ha) initially scorched the Sweet Williams but they grew away from the damage, and the new growth coming through was unaffected.

Species 6: Wallflower

Materials and methods

The drilled Wallflower trial at the CFC was carried out between July and September 2015. The crop was grown outdoors on a Lincolnshire silt. The trial was a fully randomised block design with 10 treatments, including an untreated control (Table 45), replicated three times. Each plot was 3 m long and 1.2 m wide and consisted of three rows of plants.

Table 45. Detail of herbicide treatments applied pre or post drilling to Wallflower seed – 2015

Trt no.	Pre – drilling	Rate kg/ha or L/ha	Post drilling	Rate kg/ha or L/ha
1	Untreated	-	Untreated	-
2	Benfluralin (incorp)	2	Butisan S	1
3	Benfluralin (incorp)	2	Butisan S + Gamit 36 CS	1 + 0.05
4	Benfluralin (incorp)	2	Gamit 36 CS	0.125
5	Untreated	-	Stomp Aqua + Gamit 36 CS	2 + 0.25
6	Untreated	-	Stomp Aqua + Gamit 36 CS	2.9 + 0.33
7	Untreated	-	Wing-p	1.75
8	Untreated	-	Wing-p	3.5
9	Untreated	-	Wing-p + Gamit 36 CS	1.75 + 0.125
10	Untreated	-	Wing-p + Gamit 36 CS	3.5 + 0.125

Prior to drilling, the site was marked out and the pre-drilling treatment was applied on 10 July. The treatments were applied to the soil using an OPS sprayer and a 1.5 m boom with 02f110 nozzles, to achieve a medium spray quality at 200 L/ha. The treatments were then incorporated into the soil using a rake, and lightly irrigated.

The trial was hand-sown on 12 July 2015 and the post-drilling treatments were applied the next day, using the same spray equipment to achieve a medium spray quality at 200 L/ha.

The trial was assessed at 2, 6 and 10 WAT (28 July, 25 August and 21 September respectively). The trial plots were assessed for phytotoxicity using a scale of 0–9, whereby 9 showed no effect, 7 was commercially acceptable damage, 1 was a very severe effect and 0 was plant death. Plots were also assessed for the number of emerged Wallflowers and percentage weed cover. Data was analysed using ANOVA.

Results

At the first phytotoxicity assessment 2 WAT, plants were at cotyledon stage and there were no phytotoxic effects visible. At the second assessment 6 WAT, the majority of the treatments appeared safe (Figure 45). However, plots treated with Wing-P 3.5 L/ha + Gamit 36 CS 0.125 L/ha (T10) did show some damage with yellowing to the foliage and slightly distorted leaves scoring 6.3 on the phytotoxicity scale.

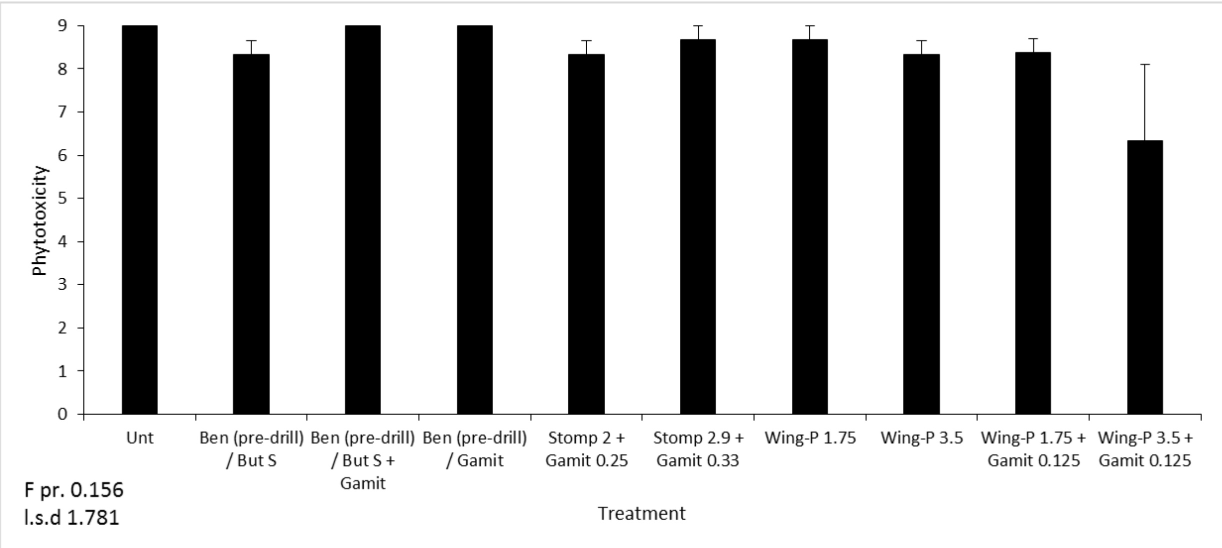


Figure 45. Phytotoxicity scores for each treatment 6 weeks after treatment – 25 August 2015 (scale of 0 - 9 where 9 is healthy, 0 is dead and 7 is commercially acceptable)

At the final assessment 10 WAT, plants treated with Wing-P 3.5 L/ha + Gamit 36 CS 0.125 L/ha (T10) had recovered, and all treatments were of marketable quality (Figure 46).

