Horticultural Fellowship Awards

Interim Report Form

Project title:	Weed control in ornamentals, fruit and vegetable crops – maintaining capability to devise sustainable weed control strategies
Project number:	CP 86
Project leader:	John Atwood, ADAS UK Ltd
Report:	Annual report, March 2014
Previous report:	March 2013
Fellowship staff:	John Atwood, Project leader Lynn Tatnell, Assistant project leader
(“Trainees”)	Harriet Roberts, (fruit) and project management Jessica Sparkes, (weed biology) David Talbot, (ornamentals) Angela Huckle, (vegetables)
Location of project:	ADAS Boxworth
Industry Representative:	Wayne Brough, HDC
Date project commenced:	April 2011
Expected completion date:	March 2016

DISCLAIMER

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 14 March 2014**

Report authorised by:

Dr Barry Mulholland

Head of Horticulture

ADAS UK Ltd

Signature Date 14 March 2014

CONTENTS

Progress against Objectives

Objectives

Objective	Original Completion Date	Actual Completion Date	Revised Completion Date
1. To develop and mentor four staff in weed biology and control.	March 2016	in progress	
1.1 Train next generation horticulture consultants with an expertise in weed control.	March 2016	in progress	
1.2 Graduate weed biologist recruited.	June 2011	June 2011	
1.2.1 Graduate weed biologist trained and experience in horticultural weed research.	March 2016	In progress	
1.3 Recognises the most common problem weed species associated with field crops (horticulture and arable), protected crops and ornamentals.	Sept 2012	Sept 2012	
1.4 Understands the biology and current control strategies for the common weed species of a range of field crops (horticulture and arable), protected crops and ornamentals.	Sept 2012	Sept 2012	

Objective	Original Completion Date	Actual Completion Date	Revised Completion Date
1.5 Visited at least 10 nurseries with J Atwood or another specialist weed control expert and discussed/reviewed control strategies for key weeds on each nursery.	March 2013	Completed, but recommend that visits should continue where thought beneficial	
1.6 BASIS qualified.	Sept 2013	Jan 2013	
1.7 Understands requirements for ORETO standard experimental work.	Sept 2013	Sept 2013	
1.8 Designed experiment and drafted experiment protocol to satisfaction of ADAS Biometrician and ORETO Study Manager.	Sept 2013	Sept 2013	
1.9 Organised and managed successful delivery of two experiments from agreed work packages.	Sept 2013	Sept 2013	
1.10 Delivered consultancy advice to growers on control on weeds of the individuals' specialist work area protected crops and ornamentals on at least five problems.	Sept 2014	In progress	
1.11 Drafted HDC Project Reports on at least two projects.	Sept 2013	Sept 2013	
1.12 Submitted to HDC or elsewhere at least three proposals on R&D	March 2014	Dec 2013	

Objective	Original Completion Date	Actual Completion Date	Revised Completion Date
topics supported by growers.			
1.13 Drafted an HDC Factsheet on biology and control of specific weed species of horticultural crops in specialist work area.	March 2013	At present, no specific requirement - will review in future	March 2016
1.14 Delivered at least three talks on weed control to nursery staff, grower groups or an HDC sponsored conference.	Sept 2014	Sept 2013	
2. Deliver applied research and KT work packages.	March 2016	In progress	
2.1.1 First pot screening for horticulture weeds set up.	Oct 2011	May 2012 (1st set) Feb 2013 (2nd set)	
2.1.2 First pot screening completed.	Aug 2012	March 2013	
2.1.3 Second pot screening for horticulture weeds set up.	Oct 2014		May 2014
2.1.4 Second pot screening completed.	Aug 2015		Aug 2014
2.2.1 First container plant screening trial set up.	Oct 2012	July 2012	
2.2.2 First container plant screening trial completed.	Sep 2013	Nov 2012	
2.2.3 Second container plant screening trial set	Oct 2013	June 2013	

Objective	Original Completion Date	Actual Completion Date	Revised Completion Date
up.			
2.2.4 Second container plant screening trial completed.	Sep 2014	Nov 2013	
2.2.5 Third container plant screening trial set up.	Oct 2015		June 2014
2.2.6 Third container plant screening trial completed.	Sep 2016		Nov 2014
2.3.1 First tree field herbicide trial set up.	April 2012	April 2012	
2.3.2 First tree field herbicide trial completed.	June 2013	Sept 2013	
2.3.3 Second tree field herbicide trial set up.	April 2013	Replaced with herbicide trial in stocks for cut flowers completed Sept 2013	
2.3.4 Second tree field herbicide trial completed	June 2013	Replaced with herbicide trial in stocks for cut flowers	
2.4.1 First vegetable herbicide trial set up.	May 2013	March 2013	
2.4.2 First vegetable herbicide trial completed.	Aug 2013	Sept 2013	
2.4.3 Second vegetable herbicide trial set up.	May 2014		
2.4.4 Second vegetable herbicide trial completed.	Aug 2014		
2.4.5 Third vegetable herbicide trial set up.	May 2015		

Objective	Original Completion Date	Actual Completion Date	Revised Completion Date
2.4.6 Third vegetable herbicide trial completed.	Aug 2015		
2.5.1 Top fruit herbicide trial set up.	April 2015		
2.5.2 Top fruit herbicide trial completed.	Sept 2015		
2.6.1 Ground cover trial set up.	April 2013	In progress (initial trial run in 2012)	
2.6.2 Ground cover trial completed.	Aug 2015		
2.7.1 Perennial weed trial set up.	March 2013	Delayed due to late spring	April 2013
2.7.2 Perennial weed trial completed.	Sept 2015		
3. Set up a working group within the European Weed Research Society.	March 2012	Not fully functional yet	March 2016

Summary of Progress

A training programme has continued in 2013 with both general ADAS courses and more specific technical training. As the trainees have gained experience and are all now BASIS qualified, training has switched to some extent from more formal training events to individual coaching on specific aspects of the job. For the trainees based at Boxworth there continues to be the opportunity to gain further experience by working on a wide range of weed control projects not just those specifically planned through the fellowship. With increasing experience and confidence the trainees have been able to plan and run weed control experiments, present results at events across all sectors and, more recently, develop project proposals outside of the weeds fellowship.

Jessica Sparkes has been on maternity leave since August 2013 but intends to return during the latter half of 2014. Maria Tzortzi was been promoted from scientific officer to replace Jessica initially on a temporary basis. She has participated fully in the fellowship training activities and experiments and her appointment as weed researcher has now been made permanent.

The nursery stock experiments for 2013 were successfully planned and written up by David Talbot in the West Midlands. The second container nursery experiment (Objective 2.2) was concluded in November 2013 as was the budded tree herbicide experiment (Objective 2.3). A follow up container nursery experiment is being planned by David Talbot for 2014, further developing some treatments first tested in 2013 and introducing new experimental compounds.

Possible species to be grown as living mulches with potential for use within the crop rows of bush and top fruit were examined for growth parameters and nitrogen balance (Objective 2.6) in pot experiments by Jessica Sparkes, Maria Tzortzi and Harriet Roberts in 2013. Field sowings were made in an apple plantation at a commercial top fruit holding in autumn 2013. This work will be continued in 2014 with growth studies, water and nitrogen usage and apple yields.

Following liaison with the industry, Angela Huckle ran a programme of herbicide trials for improved control of groundsel in salad leaf rocket (Objective 2.4) during 2013. These trials were based on growers' holdings. Further work on salad crops is planned for 2014 with both herbicide screening and weed reducing green manure treatments.

At the request of the cut flower industry, an additional project was included in the programme of work for 2013. Angela Huckle managed an herbicide trial on stocks for cut flowers at the Cut Flower Centre (CFC) Spalding in liaison with CFC manager Lyndon Mason. This trial was be run instead of a second field tree herbicide trial, as it was thought that sufficient information was gained from the first tree trial which covered two seasons. Further herbicide screening work on cut flowers will be managed by Angela Huckle outside the fellowship project.

The control of perennial weeds is being covered by several experiments investigating different aspects. An experiment investigating control of perennial weeds (Objective 2.7) by the allelopathic effects of cover crops started in 2013, managed by Jessica Sparkes and Maria Tzortzi and follows a research area initially developed by Lynn

Tatnell. It is hoped to develop this further in 2014 with field trials but will be dependent on finding a suitable site. An herbicide screening on perennial thistle control in peony for cut flowers was carried out during 2013. Further work on perennial control includes a fallow year herbicide trial started in autumn 2013 and a literature review on non-chemical methods for perennial weed control is being undertaken in 2014.

Liaison with researchers in other European countries is proceeding (Objective 3.0). Lynn Tatnell presented posters on cover crops and herbicide resistance, respectively, at a European Weed Research Society Symposium in Turkey in June 2013.

Initially through contacts made at the minor crops working group Brussels March 2012, John Atwood has made contact with researchers in the Netherlands and Germany and set up a SharePoint web site to share outline details of current research projects. Currently we have access to horticultural research reports from Germany (some can be accessed at http://www.hortigate.de) and these have proved useful in developing treatments for the salad leaf rocket experiments. Further contacts were made during 2013 through meetings with Peter Hartvig Aarhus University, Denmark, and Heinrich Loesing LWK Schleswig-Holstein, Germany.

European contacts

The Netherlands

Wageningen University and Research Centre, Wageningen Campus, Droevendaalsesteeg 4, 6708 PB Wageningen, Netherlands

Ornamentals: Fons van Kuik

Vegetables: Rommie van der Weide, Marleene Riemens

Fruit: Bart Heijne

General (Principal contact): Corne Kempenaar

Germany

Dienstleistungszentrum Ländlicher Raum - Rheinpfalz -(DLR), Berufsbildende Schule für Wein- und Gartenbau, Breitenweg 71, 67435 Neustadt/Weinstrasse (Germany)

Vegetables (Principal contact): Ingeborg Koch

Fruits: Michael Glas

Vines: Friedrich Louis

Ornamentals: Bernd Böhmer

LWK Schleswig-Holstein, Aussenstelle, Baumschulberatung, 25421 Pinneberg, Germany

Ornamentals: Heinrich Loesing

Denmark

Aarhus University, Department of Agroeconomy- Crop Health, Forsogsvej 1, 4200 Slaelse, Denmark

All crops: Peter Hartvig

Eire

Tillage Crops KT and Horticulture Development

Teagasc Kildalton College, Piltown, Co Kilkenny

Ornamentals and foliage: Andy Whelton

USA

North Carolina State University, Raleigh, 27695, North Carolina

Ornamentals: Joe Neal

Contacts from France are being sought. The most active interest so far has come from researchers in the Netherlands and Germany. Good links also exist with researchers in Eire and the US working on ornamentals and foliage crops.