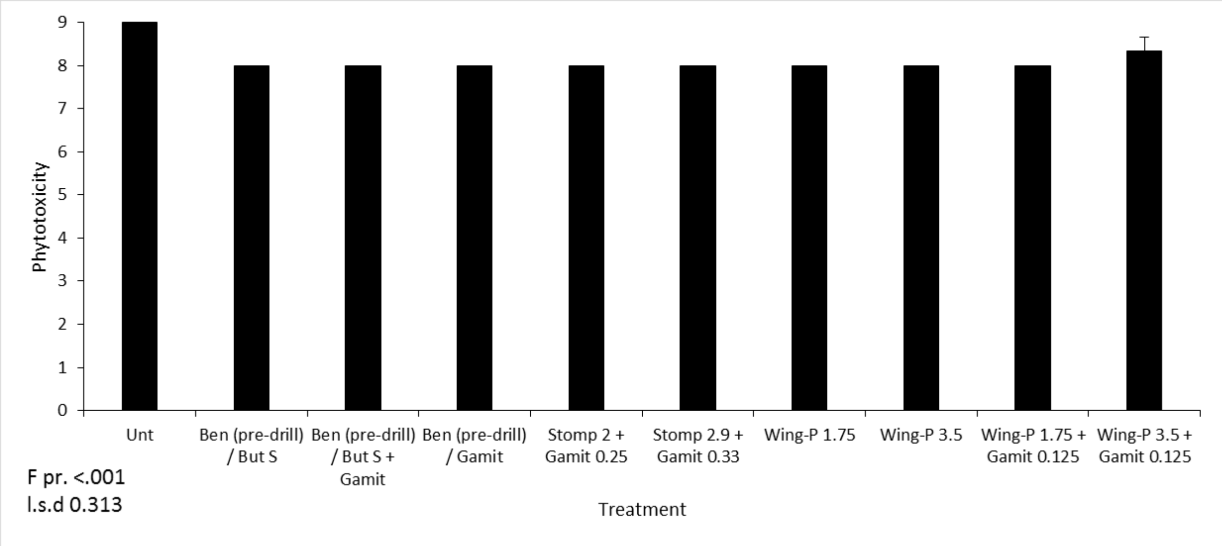


Figure 46. Phytotoxicity scores for each treatment 10 weeks after treatment – 21 September 2015 (scale of 0 - 9 where 9 is healthy, 0 is dead and 7 is commercially acceptable)

The number of emerged plants per plot were assessed 6 WAT and differences between the treatments were noted (Figure 47). Emergence was as good as in the untreated plots; 108 seedlings per plot, in plots treated with Benfluralin / Gamit 36 CS (T4), Wing-P 1.75 L/ha (T7) and Wing-P 1.75 L/ha + Gamit 36 CS 0.125 L/ha (T9). Plots treated with Stomp Aqua + Gamit 36 CS at both 2 L/ha + 0.25 L/ha and 2.9 L/ha + 0.33 L/ha (T5 and T6), Wing-P 3.5 L/ha (T8) and Wing-P 3.5 L/ha + Gamit 36 CS 0.125 L/ha (T10) showed the lowest rate of emergence (84, 87.3, 86 and 72 emerged seedlings per plot respectively), although this was not significantly lower than the control (Figure 48).

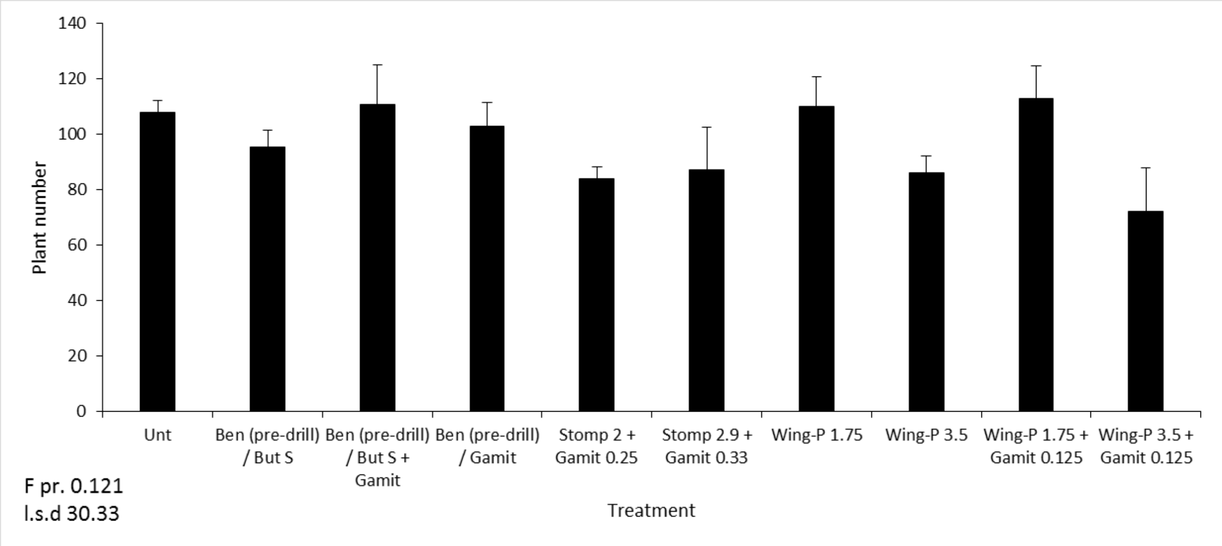


Figure 47. Average number of emerged seedlings per plot for each treatment – 25 August 2015

Figure 48. Reduced emergence in Wallflowers treated with Wing-P 3.5 L/ha and Gamit 36 CS 0.125 L/ha (left) compared to Wing-P 1.75 L/ha and Gamit 36 CS 0.125 L/ha (right) – 25 August 2015

A weed assessment was carried out 6 WAT. Weed control was very good in all of the treatments (see Figure 49), although slightly less so in plots treated with Benfluralin / Gamit 36 CS (T4). At the final assessment 10 WAT, weed control remained good in all treatments, and this was significantly different from the control where weed cover was 50% (p=0.002, Appendix 3, Table 9). At 10 WAT the lowest percentage weed cover was seen in plots treated with Wing-P + Gamit 36 CS (T10), Benfluralin followed by Butisan S (T2), Stomp Aqua + Gamit 36 CS (T6) and Wing-P (T7, with percentage covers of 5, 5.7, 8.3 and 8.3% respectively.

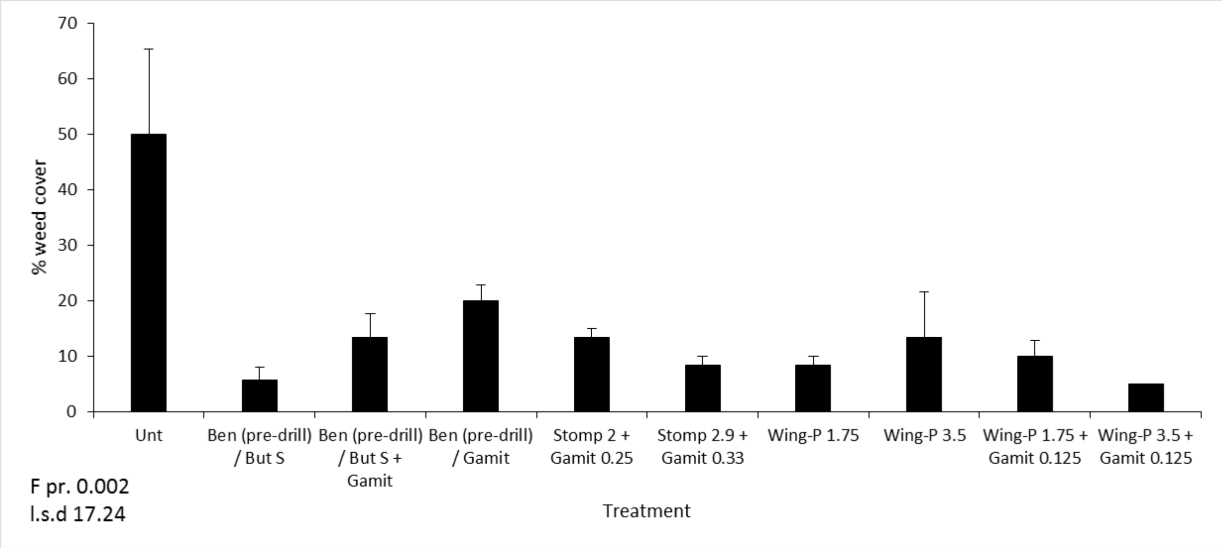


Figure 49. Average weed cover for each treatment – 25 August 2015

Discussion

At the final assessment 10 WAT all treatments were safe in terms of foliar phytotoxicity on the Wallflowers. However, emergence remained reduced by some of the treatments, notably Stomp Aqua + Gamit 36 CS at both 2 L/ha + 0.25 L/ha and 2.9 L/ha + 0.33 L/ha (T5 and T6), Wing-P 3.5 L/ha (T8) and Wing-P 3.5 L/ha + Gamit 36 CS 0.125 L/ha (T10).