Milestones not being reached

The working group of European weed control researchers was not set up by March 2012 as planned. The timing of this target was too optimistic but progress is being made in building links with researchers from the Netherlands, Denmark and Germany. It is planned to continue building links with researchers in continental Europe through the life of the project by attendance at EWRS workshops and informal contacts, so a revised target of March 2016 is proposed.

Do remaining milestones look realistic?

1.10. Consultancy advice. This should be broadened beyond protected crops and ornamentals.

1.13. Drafting HDC factsheets. This will depend on HDC requirements. Nothing is planned at present, but there are possible gaps that could be filled such as weed control in cut flowers.

2.3.3. Second field tree herbicide trial. This experiment was replaced with an herbicide trial on column stocks grown for cut flowers at the request of the industry.

Training undertaken

During the year the four fellowship trainees undertook a range of training activities and "on-the-job" work experience in the field of weed control research and consultancy. Activities included formal training courses, internal seminars, attendance at conferences and field visits with experienced consultants. The trainees' training activities are listed in Appendix 1.

Expertise gained by trainees

In addition to the formal non-technical ADAS training programme, the trainees have gained practical experience of drafting protocols to the ADAS standard, setting up and managing experiments and drafting experimental reports. The main experience gained during the three years of the fellowship is summarised below:

Jessica Sparkes

- Improved background knowledge of UK agriculture and horticulture
- Experience in weed resistance testing
- Seedling weed identification
- Providing consultancy advice
- Research on non-chemical weed control methods
- Gained BASIS qualification for Horticulture
- Delivered a weed control presentation at a grower meeting (HDC Narcissus technical seminar, Cornwall)

Harriet Roberts

- Technical writing improved
- Experience in contract management, protocol development, managing herbicide trials and drafting reports
- Experience in new project development, drafting proposals and presentation of concepts
- Weed seedling identification
- Trained in aspects of herbicide advice in fruit and nursery stock crops
- Gained BASIS qualification for Horticulture
- Presented fruit weed control research results at SCEPTRE project management meeting
- Presented weed control research results at HDC hardy ornamentals panel meeting
- Presented weed control research results at amenity forum meeting, Lancaster

Angela Huckle

- Networking with European researchers
- Staff management and quality systems
- Gave seminar to staff following visit to EWRS workshop in Spain
- Trained in weed control in nursery stock and fruit
- Gained BASIS qualification for Horticulture
- Developed experiment protocols for vegetable weed control projects in consultation with industry leading producer

David Talbot

- Confident and skilled in giving “on-nursery” advice on weed control programmes in nursery stock and protected ornamentals
- Gaining experience in ADAS quality management systems when running “off-site” experiments
- Consolidated existing skill in identification of seedling weeds

Other achievements in the last year not originally in the objectives

Harriet Roberts has taken the lead in drafting protocols, setting up experiments and drafting reports under John Atwood's supervision for several important weed control projects outside of the fellowship including SCEPTRE projects on perennial weed control in bush and cane fruit. She has developed new herbicide proposals for the HDC soft panel including the use of Shark (carfentrazone-ethyl) as a winter treatment for strawberries. These proposals were well received and are being funded.

Jessica Sparkes, guided by Lynn Tatnell has undertaken a comprehensive economic review of electrical weed control methods for CRD. She has also worked with ADAS colleagues running a commercial programme of screening for herbicide resistance in grass weeds such as black-grass.

Changes to project

Are the current objectives still appropriate for the Fellowship?

Broadly speaking the current objectives remain appropriate for the fellowship but some adjustments to the timing of the milestones have been requested.

Grower Summary - Objective 2.2 – Second container plant screening trial

Headline

- HDC H18 proved safe to the majority of crop species tested and will be taken forward for further crop safety assessments and detailed weed control spectrum testing.
- Wing-P was promising in terms of safety to the crop species tested but subsequently proved too difficult to gain an authorisation for use over crop foliage, an EAMU for pre-emergence use remains available.

Background

Weed control in container-grown nursery stock continues to rely on an increasingly limited range of active ingredients following the loss of key active ingredients in recent years. The loss of Ronstar 2G (oxadiazon) which has a final use date of 30 June 2015 has serious implications for the UK horticultural industry.

The focus of this project was to find alternative herbicides that would be safe to apply over foliage immediately after potting and to follow up with later in the summer. At present the main herbicide for this period is Flexidor 125 (isoxaben). Hitherto Flexidor 125 has been used as a supplementary treatment to follow up Ronstar 2G, however it will now be the main treatment. The problems with relying on Flexidor 125 are however:

- **Some shrub species and even more herbaceous species are sensitive to it.**
- **Groundsel, willowherb, moss and liverwort are not controlled.**
- **Only two applications per year are permitted and in any case reliance on one herbicide will lead to resistance problems.**

The main objective of the trial was to assess the crop safety of two new herbicides: Wing-P (pendimethalin + dimethenamid) and HDC H18 (experimental product) to a range of container-grown nursery stock species.

Summary

A weed control trial was carried out on container-grown nursery stock at Wyevale Container Plants, Hereford. The main objective of the trial was to assess the crop safety of two new herbicides: Wing-P (pendimethalin + dimethenamid) alone, and in mixtures with Flexidor 125 (isoxaben) in order to broaden the weed control spectrum, and HDC H18 (experimental product) to a range of container-grown nursery stock species. A commercial standard treatment; Flexidor 125 was included for comparison. Wing-P was included in the trial carried out in 2012 and appeared to be relatively safe so was included again in 2013, to broaden the knowledge of the products' performance on different plant species. The Wing-P treatment proved to be more damaging on the species tested in 2013 than those tested in 2012. In 2013 damage was still evident on *Buddleja, Hydrangea* and *Perovskia* 12 weeks after treatment. Mixing Wing-P with Flexidor 125 resulted in similar levels of damage with *Buddleja* and *Perovskia,* in addition damage was noted on *Spiraea* 12 weeks after treatment. HDC H18 initially proved to be more damaging than Flexidor 125, however most species recovered; with the exception of *Buddleja* and *Perovskia* where damage was still visible 12 weeks after treatment. If authorisation can be obtained, HDC H18 has potential for use on a range of hardy nursery stock species. Unfortunately, subsequent to these experiments it proved too difficult to obtain an authorisation for the use of Wing-P over the crop at a rate high enough to be effective; the existing Extension of Authorisation for Minor Use (EAMU 0253/13) for Wing–P in outdoor ornamental plant production limits use to seed-grown and bulb crops, as the product has to be applied prior to crop emergence, this EAMU also prohibits application via hand held equipment.

Phytotoxicity was recorded on a 0–9 Scale with 0 representing plant death, 9 being comparable with controls and 7 being commercially acceptable damage. Table 2.2.1 lists the treatments and approval status and Table 2.2.2 summarises phytotoxicity scores 12 weeks after treatment.

Table 2.2.1. Approval status of herbicides used in the container HNS experiment

Treat no.	Product name	Active ingredient	Rate (L/ha or kg/ha)	Approval status
1	Untreated			
2	Flexidor 125	Isoxaben (125 g/L)	1.0 L/ha	Label
3	Wing P	Pendimethalin (250g/L) + dimethenamid – p (212.5 g/L)	4.0 L/ha	Not approved
4	Wing P + Flexidor 125	Pendimethalin (250g/L) + dimethenamid – p (212.5 g/L) isoxaben (125 g/L)	4.0 L/ha 1.0 L/ha	Not approved + Label
5	HDC H18	Confidential		Not approved

Table 2.2.2. Mean phytotoxicity scores (9 = similar to untreated, 7 = acceptable slight damage, 0 = plant death) 12 weeks after treatment

Treatment Number	**Scores**											
	Buddleja	***Ceratostigma***	***Cistus***	***Cornus***	***Escallonia***	***Hebe***	***Hydrangea***	***Perovskia***	***Physocarpus***	***Santolina***	***Sorbaria***	***Spiraea***
1	9	9	9	9	9	9	9	9	9	9	9	9
2	7	9	9	9	9	9	9	7	9	9	9	8.50
3	7	9	9	9	9	9	7.50	6	9	9	9	8.75
4	7	9	9	9	9	9	7.75	6.50	9	9	9	7.50
5	6.50	9	9	9	9	9	8.75	7	9	9	9	8.25
F pr.	<.001	-	-	-	-	-	<.001	<.001	-	-	-	0.045
l.s.d (19 d.f)	0.398	0.000	0.000	0.000	0.000	0.000	0.703	0.398	0.000	0.000	0.000	0.964

Financial benefits

There are no financial benefits as yet from this experiment. If it is possible to obtain authorisation for use of HDC H18 on container-grown nursery stock then it is likely that hand weeding costs of up to £43,000 per hectare (based on three rounds of hand weeding) will be saved. The likely cost of the herbicide is not known, but it will be significantly less than any hand weeding costs.

Action points

- If HDC H18 becomes available it will be a useful treatment for post-potting summer treatment of hardy nursery stock species.
- *Buddleja* and *Perovskia* are sensitive to HDC H18 and should not be treated when or if the product becomes commercially available.

Grower Summary - Objective 2.3 - Tree field herbicide trial

Headline

- HDC H30 was the best weed control treatment when used in addition to the nursery standard herbicide programme, but caused some stunting to rootstocks especially *Malus* in the unusually wet growing season of 2012.

Background

Weed control programmes in field-grown nursery stock have relied upon a limited number of active ingredients for a number of years. The gradual withdrawal of the Long Term Arrangements for Extension of Use (LTAEU) has also impacted upon the herbicides that HNS growers are able to utilise.

During 2013 it was announced that the authorisation for Ronstar Liquid (oxadiazon) would be withdrawn, with use up of existing stocks allowed until June 2015. The loss of Ronstar Liquid will further reduce weed control options in field-grown production. Although relatively expensive, Ronstar Liquid is a reliable herbicide used both in the field and around nurseries on container beds (before standing down). A number of alternatives which could potentially be used in field-grown stock were selected for testing in this herbicide screening.

Summary

The trial commenced in 2012 investigating weed control on field-grown *Malus, Prunus, Quince* and *Sorbus* at Frank P Matthews Ltd, Tenbury Wells, with treatments applied after planting in April 2012 and again after heading back in March 2013. Nine herbicide treatments were assessed, seven of which were novel treatments. All March 2012 treatments were applied after planting in addition to a standard programme of Devrinol (napropamide) + Flexidor 125 (isoxaben), and also applied post-heading back the following spring to dormant budded trees added to the nursery standard treatment of Flexidor 125 (isoxaben) + Stomp Aqua (pendimethalin). The treatment programmes are summarised in Table 2.3.1.