Benfluralin as a pre-drilling treatment followed by Gamit 36 CS (T4) was safe and emergence was as good as the untreated plots. Crop emergence was also good in plots treated with Wing-P 1.75 L/ha (T7) and Wing-P 1.75 L/ha + Gamit 36 CS 0.125 L/ha (T9), emergence was virtually the same in these two treatments.

In terms of weed control, all products achieved sufficient weed control, although Benfluralin / Gamit 36 CS (T4) was slightly poorer. There was little difference between T7 and T9, Wing-P 1.75 L/ha and Wing-P 1.75 L/ha + Gamit 36 CS 0.125 L/ha, which suggests that for the weed population at this site there was no benefit to mixing Wing-P with Gamit.

Species 7: Peony

Materials and methods

The Peony trial was set up to test the safety and efficacy of nine different herbicide treatments (Table 46), when applied either pre-planting or post-planting to a crop of newly planted peonies (*Paeonia* Hybrids; Paeonaciae). The trial was located on a grower's holdings in Lincolnshire and was set up as a randomised block design with three replicated blocks. The pre-planting treatments were applied immediately before planting and the post-planting treatments were applied after planting, on the same day, 2 April 2014. The site was weed free prior to applying the test treatments. Herbicide treatments were applied to plots by ADAS staff using a 1 m lance and OPS knapsack sprayer at a medium spray quality. Herbicides were applied at 200 L/ha. Plots measured 3.5 m long by 1.2 m wide and consisted of two rows of plants.

Plants were assessed for phytotoxicity on three occasions. Phytotoxicity was recorded on a scale of 0 to 9, where 0 was dead, 9 was healthy and comparable to the untreated plants and a score of 7 would be considered commercially acceptable. The first assessment was delayed due to slow emergence of the crop and so was carried out on 13 May 2015, 6 weeks after the treatments had been applied. The remaining phytotoxicity assessments were carried out at 10 WAT and at 14 WAT. Weed assessments were carried out on the same day as the phytotoxicity assessments. Weed assessments involved measuring the percentage of the different weed species in a plot using 1 m² quadrats.

Table 46. Details of herbicide treatments applied pre or post planting to a Peony crop - Lincolnshire 2015

Trt no.	Pre-planting	Rate kg/ha or L/ha	Post-planting	Rate kg/ ha or L/ha
1	Untreated	-	Untreated	-
2	Benfluralin*	2.0	Butisan S + Flexidor 500	1.5 + 0.5
3	Untreated	-	Stomp Aqua + Butisan S + Flexidor 500	2.9 + 1.5 + 0.5
4	Untreated	-	Successor	2.0
5	Untreated	-	Successor + Stomp Aqua	2.0 + 2.9
6.	Untreated	-	Successor + Flexidor 500	2.0 + 0.5
7.	Untreated	-	HDC H24 + Venzar Flowable	X + 3.0
8.	Untreated	-	HDC H24 + Stomp Aqua	X + 2.9
9.	Untreated	-	HDC H24 + Flexidor 500	X + 0.5
10.	Wing-P + Gamit 36 CS**	3.5 + 0.125	Untreated	-

* Pre-planting treatment to be sprayed then incorporated into the soil using a rake

** Pre-planting treatment to be sprayed but not incorporated into soil

X Undisclosed

Results

Very little phytotoxicity was seen in the trial except for a slight effect of Wing-P (3.5 L/ha) + Gamit 36 CS (0.125 L/ha) when applied pre-planting which scored a phytotoxicity score of 8 at the assessment carried out on 14 May, however results were not significant (Table 47). This treatment combination initially stunted the crop but plants recovered by the final assessment and were comparable to the untreated plants with a phytotoxicity score of 9.

Table 47. Phytotoxicity results for peony trial – 2015 (scale of 0 - 9 where 9 is healthy, 0 is dead and 7 is commercially acceptable)

Trt no.	Pre-planting	Post-planting	Score 13.05.15	Score 11.06.15	Score 11.07.15
1	Untreated	Untreated	9.0	9.0	9.0
2	benfluralin	Butisan S + Flexidor 500	9.0	9.0	9.0
3	Untreated	Stomp Aqua + Butisan S + Flexidor 500	8.7	9.0	9.0
4	Untreated	Successor	9.0	9.0	9.0
5	Untreated	Successor + Stomp Aqua	9.0	9.0	9.0
6	Untreated	Successor + Flexidor 500	9.0	8.7	9.0
7	Untreated	HDC H24 + Venzar Flowable	9.0	9.0	9.0
8	Untreated	HDC H24 + Stomp Aqua	8.7	9.0	9.0
9	Untreated	HDC H24 + Flexidor 500	8.7	9.0	9.0
10	Wing-P + Gamit 36 CS	Untreated	8.0	8.3	9.0
P value			NS	0.093	NS
L.S.D (df 18)			NS	0.4669	NS

The percentage weed cover of plots was significantly different between the treatments at the first assessment carried out 6 WAT (Figure 50). All treatments had significantly lower percentages of weeds per plot than the untreated control (p=0.001). At 6 WAT, Benfluralin + Butisan S + Flexidor 500 (T2), Stomp Aqua + Butisan S + Flexidor 500 (T3), Successor + Stomp Aqua (T5), H24 + Venzar flowable (T7) and H24 + Stomp aqua (T8) looked most promising in terms of weed control with 1, 1, 5, 1 and 1% weed cover of a plot respectively .

At the assessment carried out 10 WAT were applied, several treatments still had a significantly lower percentage cover of weeds compared to the untreated control (p<0.001). On this date, Stomp Aqua + Butisan S + Flexidor 500 (T3), H24 + Venzar Flowable (T7) and H24 + Stomp aqua (T8) (Figure 51) were all still providing good weed control with 6.6, 8.3 and 5% weed cover respectively.

After 14 weeks the persistence of all treatments was breaking down, however T3, T7 and T8 all had significantly smaller percentages of weeds per plot compared to the untreated control (p=0.003). H24 + Stomp Aqua (T8) provided the best weed control results at this stage with a mean percentage plot cover of 53% compared to the untreated which had a mean of 100% weed cover per plot. However in order to keep weeds to an acceptable level a cultivation and re-application of herbicides would be required between 10 and 14 weeks.

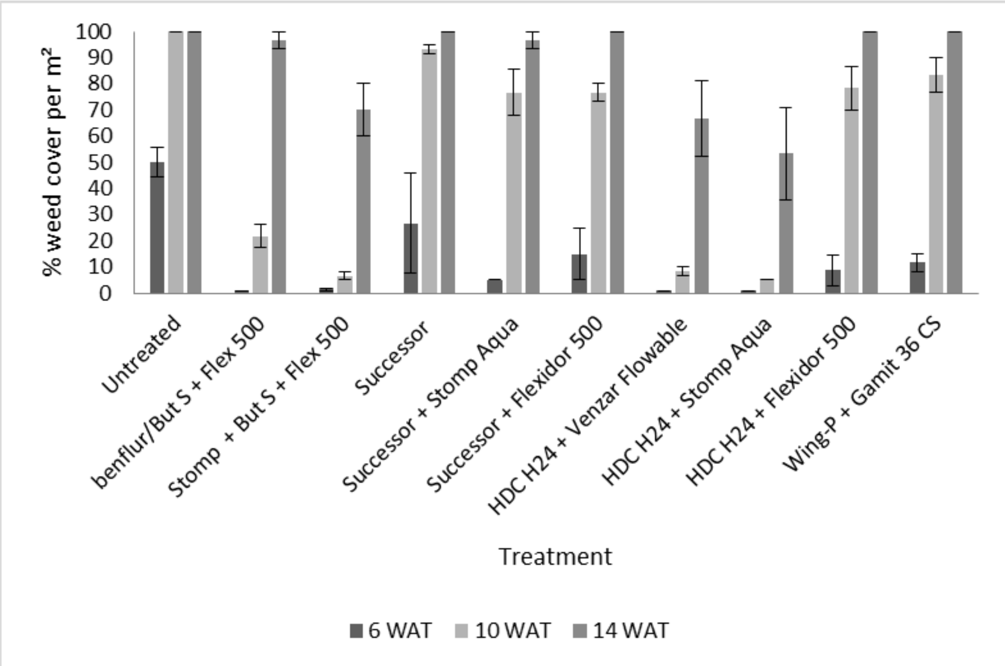


Figure 50. Average percentage weed cover per m² in the Peony trial - Lincolnshire 2015

Figure 51. Weed cover in untreated plot, left, and HDC H24 + Stomp Aqua, right, in Peony trial on 11 June 2015 (10 weeks after treatment) – Lincolnshire

Discussion

Very little phytotoxicity was seen in the trial except for a slight effect of Wing-P (3.5 L/ha) + Gamit 36 CS (0.125 L/ha) applied pre-planting. Initially, this treatment combination slightly stunted the crop in comparison to plants from the other treatments, but plants recovered by the final assessment. No other treatments caused any stunting or phytotoxic damage to the crop. Tank mixtures of Stomp Aqua (2.9 L/ha) with either HDC H24 or Butisan S (1.5 L/ha) gave the best weed control out of the treatments tested.