When recorded 12 weeks after treatment in 2013 the standard treatment had weed cover of 13.2%, with predominant weeds groundsel *(Senecio vulgaris),* white clover *(Trifolium repens)* and common chickweed *(Stellaria media).* The best additional treatments for weed control were HDC H30, Ronstar Liquid (oxadiazon) and Gamit

36 CS (clomazone) with 0.8%, 1% and 7% weed cover respectively. Only HDC H30 and Ronstar Liquid persisted sufficiently to give improved weed control by 16 weeks after treatment. It is now known that the authorisation for the use of Ronstar Liquid will cease from 30 June 2015. No stunting was noted on any species treated with HDC H30 during 2013; it is thought that the excessive summer rainfall washed this herbicide into the crops rooting zone in 2012 and root uptake occurred resulting in some stunting. No carry over effect was noted in the maiden year 2013.

Phytotoxicity was recorded on a 0–9 Scale with 0 representing plant death, 7 commercially acceptable damage and 9 being comparable with controls, however, no phytotoxicity symptoms were noted in the trial. Table 2.3.2 lists treatments and their approval status and Table 2.3.3 summarises percentage weed cover.

Table 2.3.1. Treatment programmes used in the field tree herbicide experiments

Treat no	After planting	After heading back
1	Devrinol + Flexidor 125	Stomp Aqua + Flexidor 125
2	Devrinol + Stomp Aqua + Flexidor 125	Devrinol + Stomp Aqua + Flexidor 125
3	Ronstar Liquid + Devrinol + Flexidor 125	Ronstar Liquid + Stomp Aqua + Flexidor 125
4	HDC H30 + Devrinol + Flexidor 125	HDC H30 + Stomp Aqua + Flexidor 125
5	Gamit 36 CS + Devrinol + Flexidor 125	Gamit 36 CS + Stomp Aqua + Flexidor 125
6	HDC H13 + Devrinol + Flexidor 125	HDC H13 + Stomp Aqua + Flexidor 125
7	HDC H14 + Devrinol + Flexidor 125	HDC H14 + Stomp Aqua + Flexidor 125
8	HDC H15 + Devrinol + Flexidor 125	HDC H15 + Stomp Aqua + Flexidor 125
9	HDC H28 + Devrinol + Flexidor 125	HDC H28 + Stomp Aqua + Flexidor 125
10	Wing P + Devrinol + Flexidor 125	Wing P + Stomp Aqua + Flexidor 125

Table 2.3.2. Approval status of herbicides used in the field tree herbicide experiments

Product name	**Active ingredient**	**Rate (L/ha or kg/ha)**	**Approval Status**
Stomp Aqua	Pendimethalin	2.9 L/ha	EAMU
Flexidor 125	Isoxaben	2.0 L/ha	Label
Devrinol	Napropamide (450 g/L)	9.0 L/ha	Label
Ronstar Liquid	Oxadiazon (250 g/L)	4.0 L/ha	Label
HDC H30	Confidential		Not approved
Gamit 36 CS	Clomazone (360 g/L)	0.25 L/ha	LTAEU
HDC H13	Confidential		Not approved
HDC H14	Confidential		Not approved
HDC H15	Confidential		Not approved
HDC H28	Confidential		Not approved
Wing P	Dimethenamid-p + pendimethalin (212.5:250g/L)	4.0 L/ha	Not approved

Table 2.3.3. Mean percentage weed cover 4, 8, 12 & 16 weeks after treatment (WAT)

Treatment	Percentage weed cover 4 WAT	Percentage weed cover 8 WAT	Percentage weed cover 12 WAT	Percentage weed cover 16 WAT
1	0.25	1.0	13.2	79.2
2	1.0	1.0	23.5	86.2
3	0.0	0.50	1.0	5.5
4	0.25	0.50	0.8	2.8
5	0.50	1.0	7.0	68.8
6	0.25	1.0	9.2	50
7	0.75	1.0	10	55
8	0.50	1.0	16	85
9	0.50	1.0	8.2	65
10	0.25	1.0	9.8	54.5
F pr.	ns	0.023	0.027	<.001
l.s.d (39 d.f)	0.784	0.375	12.14	23.17

Financial benefits

There are no financial benefits from the results regarding HDC H30 because the product has yet to get approval for use on nursery stock. The additional use of Gamit 36 CS however has the potential to improve weed control with standard herbicide programmes giving additional control of groundsel, willowherb and cleavers which can be costly to remove by hand weeding/machine or by directed contact herbicide applications.

Action points

- If HDC H30 gains authorisation for use on outdoor nursery stock it could be a valuable additional treatment to include in an herbicide programme but care should be taken with *Malus* as leaching under exceptional rainfall conditions at the trial site caused significant stunting in 2012.
- Gamit 36 CS could be readily developed as an addition to the tank mix of standard herbicides such as Stomp Aqua + Flexidor 125 to add control of groundsel, willowherb and cleavers.

Grower Summary - Objective 2.4 - Vegetable herbicide trial: rocket

Headline

- Devrinol (napropamide) was confirmed as a crop safe treatment when incorporated pre-drilling or irrigated in post-drilling.
- A low rate of Goltix Flowable (metamitron) improved control of groundsel when added as a tank mix to the Devrinol incorporation treatment. It was crop safe at one site but reduced emergence by around 10 or 20% at a second site depending on whether primed or un-primed seed was used.
- A range of alternative herbicides were tested but none proved crop safe even where primed seed was used.

Background

The control of weeds in short season baby leaf salad crops can be difficult, especially in crops such as wild rocket which are sensitive to a number of commercially available herbicides. Crop rotations and soil sterilants such as dazomet (Basamid) are used to reduce the weed spectrum before drilling a crop of wild rocket. However, a number of weeds can still be problematic, including groundsel which is a particular problem as, due to its similar appearance to rocket, it can be missed during hand weeding leading to contamination and rejections by retailers. Hand weeding is also expensive (c. £150/ha) and with the threat of the possible loss of soil sterilants in the future, alternative herbicides for use in wild rocket are needed. The aim of the trial was to test alternatives to the current standard Devrinol, for crop safety and efficacy.

Summary

The main objective of the trial was to assess the crop safety of a range of new herbicides to be used alone or as an addition to the standard Devrinol treatment to improve control of groundsel in drilled wild rocket grown for salad leaf. Supplementary objectives were to see if the use of primed seed would enable more aggressive herbicide treatments to be used safely and to examine the efficacy and crop safety of different methods applying the standard Devrinol treatment.

Table 2.4.1. Approval status of herbicides used in the wild rocket experiments

Product name	Active ingredient	Rate (L/ha or kg/ha)	Approval Status
Devrinol	napropamide (450 g/L)	0.85 L/ha	EAMU
Dow Shield 400	clopyralid (400 g/L)	0.25 L/ha	EAMU
Goltix Flowable	metamitron (700 g/L)	1.0 L/ha	EAMU
Dual Gold	s-metolachlor (960 g/L)	1.4 L/ha	EAMU
Butisan S	metazachlor (500 g/L)	1.5 L/ha	Not approved
Wing-P	dimethenamid-p + pendimethalin (212.5:250g/L)	1.25 L/ha	Not approved

Site 1–Kent

The experiment was carried out on a commercial field crop in Kent, between June and July 2013. The variety 'Napoli' was used, and was drilled into non–sterilised soil containing four major weeds; common fumitory *(Fumaria officinalis)*, volunteer oil seed rape (*Brassica napus* ssp. *Oleifera)*, annual mercury *(Mercurialis annua)* and black bindweed *(Fallopia convolvulus)*. There were two trials situated side by side, one using non-primed seed, and the other using primed seed. Eight main treatments (including an untreated control) using six different pre-emergence applications of herbicides were tested and, as sub treatments, the effect of Dow Shield (clopyralid) was tested post-emergence with each pre-emergence herbicide treatment (for a complete treatment list see the Science Section of the report). Pre–drilling treatments were applied on 3 June and the trial was drilled immediately after treatment. Post-drilling treatments were also applied on the same day. Post-emergence treatments were applied on 25 June.

Phytotoxicity was first assessed in the crop on 25 June, 3 weeks after the pre and post drilling treatments. Levels of damage varied, with the most severe effects seen in Dual Gold, Butisan S and Wing-P plots (Figure 2.4.1). A final phytotoxicity assessment was carried out on 9 July, just prior to harvest.

Plots were also assessed for percentage of crop emergence, and percentage weed cover. Crop emergence was significantly reduced in plots treated with Dual Gold, Butisan S and Wing-P, and percentage weed cover also increased in these treatments, likely due to the reduced competition by the crop. Weed species included common fumitory *(Fumaria officinalis)*, volunteer oil seed rape (*Brassica napus* ssp. *Oleifera)*, annual mercury *(Mercurialis annua)*, black bindweed *(Fallopia convolvulus)* and fathen (*Chenopodium album*).

Results (Figure 2.4.2) indicate that Devrinol is the most crop safe treatment, and although weed germination was not fully controlled, the area covered by weeds was reduced. At this site, the addition of Goltix Flowable as a tank mix to the Devrinol treatment did not significantly affect emergence.

Figure 2.4.1. Plots treated with Dual Gold, Butisan S and Wing P can be clearly picked out due to the phytotoxic effect of these herbicides on the crop – 2013 (Site 1, Kent)

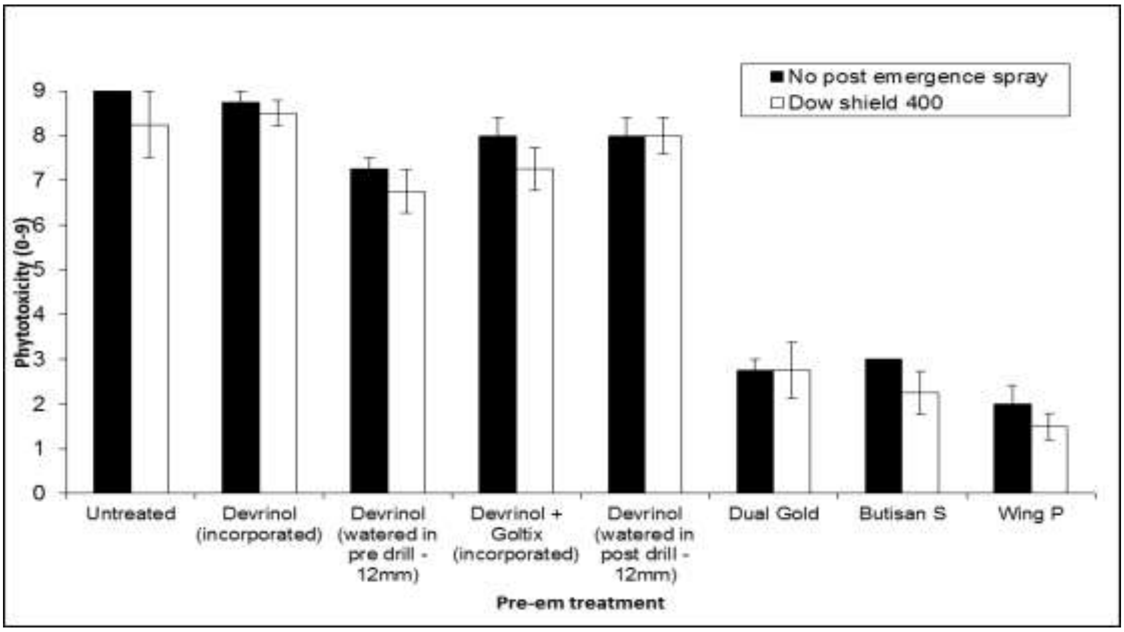


Figure 2.4.2. Phytotoxicity scores on non-primed seed – 2013 (Site 1, Kent). Error bars indicate standard errors. Treatments on the x axis show the pre-emergence applications (either pre drilling or post). White bars show plots which received Dow shield 400 as a post-emergence spray on top of the pre-emergence applications

Primed seed lead to a slight reduction in phytotoxicity, but did not decrease the damage to a point where the crop would become commercially acceptable in the most severely affected treatments.

Incorporation into the soil pre–drilling was the most crop safe method on non-primed seed. Also, Devrinol watered in post-drilling, as per current commercial practice, showed less phytotoxicity than Devrinol watered in pre-drilling, on non-primed seed. There was little difference between the Devrinol treatment application methods for primed seed at this site.

When Devrinol was tank-mixed with Goltix and incorporated pre-drilling this combination caused some very slight phytotoxic and crop emergence effects, but were of an acceptable commercial standard, therefore there is a possibility that this combination could potentially be crop safe at lower rates of Goltix.

Site 2 – Wiltshire

The experiment was carried out on a commercial field crop in Wiltshire, between May and June 2013. The variety 'Napoli' was used, and was drilled into soil sterilised with Basamid (dazomet). The two trials were situated side by side, one using non–primed seed, and the other using primed seed. Seven main treatments (including an untreated control) using five different pre-emergence applications of herbicides were tested and, as sub treatments, the effect of Dow Shield was tested post-emergence with each pre-emergence herbicide treatment. Pre–drilling treatments were applied on 7 May and the trial was drilled immediately after. Post-drilling treatments were then applied on 8 May. Post-emergence treatments were applied on 7 June.

Phytotoxicity was first assessed in the crop on 7 June, four weeks after the pre- and post-drilling treatment. Levels of damage varied, with the most severe effects seen for Dual Gold, Butisan S and Wing-P. A final phytotoxicity assessment was carried out on 20 June, just prior to harvest.

The trial was also assessed for percentage of crop emergence, and percentage weed cover. Emergence was significantly reduced by Dual Gold, Butisan S and

Wing-P, and percentage weed cover increased in the Butisan S treatment as a result of poor crop cover. There was a wide variety of weed species on this site including knotgrass (*Acronicta rumicis*), groundsel (*Senecio vulgaris)*, field pansy (*Viola arvensis*) and spear thistle (*Cirsium vulgare*). Results (Figure 2.4.3) indicate that Devrinol was the most crop safe treatment, and although weed germination was not fully controlled, percentage weed area cover was reduced.

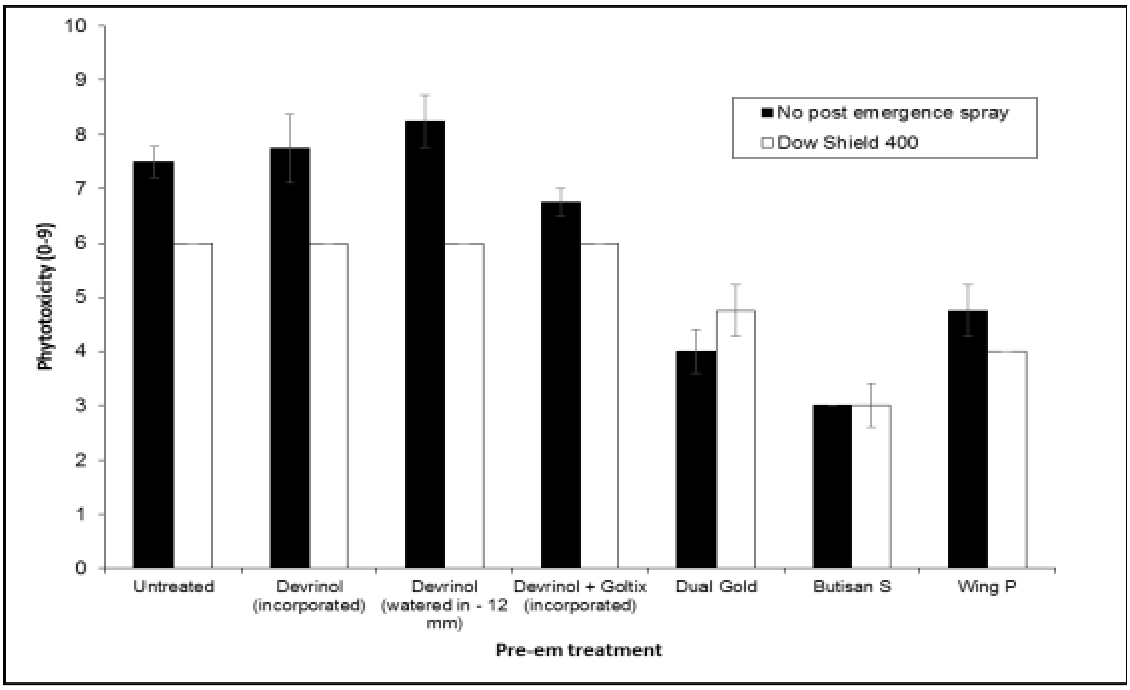


Figure 2.4.3. Phytotoxicity scores on non-primed seed – 2013 (Site 2, Wiltshire). Treatments on the x axis show the pre emergence applications (either pre-drilling or post). White bars show plots which received Dow shield 400 as a post-emergence spray on top of the pre-emergence applications

Where Devrinol incorporated and Devrinol watered in pre–drilling were used the primed seed showed the highest percentage of crop emergence. The use of primed seed also increased the percentage emergence in the plots treated pre-emergence with Dual Gold, Butisan S and Wing-P, compared with non-primed but emergence was still significantly supressed compared with the untreated. Unlike the Kent site in Wiltshire, the addition of Goltix to the Devrinol treatment did not appear as crop safe with a reduction of 20% emergence in the non-primed, but with the use of primed seed the reduction in emergence was only around 10%.

Financial benefits

Devrinol was confirmed as being the most suitable herbicide for use in wild rocket production. The addition of a low rate of Goltix Flowable as a tank mix with the treatment has the potential to improve control of groundsel and reduce hand weeding costs and the risk of crop rejection.

Action points

- **The current commercial standard, Devrinol is still the most crop safe treatment used in the trials, either incorporated into the soil pre–drilling, or watered in post-drilling.**
- **Goltix Flowable has the potential to improve control of groundsel when used as a tank mix with Devrinol. At 1 L/ha it slightly reduced the percentage crop emergence at one site but the effect was minimal where primed seed was used.**
- **Dual Gold, Butisan S and Wing-P are not crop safe to use on wild rocket.**
- **Dow Shield 400 is slightly phytotoxic to wild rocket, and no appreciable benefits were seen in reduction of weed cover when compared to treatments that did not receive a post-emergence spray.**

Grower Summary - Objective 2.6 - Ground cover trial: living mulches

Headline

- Creeping red fescue alone and as a mixture with birdsfoot trefoil were the most suppressive for both perennial and annual weeds.
- Other living mulch species efficiently suppressed the annual weeds but were less effective on perennial weeds, however most reduced levels compared with the untreated control.

Background

The main objective of the trial was to investigate the suitability of a range of living mulch species for weed control within the rows of top fruit and blackcurrants by evaluating the growth rate of the mulch, and the soil nitrogen level following one growing season.

Summary

A container trial was carried out at ADAS Boxworth to investigate the suitability of a range of living mulch species for weed control in top fruit and blackcurrants. The trial was separated in two parts: (1) Living mulches being sown in two different sowing densities alone with no weeds and the ground cover of each living much species assessed (2). The same living mulch species as part one plus two weed types, annuals and perennials (sown separately from each other). The annual species were chickweed, groundsel and mayweed and the perennials were broad-leaved dock and common couch. The information presented in Tables 2.6.1 and 2.6.2, sets out the treatments and species used for each part of the trial.

Table 2.6.1. Treatment list part 1

Treatment	Common name	Scientific name	Sowing density (g/m²)	Seeds per container (g)
1	White clover	*Trifolium repens*	0.70	0.50
2	White clover	*Trifolium repens*	1.40	1.00
3	Black medic	*Medicago lupulina*	0.80	0.60
4	Black medic	*Medicago lupulina*	1.60	1.20
5	Creeping red fescue	*Festuca rubra*	3.75	2.70
6	Creeping red fescue	*Festuca rubra*	7.50	5.40
7	Birdsfoot trefoil	*Lotus corniculatus*	0.70	0.50
8	Birdsfoot trefoil	*Lotus corniculatus*	1.40	1.00
9	Creeping red fescue + birdsfoot trefoil	*Festuca rubra + Lotus corniculatus*	3.75 + 0.70	2.70 + 0.50
10	Creeping red fescue + birdsfoot trefoil	*Festuca rubra + Lotus corniculatus*	7.50 +1.40	5.40 + 1.00
11	Untreated	-	-	

Table 2.6.2. Treatment list part 2

Treatment	Common name	Sowing density (g/m²)	Weed type
1	White clover	0.70	Annuals
2	White clover	1.40	Annuals
3	Black medic	0.80	Annuals
4	Black medic	1.60	Annuals
5	Creeping red fescue	3.75	Annuals
6	Creeping red fescue	7.50	Annuals
7	Birdsfoot trefoil	0.70	Annuals
8	Birdsfoot trefoil	1.40	Annuals
9	Creeping red fescue + birdsfoot trefoil	3.75 + 0.70	Annuals
10	Creeping red fescue + birdsfoot trefoil	7.50+1.40	Annuals
11	Untreated	-	Annuals
12	White clover	0.70	Perennials
13	White clover	1.40	Perennials
14	Black medic	0.80	Perennials
15	Black medic	1.60	Perennials
16	Creeping red fescue	3.75	Perennials
17	Creeping red fescue	7.50	Perennials
18	Birdsfoot trefoil	0.70	Perennials
19	Birdsfoot trefoil	1.40	Perennials
20	Creeping red fescue + birdsfoot trefoil	3.75 + 0.70	Perennials
21	Creeping red fescue + birdsfoot trefoil	7.50 + 1.40	Perennials
22	Untreated	-	Perennials

There were no measured differences between the two living mulch sowing densities for ground cover and efficacy of weed suppression. All of the cover crop species suppressed the perennial weeds to some extent compared with the untreated control creeping red fescue alone and in a mixture with birdsfoot trefoil were the most suppressive for both perennial and annual weeds. This could be explained by the dense ground cover that creeping red fescue provides. Some of the living mulch species also efficiently supressed the annual weed species. The most effective included the creeping red fescue alone and in mixture with birdsfoot trefoil and also the white clover at the higher sowing density for groundsel and mayweed and black medic for the mayweed alone. However it is important to note that, creeping red fescue reduced the nitrogen availability in the soil in contrast to the leguminous species. Potentially, a mixture of creeping red fescue and a species which provides high nitrogen availability should be considered for future research. These experiments will be repeated in field conditions to further validate the results.