Conclusion

Work carried out at the Cut Flower Centre (CFC) found Stomp Aqua + Gamit 36 CS, post drilling pre emergence to be safe and effective for use on drilled China aster. This could then be followed up with a post-emergence application of Shark if required. This treatment was also found to be the best in the grower trial on transplanted China aster when applied pre-planting. The tank mix Stomp Aqua + Goltix provided the best weed control and was the safest option in both the CFC and grower trials of Sweet William. In the Wallflower trial at the CFC Butisan S, Gamit 36 CS and Wing-P at the lower rate appeared safe when applied at drilling. Wing-P at the lower rate + Gamit 36 CS also appeared to be safe when applied as a tank mix. Benfluralin was also safe as a pre-drilling incorporated treatment on Wallflower and could be combined with some of the post drilling treatments. Although it is not yet available in the UK it is anticipated that it will be introduced in the future for vegetable and oil seed rape crops with an EAMU for ornamentals. In peony, Stomp Aqua tank mixed with either Butisan S or HDC H24 were safe and provided effective weed control when used post-planting.

The next steps will involve identifying follow up treatments to maintain weed control up to harvest in the different cut flower crops.

Knowledge and Technology Transfer

Cut Flower Centre Open Day – Crop Walk. 5 August 2015

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References

Atwood, J. (2015). Herbicide screening for ornamental plant production (nursery stock, cut flowers and wallflowers). Horticultural Development Company Final report for project HNS/PO 192.

Briggs, J.B. (1993). Evaluation of systems of weed control for *dianthus barbatus* (sweet william) grown for flower production outdoors. Horticultural Development Company Final report for project BOF 029.

Briggs, J.B. (1997). Larkspur: evaluation of weed control systems in *delphinium ajacis* and *D. consolida* grown for flower production outdoors. Horticultural Development Company Final report for project BOF 040.

Knott, C., Hanks, G.R., Atwood, J. and Hughes, P. (2006). Outdoor flowers: an evaluation of herbicides. Horticultural Development Company Final report for project BOF 051.

Knott, C., Hanks, G.R. and Hughes, P. (2008). Lily: Herbicide trials. Horticultural Development Company Final report for project BOF 058.

Knott, C. (2012). Evaluation of potential alternative herbicides for narcissus following the loss of active ingredients. Horticultural Development Company Final report for project BOF 073.

Mason, L. (1993). Evaluation of systems of weed control in chrysanthemums grown for flower production outdoors. Horticultural Development Company Final report for project BOF 030.

Meeks, R., Hanks, G.R., Atwood, J., Briggs, J.B. & Meacham, M. (2001). Evaluation of herbicides for safe use on transplanted cut flower crops grown in Spanish tunnels. *Tests of Agrochemicals and Cultivars*, **22**, 24-25.

Meeks, R., Hanks, G.R., Atwood, J., Briggs, J.B. & Meacham, M. (2001). Evaluation of herbicides for safe use on direct-drilled cut flower crops grown in Spanish tunnels. *Tests of Agrochemicals and Cultivars*, **22**, 26-27.

O'Neill, T. (2014). SCEPTRE: Sustainable Crop & Environment Protection – Targeted Research for Edibles. Horticultural Development Company report for project CP 077

Appendices

Appendix 3. Raw data for charts

Drilled China aster

Table 1. Mean phytotoxicity scores at 4 weeks after treatment (WAT) and 10 WAT (1 WAT for Shark) - Drilled China aster 2015

Treatment	**Phyto 4 WAT**	**Phyto 10 WAT**
1. Untreated	9.0	9.0
2. Benfluralin / Gamit 36 CS	8.7	8.3
3. Unt / Kerb Flo 400	8.0	8.7
4. Unt / Nirvana (3)	8.3	8.3
5. Unt / Nirvana (4.5)	6.0	6.3
6. Unt / Stomp Aqua + Gamit 36 CS (2 + 0.05)	8.7	9.0
7. Unt / Stomp Aqua + Gamit 36 CS (2 + 0.125)	8.0	9.0
8. Unt / Stomp Aqua + Gamit 36 CS (2 + 0.25)	8.0	8.7
9. Unt / Shark (post em) (0.33)	N/A	5.7
10. Unt / Shark (post em) (0.66)	N/A	6.0
F pr.	**0.004**	**<.001**
l.s.d (18 d.f)	**1.274**	**1.587**

Table 2. Mean number of emerged seedlings per plot and% weed cover - Drilled China aster 2015