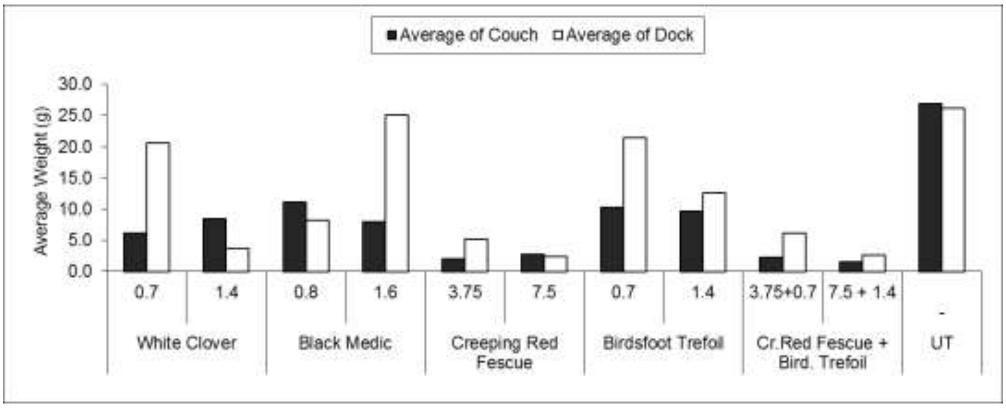


Figure 2.6.1. Perennial weeds - average fresh weed weight (g) at the destructive assessment five months after planting

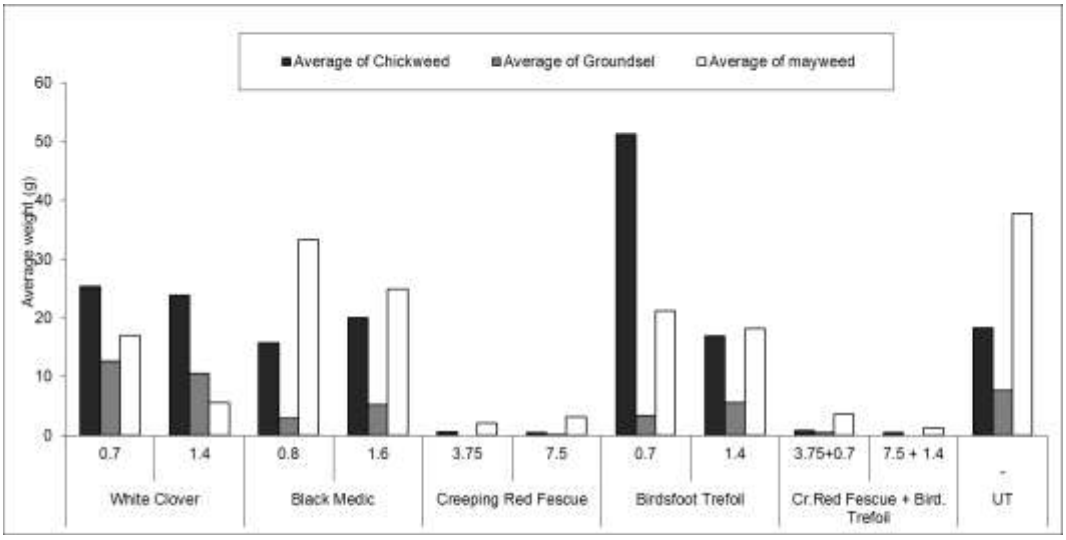


Figure 2.6.2. Annual weeds – average fresh weed weight (g) at the destructive assessment five months after sowing

Financial benefits

There are no financial benefits as yet from this project. The field work needed for an economic assessment will continue through 2014 and 2015.

Action points

- Creeping red fescue alone or grown in combination with birdsfoot trefoil could be used to suppress both perennial and annual weeds.
- The legume living mulch species could be used to suppress the annual weeds, but were less effective on perennials.
- Creeping red fescue alone and in a mixture decreased the nitrogen availability in contrast to the leguminous species. As a result additional nitrogen application may be required when using these species as a living mulch.

Grower Summary - Objective 2.7 - Perennial weed trial: green manures

Headline

- Buckwheat was the most suppressive green manure for both perennial and annual weeds.

Background

The main objective of the trial was to investigate the suitability of a range of species grown as a green manure cover crop for perennial weed control prior to planting the main crop.

Summary

A container trial was carried out at ADAS Boxworth to investigate the control of perennial weeds including broad-leaved docks, creeping thistles and field bindweed from various cover crop species as green manures. Untreated containers with weeds only, were used as reference to compare any weed suppression from the different cover crops. The table below shows the investigated weed species and treatments (Table 2.7.1). A fresh weight assessment of the weed species took place after flowering and a second assessment a month later.

Table 2.7.1. Treatment list

Treatment no.	Cover crop species	Sowing density	Seed needed per pot	Perennial weed species
1	Buckwheat (*Fagopyrum esculentum*)	120 kg/ha	8.6g	Creeping Thistle
2	Buckwheat (*Fagopyrum esculentum*)	120 kg/ha	8.6g	Broad-leaved dock
3	Buckwheat (*Fagopyrum esculentum*)	120 kg/ha	8.6g	Field bindweed
4	Caliente 119R	11 kg/ha	0.79g	Creeping Thistle

Treatment no.	Cover crop species	Sowing density	Seed needed per pot	Perennial weed species
5	Caliente 119R	11 kg/ha	0.79g	Broad-leaved dock
6	Caliente 119R	11 kg/ha	0.79g	Field bindweed
7	Caliente 61	8 kg/ha	0.57g	Creeping thistle
8	Caliente 61	8 kg/ha	0.57g	Broad-leaved dock
9	Caliente 61	8 kg/ha	0.57g	Field bindweed
10	Caliente 99	10 kg/ha	0.72g	Creeping thistle
11	Caliente 99	10 kg/ha	0.72g	Broad-leaved dock
12	Caliente 99	10 kg/ha	0.72g	Field bindweed
13	-	-		Creeping thistle
14	-	-		Broad-leaved dock
15	-	-		Field bindweed

The results show that the cover crops are capable of suppressing the weed growth as well as weed re-growth when used as green manures. Buckwheat was the most suppressive cover crop of all the weed species as it had the densest mass of foliage over the soil. Buckwheat and Caliente 61 were the most suppressive cover crops on the thistle population after being mulched. The use of the green manure species in general appeared to be less effective in reducing the growth of docks. Caliente 99 did not significantly control the dock re-growth. Field bindweed had a poor establishment and results were too difficult to accurately conclude from this experiment.

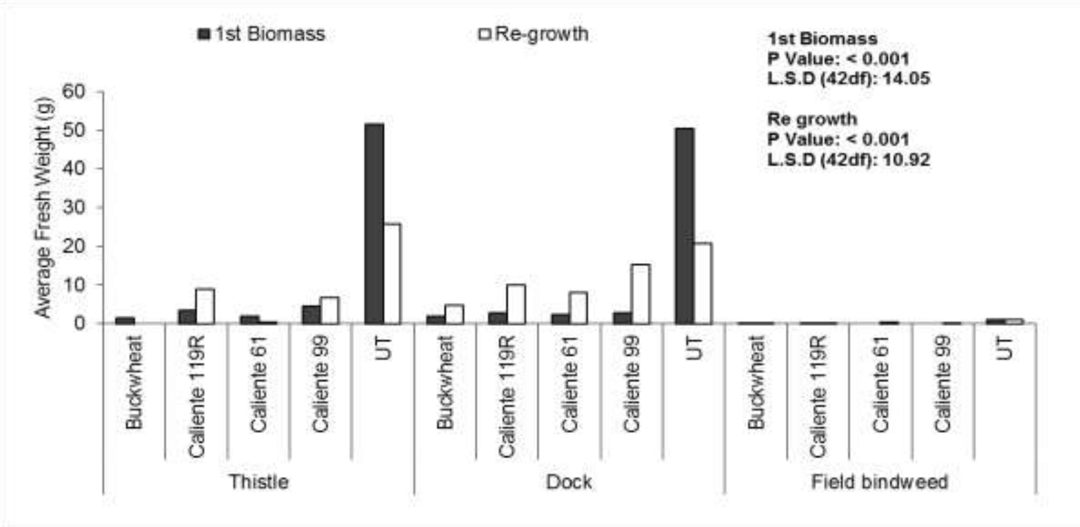


Figure 2.7.1. First biomass assessment 1 August 2013 and re-growth assessment 5 September 2013

Financial benefits

There are no financial benefits as yet from this project. The economic benefits will depend on the persistence of control achieved and this is yet to be assessed.

Action points

- Buckwheat has the best potential as a suppressive cover crop for perennial and annual weed species.

Grower Summary - Column stocks herbicide screen

Headlines

- Dual Gold appears to be safe to use with column stocks when applied post-planting but it currently only has approval for use during May on crops which are uncovered at the time of application.

Background

There are a limited range of herbicides which are safe for use on column stocks, and there is a need for crop safety information on current and new herbicides for use on the newer 'Figaro' varieties desired by the retailers.

Summary

The objective of the trial was to assess the crop safety of a range of herbicides pre and post-planting in column stocks for cut flower production. The trial re-evaluated herbicides with approval for use in ornamental plant production: HDC H29 and Butisan S, alongside newer herbicides recently developed for brassica production such as Wing-P and Dual Gold. The newer stocks varieties are thought to be more susceptible to herbicide damage than the older varieties and so both were compared in the trials.

The experiment was carried out on a commercial crop of column stocks at the National Cut Flower Centre, Holbeach St Johns, Spalding within a polythene tunnel, between April and July 2013. Two varieties were used in the trial; 'Figaro Lavender', a variety of limited vigour, and 'Fedora Deep Rose', which is more vigorous. The trial was planted into soil which had been sterilised two or three years previously, two of the four trial blocks were situated in each area. There were seven treatments, including an untreated control (Table (stocks) 1).