Treatment	**Emergence (No.)**	**% weed cover**
1. Untreated	76.0	6.3
2. Benfluralin / Gamit 36 CS	101.7	6.0
3. Unt / Kerb Flo 400	96.7	5.0
4. Unt / Nirvana (3)	79.3	3.7
5. Unt / Nirvana (4.5)	82.7	1.7
6. Unt / Stomp Aqua + Gamit 36 CS (2 + 0.05)	85.0	3.7
7. Unt / Stomp Aqua + Gamit 36 CS (2 + 0.125)	86.7	3.7
8. Unt / Stomp Aqua + Gamit 36 CS (2 + 0.25)	69.7	4.0
9. Unt / Shark (post em) (0.33)	N/A	N/A
10. Unt / Shark (post em) (0.66)	N/A	N/A
F pr.	**NS**	**0.064**
l.s.d (18 d.f)	**NS**	**2.914**

Transplanted China aster

Table 3. Mean phytotoxicity scores at 2 weeks after treatment (WAT) and 10 WAT and% weed cover - Transplanted China aster 2015

Treatment	Phyto 2 WAT of Shark	Phyto 10 WAT	% weed cover (03.07.15)
1.a Stomp Aqua + Gamit 36 CS	9.0	9.0	11.0
1.b Stomp Aqua + Gamit 36 CS / Shark (post-emergence)	**6.5**	9.0	3.5
2. Stomp Aqua + Dual Gold	9.0	9.0	12.5
3. Ronstar	9.0	9.0	7.5
F pr.	**<0.001**	**NS**	**0.065**
l.s.d (19 d.f.)	**0.2940**	**NS**	**7.03**

NS not significant

Larkspur

Table 4. Mean phytotoxicity score 11 weeks after treatment (WAT), number of emerged seedlings per plot and% weed cover – Larkspur 2015

Treatment	Phytotoxicity 11WAT	Emergence (No.)	% weed cover
1. Untreated	9.0	46.0	21.7
2. Benfluralin / Defy	6.0	58.7	18.3
3. Benfluralin / Gamit 36 CS	5.7	36.3	15.0
4. Unt / Stomp Aqua + Gamit 36 CS	6.3	50.3	6.7
5. Unt / Stomp Aqua + Defy	6.7	29.3	20.0
6. Unt / Stomp Aqua + Dual Gold	4.0	39.0	11.7
7. Unt / Wing-P	5.3	30.7	10.0
8. Unt / Dual Gold + Gamit 36 CS	8.0	46.0	16.7
9. Unt / Successor	4.0	31.3	13.3
Unt / H24	6.0	51.3	18.3
F pr.	**0.008**	**NS**	**NS**
l.s.d (18 d.f)	**2.394**	**NS**	**NS**

Sweet Williams - CFC

Table 5. Mean phytotoxicity scores at 6 weeks after treatment (WAT) (1 WAT for Shark) and 10 WAT (5 WAT for Shark) – Sweet Williams 2015

Treatment	Phyto 6 WAT	Phyto 10 WAT
1. Untreated	9.0	9.0
2. Benfluralin / Defy	8.0	8.0
3. Stomp Aqua + Goltix (0.75 + 1)	7.7	8.3
4. Stomp Aqua + Goltix (0.75 + 2)	7.7	8.0
5. Stomp Aqua + Defy (0.75 + 1)	8.0	8.0
6. Stomp Aqua + Defy (0.75 + 2)	6.7	6.0
7. Stomp Aqua + Defy (1 + 1)	8.0	6.7
8. Stomp Aqua + Defy (1 + 2)	7.7	6.3
9. Goltix	7.7	8.0
10. Shark (post-em)	4.7	9.0
F pr.	**0.015**	**0.072**
l.s.d (18 d.f)	**1.870**	**2.098**

Table 6. Mean number of emerged seedlings per plot and% weed cover – Sweet Williams 2015

Treatment	Emergence (No.)	% weed cover
1. Untreated	283	65.0
2. Benfluralin / Defy	176	60.0
3. Stomp Aqua + Goltix (0.75 + 1)	343	36.7
4. Stomp Aqua + Goltix (0.75 + 2)	291	11.7
5. Stomp Aqua + Defy (0.75 + 1)	231	45.0
6. Stomp Aqua + Defy (0.75 + 2)	182	46.7
7. Stomp Aqua + Defy (1 + 1)	227	36.7
8. Stomp Aqua + Defy (1 + 2)	314	43.3
9. Goltix	343	43.3
10. Shark (post-em)	N/A	23.3
F pr.	**0.021**	**NS**
l.s.d (18 d.f)	**118.4**	**NS**

Sweet Williams – Grower sites

Table 7. Mean number of emerged seedlings per plot, phytotoxicity 8 weeks after treatment (WAT) and% weed cover – Sweet Williams 2015 (grower's holdings Norfolk)