Table (stocks) 1. Detail of herbicide treatments applied pre- or post-planting on stocks - 2013

Treatment	Pre-planting	Post-planting	
1	Untreated	Untreated	
2	HDC H29	Butisan S	1.5 L/ha
3	HDC H29	Wing-P	3.5 L/ha
4	HDC H29	Dual Gold	0.78 L/ha
5	-	Wing-P	3.5 L/ha
6	-	Butisan S	1.5 L/ha +
		HDC H31	
7	-	Butisan S	1.5 L/ha +
		Dual Gold	0.78 L/ha

Table (stocks) 2. Approval status of herbicide treatments used on stocks 2013

Product	Active ingredient	Approval status	
		Outdoor	Protected
Butisan S	Metazachlor (500 g/L)	Approved	Not approved*
Dual Gold	S-metolachlor (960 g/L)	Approved	Not approved
HDC H29	Confidential	Approved	Not approved
HDC H31	Confidential	LTAEU	Not approved
Wing-P	Dimethenamid-p (212.5 g/L) + pendimethalin (250 g/L)	Approved pre-planting only	Not approved

*Some metazachlor products can be used on protected crops as unlike Butisan S they do not contain a label warning stating not to use on protected crops.

Pre–planting treatments were applied on the 25 April, and the trial was planted on 26 April. Post-planting treatments were applied on the 2 May. Phytotoxicity was first assessed in the crop approximately two weeks after treatment on 15 May, and then fortnightly until 10 weeks after treatment. Levels of damage varied, with the most severe effects after applications of HDC H29 + Wing-P, Wing-P post-planting and Butisan S + HDC H31 post-planting. A final assessment was carried out on 8 July, just prior to harvest.

At each phytotoxicity assessment, the trial was also assessed for crop vigour. HDC H29 + Wing-P, Wing-P post-planting and Butisan S + HDC H31 post-planting also caused a reduction in crop vigour

Figure (stocks) 1. Effect of Wing-P on column stocks 10 weeks after treatment

At harvest, on 9 July, plots were assessed by Cut Flower Centre staff for the percentage of marketable stems. For all treatments, 'Fedora Deep Rose' had a higher number of marketable stems, and treatments of Ronstar liquid followed by Butisan S or Dual Gold and Butisan S + Dual Gold post-planting had a higher percentage of marketable stems relative to the crops that did not receive the HDC H29 pre-planting treatment (Figure (stocks) 2).

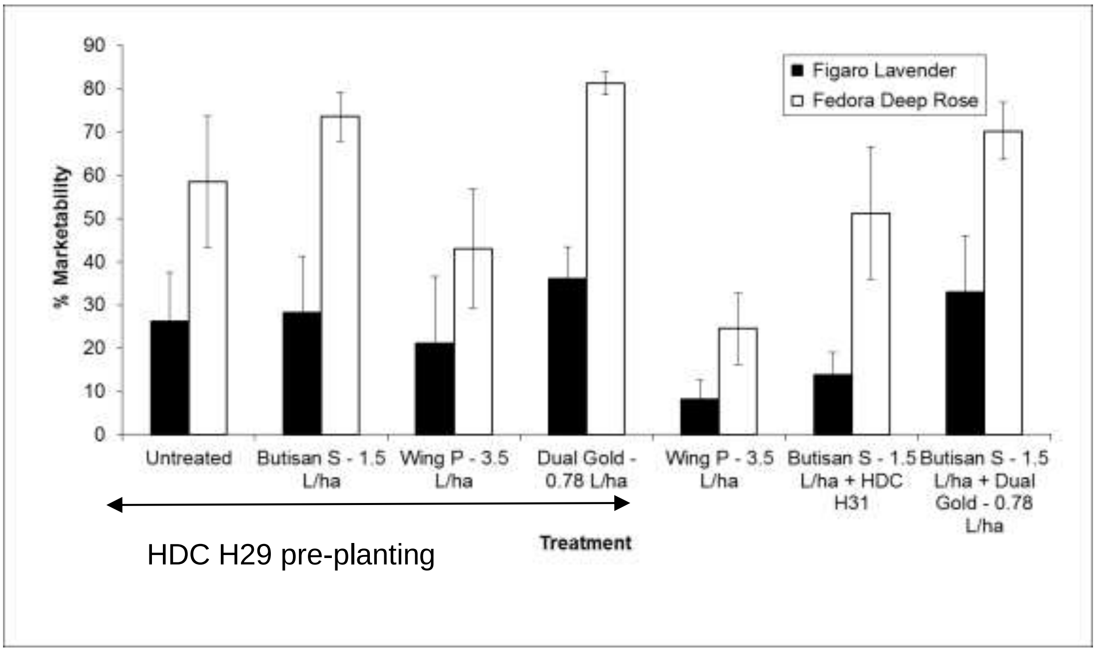


Figure (stocks) 2. Percentage of marketable stems at harvest - 2013

During the course of the project it was announced that the approval for HDC H29 would be revoked with use up of existing stock by 30 June 2015. Alternative herbicides such as Dual Gold and Butisan S do not have as wide a range of activity, although they do control chickweed which was resistant to HDC H29. Dual Gold which was found to be crop safe may need to be tank mixed depending upon the anticipated weed spectrum, and this product is only approved for application during May. Although Butisan S was crop safe in this trial when used post planting as a tank mix with Dual Gold or after pre-planting HDC H29, caution must be advised with its use as damage has been known to occur in some commercial situations. The revocation of approval for HDC H29 will be a great loss, and further work on crop safe alternatives is still needed.

Financial benefits

There are no financial benefits as yet from this project. The use of Dual Gold may save some hand weeding costs compared to untreated but the situations under which it can be used (outdoor during May only) will be too limiting.

Action points

- **Dual Gold can be used as a post-planting treatment on column stocks provided application is made during May on crops which are uncovered at the time of application**

Grower Summary - Peony herbicide screen

Headlines

- Dow Shield 400, HDC H15, Peak + Butryflow, HDC H30 and a repeated treatment of HDC H21 all reduced the spread of creeping thistle compared with the untreated control.
- Of the most effective treatments Dow Shield 400 was the least damaging when applied over the Peony foliage.

Background

Weed control within a long lived perennial crop such as peony is a considerable challenge, and with few herbicide options available to growers, the control of weeds such as creeping thistle (*Cirsium arvense*) growing within and between the rows is virtually impossible without damaging the crop, requiring manual removal. Control currently relies on directed sprays of Roundup (glyphosate) and hand removal. The objective of this project was to compare directed herbicide treatments for peonies for crop safety and control of creeping thistles.

Summary

The objective of the trial was to assess the efficacy and crop safety of a range of herbicides applied as directed sprays against creeping thistle (*Cirsium arvense*) in peony grown for cut flower production.

Table (peony) 1. Treatments applied to peony trial site – Winchester growers 2013

Trt no.	Treatment	Active ingredient	Rate	Approval
1	Untreated			
2	HDC H19 *	Confidential		Not approved
3	HDC H20 *	Confidential		Not approved
4	HDC H21 + adjuvant *	Confidential		Not approved
5	Dow Shield 400	Clopyralid (400 g/L)	0.5 L/ha	On label
6	HDC H29	Confidential		Not approved
7	HDC H15	Confidential		Not approved
8	Callisto	Mesotrione (100g/L)	1.5 L/ha	Not approved
9	Titus	Rimsulfuron (25% w/w)	50 g/ha	Approved
10	Callisto + Titus	Mesotrione (100g/l) rimsulfuron (25% w/w)	1.5 L/ha + 50 g/ha	Not approved EAMU
11	Peak + Butryflow	Prosulfuron (75% w/w) bromoxynil (402g/l)	20 g/ha + 1.0 L/ha	Not approved Not approved[1]
12	Florasulam	Florasulam (4.54% w/w)	0.15 L/ha	Not approved[2]

*** Applied twice, initially same timing as all the other treatments then again 14 days after**

[1]Approved post-flower harvest for bulbs

[2]Similar product Barton has an EAMU for use on outdoor ornamentals

No one treatment reduced thistles to a commercially acceptable level. Dow Shield 400, HDC H15, Peak + Butryflow, HDC H29 and HDC H21 all reduced the spread of thistle to some extent. HDC H21 and Callisto + Titus caused the most lasting damage to the peony foliage, causing necrosis and chlorosis respectively. Further screening is required to help develop strategies for effective thistle control in this crop.

Financial benefits

There are no financial benefits as none of the treatments tested provided a commercially acceptable level of creeping thistle control.

Action points

- Although not full effective in situations with high infestation, Dow Shield 400 can be used as the safest and most effective directed spray treatment for thistle control in peony.

Grower summary –Hot foam application in horticulture: scoping trials

Headlines

- The Foamstream system is a potentially viable alternative to chemical and hand weeding options for container standing ground preparation before standing down container plants.
- For soft fruit or vegetable production the Foamstream system is not yet in a form that can be readily adopted in these sectors.

Background

Foamstream is a new thermal weeding technology which has been developed for weed control in the amenity sector. The technology works by denaturing proteins and destroying enzymes within the target plant using hot water with foam. The natural foaming agents provide an insulating layer to retain heat for longer and provide a greater level of weed control.

Summary

Trials were carried out in summer 2013 to investigate the potential of using Foamstream technology in three different horticultural situations:

- **Hardy nursery stock: container plant standing areas in glasshouse, polytunnels and outdoors - containers on sand, gravel and mypex, over empty beds and in, around and over containers.**
- **Strawberry: established crop post-harvest - runner control, a newly planted crop – general weed control and a headland area – general weed control.**
- **Organic field vegetables: inter-plant and inter-row application to control annual and perennial weeds which cannot be mechanically removed in calabrese – non-cropped and cropped area and leeks – within row and headland plot treated.**

For each situation the host grower was consulted on where the Foamstream technology may be of most use in their sector and this was used to help decide upon where would be best to trial the technology.

Figure (Foamstream) 1. Foamstream technology supplied by Weedingtech

Hardy nursery stock

Foamstream provided very effective weed control for up to four weeks controlling virtually all weed, moss and liverwort species it came in contact with. The water and foam flowed well around the containers and caused no damage to the plants in them. As a result of the speed of foliage kill, the ability to use it in any weather and its safety from an environmental and health and safety point of view the host grower was very keen to replace conventional herbicides with this equipment. However, Foamstream lacked persistence, and was slower than conventional spray systems to apply. Changes that could help improve the product would include a lance head that was adaptable to the right situation (i.e. a narrower head) and if the equipment allowed the flow of the foam to be adjustable. A faster flow of foam could be used to increase speed of application and reduce labour cost. Finally, if the equipment could be downsized, a smaller version would be more suitable to treat smaller areas as small and medium sized nurseries wouldn't have large enough bed areas for the current sized equipment. From conversation with our host grower if the cost of application was similar to or less than hand weeding (£6.93/hour) then he would be interested in trialling on a larger scale in combination with residual herbicides.

During

1 WAT

Before

1 WAT




2 WAT **4 WAT** **2 WAT** **4 WAT**

Sand pot standing area **Sand tree pot standing area**

Figure (Foamstream) 2. Effects of foam stream on sand container standing area, and tree container standing area at 1, 2, and 4 weeks after treatment (WAT)

Strawberries

Foamstream provided very effective weed control up to four weeks. Six weeks after treatment however, annual weeds had begun to germinate in addition to thistles, fine grasses and cow parsley re-growing from rhizomes. There were still however many more weeds in the untreated rows than in the treated. For the inter-row area treatment, application of Foamstream caused runners to immediately wilt and provided good control of weeds. After six weeks no regrowth from runners was visible. The Foamstream also offered good control of cereals, shepherd's purse, nettle, poppy and wild oats. There was some recovery from the deliberately treated strawberry crop plants, the plant where the hot foam was applied directly over the crown was cut open and showed some vascular staining and a corky outer cuticle but overall remained a fairly healthy looking. This could mean that Foamstream has potential as a dormant season treatment or even as a post-harvest treatment to the crop.

The comment from the host grower was that the technology killed the weeds present regardless of species or size, however it would need repeating regularly, therefore either a lower dose or higher speed, or the introduction of a residual herbicide element to the program would be needed. To make this technology into a commercially viable operation, the steam boiler, tanks, mixer etc. would need to be tractor mounted and automated to provide for one man operation.

During 1 WAT 1 WAT UTC 2 WAT 2 WAT UTC

During 1 WAT 1 WAT UTC 2 WAT 2 WAT UTC

Figure (Foamstream) 3. Strawberry plots during then one and two weeks after treatment (WAT) compared with the untreated controls (UTC). Top row mainseason strawberries, bottom row 60 day.

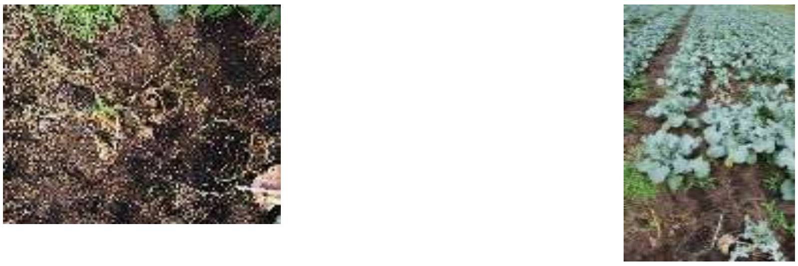
Organic field vegetables

For the non-cropped brassica field, a similar outcome was observed, the Foamstream worked very well killing some fairly large weeds including polygonums, fat hen and creeping thistle. For the cropped brassica field with calabrese in situ, the foam flowed nicely around the crop plants but needed careful application to ensure the treatment reached all the surrounding weeds. Initially most of the weeds in the treated plot were killed but by six weeks there were quite a few species of weeds that were germinating. There was also some damage to brassicas where the plants were treated close to the stem; approximately 10% of plants were affected.

In the cropped leek field, it was hard to get between leeks because of the spacing and so as a result the weeds within the rows remained un-touched.

Over both vegetable situations the equipment was not really at a stage to be able to make a direct comparison with standard methods, but there was an impressive level of knock-down of a large and dense weed population. The crop damage observed was a concern and the tractor mounting and speed of application would need to be improved.

During 1 WAT 2 WAT 4 WAT



Brassica crop damage Brassica crop damage

Before 1 WAT 2 WAT 4 WAT and leek crop damage

Figure (Foamstream) 4. Calabrese and leek plots before, during, one, two and four weeks after Foamstream treatment

In conclusion:

- Foamstream provided immediate weed control to all species tested.
- Application was possible in any weather, no toxicity or residues were associated.
- Weed control was not long lived for thistles, liverwort (four to six weeks) and had no effect on surface germinating seeds.

- Investigation of optimal timing and integration with herbicide programs could make this a very useful tool as herbicide options become more limited.
- In the long-term, adaptations to flow rates and application equipment would be necessary to commercialise it for intensive horticulture.

Financial benefits

For nursery stock production the Foamstream kit is fairly well suited to the production systems however at present there is not enough information on the cost of the equipment and time and frequency of application required to provide an accurate financial appraisal. Further development of the Foamstream technique is required before it can be used for commercial application with soft fruit and vegetable crops.

Action points

- The Foamstream system is a potentially viable alternative to chemical and hand weeding options for container standing ground preparation before standing down container-grown plants.

SCIENCE SECTION

Objective 2.2 - Second container plant screening trial

Introduction

Weed control in container-grown nursery stock continues to rely on an increasingly limited range of active ingredients following the loss of key active ingredients in recent years. The loss of Ronstar 2G (oxadiazon) which has a final use date of 30 June 2015 has serious implications for the UK horticultural industry.

Ronstar 2G is an important and universally used product for container HNS growers because it is:

- **The only granular product available – very practical and easy to use compared with sprays on batches of plants after potting.**
- **Very safe to use on a wide range of tree and shrub species and also on herbaceous perennials.**
- **Effective on a wide range of weed species including bittercress, groundsel (*Senecio vulgaris*) and willowherb (*Epilobium ciliatum*).**

The main issue is to find alternative herbicides that are safe to apply over foliage immediately after potting and to follow up with later in the summer. At present the main herbicide for this period is Flexidor 125 (isoxaben). Hitherto Flexidor 125 has been used as a supplementary treatment to follow up Ronstar 2G, however it will now be the main treatment. The problems with relying on Flexidor 125 are several however:

- **Some shrub species and even more herbaceous species are sensitive to it.**
- **Groundsel, willowherb, moss and liverwort are not controlled by it.**
- **Only two applications per year are permitted and in any case reliance on one herbicide will lead to resistance problems.**

Projects HDC 139 and HNS 139a identified Dual Gold (S-metolachlor) as a possible summer treatment to supplement Flexidor 125. This will be useful, particularly when Ronstar 2G is not available but the approval only permits use in May and there are a further range of species that are slightly damaged by it (although most recover). Lists have been published in the HDC weed control handbook.

This project includes three screenings of new herbicides during the duration of the project. The first (in 2012) included a confidential product HDC H14 (experimental product) which was considered less promising (poor residual control and some crop damage) and Wing-P (pendimethalin + dimethenamid-P) which was promising. The features of Wing-P observed from the 2012 weed seeded pot screening and container plant phytotoxicity trials were:

- **Residual control of groundsel, willowherb and grasses – which are resistant to Flexidor 125.**
- **Potential to use as a mix with Flexidor 125.**
- **Good crop safety results so far – although relatively few species were tested.**

The 2013 container nursery experiments reported here also included HDC H18 for the first time.

Development of 'new' available actives is normally driven by the HDC through the screening of herbicides that are already authorised for use in other sectors of agriculture and horticulture within the UK and occasionally from overseas, for crop safety. Suitable products are then normally put forward for an Extension of Authorisation for Minor Use (EAMU).

This experiment evaluated Wing-P on its own and tank mixed with Flexidor 125 alongside HDC H18 as a summer treatment applied to a range of deciduous and evergreen hardy nursery stock (HNS) species. Flexidor 125 was applied to provide a comparison as a standard treatment. Products within the trial were applied to recently potted plants; any weeds were removed by hand prior to the application of these treatments. The experiment focused on crop safety assessments rather than weed control efficacy.

Materials and methods

The experiment was a randomised split plot design with two treatment factors (i) weed control treatments (five treatments) and (ii) crop species (12 species) with four replicate blocks; totalling 20 main plots. Plots were 1.5 m wide and 4 m long divided into 12 sub plots each containing five plants of each crop species. There was a pathway of 0.5 m to allow access to apply treatments, prevent drift and carry out assessments.

The plant species included in the trial were: *Buddleija davidii* ‘Black Knight’, *Ceratostigma plumbaginoides, Cistus x pulverulentus* ‘Sunset’, *Cornus sericea* ‘Kelseyi’, *Escallonia* ‘Red Dream’, *Hebe pinguifolia* ‘Sutherlandii’, *Hydrangea* Mariesii Perfecta’, *Physocarpus opulifolius* ‘Lady in Red’, *Santolina chamaecyparissus*, *Sorbaria sorbifolia* ‘Sem’ and *Spiraea nipponica ‘*Snowmound*’*.

All treatments were applied to the respective plots using a 1.5m boom sprayer in 1,000 L/ha on 11 July 2013.

The treatment list is shown in Table 2.2.1**.**

Table 2.2.1. Treatment list container plant screen

Trt no.	Product name	Active ingredient	Rate (L/ha)	Approval status
1	Untreated			
2	Flexidor 125	Isoxaben (125 g/L)	1.0 L/ha	Label
3	Wing P	Pendimethalin (250 g/L) + dimethenamid – p (212.5 g/L)	4.0 L/ha	Not approved
4	Wing P +	Pendimethalin (250 g/L) + dimethenamid – p (212.5 g/L)	4.0 L/ha +	Not approved
	Flexidor 125	Isoxaben (125 g/L)	1.0 L/ha	Label
5	HDC H18	Confidential		Not approved

Results

Wing–P initially caused widespread, but slight damage, recorded two weeks after treatment (2 WAT); in the majority of cases however the plants had grown away from any damage 6 WAT. Damage was still noted on *Cornus* 6 WAT but plants grew away from any damage by 12 WAT. Damage on *Buddleja, Hydrangea* and *Perovskia* remained visible at the 12 WAT score.

Wing–P tank mixed with Flexidor 125 caused similar levels of damage as Wing–P alone. Again the majority of species grew away from damage by 6 WAT; damage was still visible on *Cornus* at 6 WAT but plants were comparable with the untreated controls by 12 WAT. Damage on *Buddleja, Perovskia* and *Spiraea* remained visible at 12 WAT.

HDC H18 caused damage, which was recorded at 2 WAT on *Buddleja, Cornus, Escallonia, Hydrangea, Perovskia, Physocarpus, Sorbaria* and *Spiraea.* All of the aforementioned species had grown away from the damage recorded at the first score by the time the second score was carried out at 6 WAT, with the exception of *Buddleja, Cornus* and *Perovskia. Cornus* grew away from this damage by 12 WAT however damage remained visible at 12 WAT on *Buddleja* and *Perovskia*.