Treatment	**Crop emergence 8 WAT**	**Phytotoxicity 8 WAT**	**% weed cover**
1.a Stomp Aqua + Defy (higher rate)	1.8	7.8	4.5
1.b Stomp Aqua + Defy (higher rate) / Shark (post-em)	2.7	6.5	4.0
2.a Stomp Aqua + Defy (lower rate)	7.8	7.8	6.3
2.b Stomp Aqua + Defy (lower rate) / Shark (post-em)	7.0	6.5	5.0
3. Ronstar	28.0	9.0	12.5
F pr.	<0.001	<0.001	0.002
l.s.d (24 d.f)	3.621	0.4213	4.098

Table 8. Mean number of emerged seedlings per plot, phytotoxicity 12 weeks after treatment (WAT) and% weed cover – Sweet William 2015 (grower's holdings Lincolnshire)

Treatment	**Crop emergence per m² 12 WAT**	**Phytotoxicity 12 WAT**	**% weed cover**
1.Untreated	4.4	9.0	77
2.a Stomp Aqua + Defy	1.0	8.5	38.1
2.b Stomp Aqua + Defy / Shark (post-emergence)	6.0	8.0	18.8
3.a Stomp Aqua + Goltix	8.0	8.8	50.6
3.b Stomp Aqua + Goltix / Shark (post-emergence)	14	8.0	6.3
F pr.	<0.001	<0.001	<0.001
l.s.d (25 d.f)	1.485	0.3619	26.33

Wallflower

Table 9. Mean phytotoxicity scores at 6 weeks after treatment (WAT)and 10 WAT– Wallflower 2015

Treatment	**Phytotoxicity 6WAT**	**Phytotoxicity 10WAT**
1. Untreated	9.0	9.0
2. Benfluralin / Butisan S	8.33	8.0
3. Benfluralin / Butisan S + Gamit 36 CS	9.0	8.0
4. Benfluralin / Gamit 36 CS	9.0	8.0
5. Unt / Stomp Aqua + Gamit 36 CS (2 + 0.25)	8.33	8.0
6. Unt / Stomp Aqua + Gamit 36 CS (2.9 + 0.33)	8.67	8.0
7. Unt / Wing-P 1.75	8.67	8.0
8. Unt / Wing-P 3.5	8.33	8.0
9. Unt / Wing-P + Gamit 36 CS (1.75 + 0.125)	8.37	8.0
10. Unt / Wing-P + Gamit 36 CS (3.5 + 0.125)	6.33	8.3
F pr.	**NS**	**<.001**
l.s.d (18 d.f)	**NS**	**0.313**

Table 10. Mean number of emerged seedlings per plot and% weed cover – Wallflowers 2015

Treatment	**Emergence (No.)**	**% weed cover**
1. Untreated	108.0	50.0
2. Benfluralin / Butisan S	95.3	5.7
3. Benfluralin / Butisan S + Gamit 36 CS	110.7	13.3
4. Benfluralin / Gamit 36 CS	102.7	20.0
5. Unt / Stomp Aqua + Gamit 36 CS (2 + 0.25)	84.0	13.3
6. Unt / Stomp Aqua + Gamit 36 CS (2.9 + 0.33)	87.3	8.3
7. Unt / Wing-P 1.75	110.0	8.3
8. Unt / Wing-P 3.5	86.0	13.3
9. Unt / Wing-P + Gamit 36 CS (1.75 + 0.125)	112.7	10.0
10. Unt / Wing-P + Gamit 36 CS (3.5 + 0.125)	72.0	5.0
F pr.	**NS**	**0.002**
l.s.d (18 d.f)	**NS**	**17.24**

Peony

Table 11. Mean phytotoxicity 10 weeks after treatment (WAT) and% weed cover – Peony 2015 (grower's holdings Lincolnshire)

Treatment	**Phytotoxicity 10 WAT**	**% weed cover 10 WAT**
1. Untreated	9.0	100.0
2. Benfluralin / Butisan S + Flexidor 500	9.0	21.7
3. Unt / Stomp Aqua + Butisan S + Flexidor 500	9.0	6.7
4. Unt / Successor	9.0	93.3
5. Unt / Successor + Stomp Aqua	9.0	76.7
6. Unt / Successor + Flexidor 500	9.0	76.7
7. Unt / HDC H24 + Venzar Flowable	9.0	8.3
8. Unt / HDC H24 + Stomp Aqua	9.0	5.0
9. Unt / HDC H24 + Flexidor 500	9.0	78.3
10. Wing-P + Gamit 36 CS / Unt	9.0	83.3
F pr.	NS	<0.001
l.s.d (18 d.f)	NS	14.68

Appendix 2. Crop husbandry

The Cut Flower Centre took care of the plants' irrigation requirements, which was done as and when required, overhead by hand.

For the trials located on growers' holdings, all additional pesticides were the responsibility of the host grower. No further herbicides were added to any of the trial areas and no irrigation was used for any of the trials.