Figure 2.2.1. *Escallonia, Sorbaria* and *Physocarpus* treated with HDC H18 had grown away from any damage by 6 WAT

Flexidor 125 damaged the least number of species compared to any of the other treatments, however damage was still noted on *Buddleja, Cornus, Hydrangea, Perovskia* and *Physocarpus* at 2 WAT. Damage was still evident on *Buddleja, Cornus* and *Perovskia* 6 WAT, however like all of the other treatments *Cornus* grew away from any damage by 12 WAT, this degree of damage was expected as *Cornus* is moderately susceptible to Flexidor 125. Damage remained evident on *Buddleja* and *Perovskia* at 12 WAT. This was not surprising as *Buddleja* is known to be susceptible to damage by Flexidor 125.

Weed control was not assessed as part of this trial.

Phytotoxicity was scored on a 0–9 scale with 0 representing plant death and 9 being comparable with controls. A score of 7 represented the maximum level of damage to be acceptable commercially.

The tables below list the mean scores given to all species and treatments at 2, 6 and 12 WAT, when compared to controls.

Table 2.2.2. Mean phytotoxicity scores, container nursery stock herbicide experiment, recorded 2 WAT

Treatment Number	Scores											
	Buddleja	***Ceratostigma***	***Cistus***	***Cornus***	***Escallonia***	***Hebe***	***Hydrangea***	***Perovskia***	***Physocarpus***	***Santolina***	***Sorbaria***	***Spiraea***
1	9	9	9	9	9	9	9	9	9	9	9	9
2	7.25	9	9	4.25	8.25	9	6.25	6	7	9	9	7.75
3	6	7	6	4	5.50	9	6	6	6	7	8.25	7
4	4.50	7.50	7.50	4	6	9	4.50	4.50	6	9	6.75	6.50
5	6	9	9	4	7	9	5	5.50	6	9	6	7.50
F pr.	P<.001	P<0.001	<.001	<.001	<.001	-	<.001	<.001	<.001	<.001	0.001	0.003
l.s.d (19 d.f)	0.889	0.974	0.889	0.345	0.563	0.000	1.089	0.933	0.000	0.000	1.399	1.071

Table 2.2.3. Mean phytotoxicity scores, container nursery stock herbicide experiment, recorded 6 WAT

Treatment Number	Scores											
	Buddleja	***Ceratostigma***	***Cistus***	***Cornus***	***Escallonia***	***Hebe***	***Hydrangea***	***Perovskia***	***Physocarpus***	***Santolina***	***Sorbaria***	***Spiraea***
1	9	9	9	9	9	9	9	9	9	9	9	9
2	7	9	9	7	9	9	9	7	9	9	9	9
3	7	9	8	6.25	8	9	7	6	9	9	9	9
4	7	8	8	6.25	8	9	7	6.25	9	9	9	7
5	7	9	9	6	9	9	8	7	9	9	9	9
F pr.	<.001	<.001	-	<.001	<.001	-	<.001	<.001	-	-	-	<.001
l.s.d (19 d.f)	0.000	0.000	0.000	0.422	0.000	0.000	0.000	0.345	0.000	0.000	0.000	0.000

Table 2.2.4. Mean phytotoxicity scores, container nursery stock herbicide experiment, recorded 12 WAT

Treatment Number	**Scores**											
	Buddleja	***Ceratostigma***	***Cistus***	***Cornus***	***Escallonia***	***Hebe***	***Hydrangea***	***Perovskia***	***Physocarpus***	***Santolina***	***Sorbaria***	***Spiraea***
1	9	9	9	9	9	9	9	9	9	9	9	9
2	7	9	9	9	9	9	9	7	9	9	9	8.50
3	7	9	9	9	9	9	7.50	6	9	9	9	8.75
4	7	9	9	9	9	9	7.75	6.50	9	9	9	7.50
5	6.50	9	9	9	9	9	8.75	7	9	9	9	8.25
F pr.	<.001	-	-	-	-	-	<.001	<.001	-	-	-	<0.05
l.s.d (19 d.f)	0.398	0.000	0.000	0.000	0.000	0.000	0.703	0.398	0.000	0.000	0.000	0.964

Discussion

Although Wing–P initially damaged the most species of any of the herbicides included within this trial, the majority of the species were comparable with the untreated control by 6 WAT. Most of the species used as test plants within this trial were unlikely to be saleable within six weeks of potting (even where no herbicide damage was evident) so this level of damage, over this time period, could be tolerated on a commercial nursery. Few nurseries treat freshly potted *Cornus* with herbicides as they are sensitive to a wide range of herbicides. Although crop damage is undesirable, the fact that *Cornus* had made a full recovery by 12 WAT and was not stunted compared to the untreated control was encouraging. Although *Hydrangea* was still slightly damaged by Wing–P at the 12 WAT assessment, in practice this was insignificant as plants were commercially acceptable; it is worth noting that *Hydrangea* was not damaged by Wing–P in the trial carried out in 2012. *Buddleja* is sensitive to a range of herbicides that are applied in the growing season and there is no obvious, safe replacement for Ronstar 2G as a summer/post potting treatment at present. There is little crop safety data for herbicide use on *Perovskia,* this is one of the reasons why it was included within this trial. All of the herbicides tested on this species caused phytotoxic crop damage, which suggests that *Perovskia* may be particularly sensitive to herbicides.

Wing–P and Flexidor 125 when applied as a tank mix resulted in similar levels of damage to Wing–P applied alone. As with Wing–P, most of the species tested were comparable with the control by 6 WAT. Although both *Cornus* and *Hydrangea* were still showing signs of damage at 6 WAT, the damage was slight on *Cornus* and very slight on *Hydrangea. Cornus* was comparable with the untreated control by 12 WAT whereas *Hydrangea* was nearly comparable with the untreated control. Although *Spiraea* was damaged by the tank mix of Wing–P and Flexidor 125 at 12 WAT the damage was so insignificant it was considered commercially acceptable. *Buddleja* and *Perovskia* were also damaged by the tank mix of Wing–P and Flexidor 125, the damage was still evident 12 WAT which suggests that this treatment is unsuitable for both *Buddleja* and *Perovskia.*

Wing–P has pre-emergence activity against important nursery weeds such as groundsel *(Senecio vulgaris)* and annual meadow grass *(Poa annua)* which are some of Ronstar 2G strengths, tank mixing the product with Flexidor 125 did not appear to increase the levels of crop damage. Tank mixing with Flexidor 125 increased the weed control spectrum and this is the option that would have been worth considering in the future, particularly where crops are tolerant of Flexidor 125. Unfortunately it has proven impossible to obtain authorisation for the use of Wing-P over crops at a high enough rate needed for acceptable weed control under commercial conditions. The existing EAMU 0253/13 for Wing–P in outdoor ornamental plant production limits use to seed grown and bulb crops as the product has to be applied prior to crop emergence, this EAMU also prohibits application via hand held equipment.

HDC H18 looked a promising treatment for the future, although it caused damage on a number of species initially; with slight damage recorded on eight of the twelve species within the trial at 2 WAT. Only three species retained signs of damage by 6 WAT; one of which was *Cornus* which was comparable with the untreated control by 12 WAT, therefore is worthy of commercial exploration as a residual herbicide on this and other HNS species. The only two species that showed persistent damage at 12 WAT were *Buddleija* and *Perovskia;* both of which are thought to be sensitive to herbicides*.*

Figure 2.2.2. *Buddleja* and *Perovskia* damaged by HDC H18 6 WAT (yellowing of lower leaves and reduced growth), damage persisted to 12 WAT

Flexidor 125 is a proven residual herbicide that is relatively crop safe (specific crop guidelines document many of the species susceptible to damage). Species with known sensitivity such as *Buddleja* and *Cornus* were damaged in this experiment. *Physocarpus* was very slightly damaged but had grown away from any damage and was comparable with the untreated control when the 6 WAT score was carried out. *Perovskia* appeared to be sensitive to herbicides as alluded to above, and as a result was still unsaleable 12 WAT. Flexidor 125 is unsuitable for some plant species, it only controls a limited number of weed species and the number of applications per year is restricted.

Figure 2.2.3. Flexidor 125 damage on *Buddleja* and *Perovskia* 6 WAT (yellowing of lower leaves and reduced growth), damage persisted to 12 WAT.

Conclusions

The loss of Ronstar 2G will have a huge impact upon weed control in container-grown HNS production. Wing–P could potentially have been a very useful herbicide in the production of HNS, particularly given the recent loss of Ronstar 2G. Wing–P has been included within these trials in the last two years which has given a good indication of crop safety. Unfortunately, it has not been possible to secure an authorisation for the use of Wing–P over crops at a rate high enough to be adequately effective. Therefore it is highly unlikely that this product will be available for HNS growers to use in the future.

HDC H18 was included within this horticulture fellowship trial for the first time this year, HDC H18 looked relatively crop safe and performed well on a number of species which is very encouraging. Only two plant species; *Buddleja* and *Perovskia* showed crop damage at 12 WAT and both of these species are thought to be sensitive to herbicides. At present HDC H18 looks the only promising product from this year's container trial to be taken forward for the future. Although the initial results look promising there are likely to be some species that are sensitive and further work will be required to develop a broader range of crop species recommendations.

The final container HNS screen was due to take place in 2015 but this has been brought forward to 2014 in an attempt to address the gap caused by the imminent loss of Ronstar 2G. HDC has also agreed to fund two additional herbicide screens; on herbaceous perennials and on a broader range of container-grown shrubs in

2014. This additional trial will allow HDC H18 to be trialled on herbaceous perennials for the first time within a trial under UK conditions.

Flexidor 125 will continue to play a very important role as a residual herbicide in container-grown HNS production in the future.

Objective 2.3 - Tree field herbicide trial

Introduction

Weed control programmes for field-grown nursery stock have relied upon the same few active ingredients for a number of years. Data on the crop safety of new or novel herbicide products is often limited, which can make it difficult to plan herbicide programmes which embrace new products. The gradual withdrawal of the Long Term Arrangements for Extension of Use (LTAEU) has also impacted upon the herbicides that HNS growers are able to utilise.

This trial evaluated seven novel herbicides in conjunction with a standard programme for both weed control and crop safety when applied after planting and after heading back in field-grown production of budded maiden trees. During 2013 it was announced that the authorisation for Ronstar Liquid (oxadiazon) would be withdrawn, with use up of existing stocks allowed until June 2015. The loss of Ronstar Liquid will further reduce weed control options in field-grown production. Although relatively expensive, Ronstar Liquid is a reliable herbicide used both in the field and around nurseries on container beds (before standing down). There are a number of alternatives that were tested in this herbicide screening which could potentially be used in field-grown stock production although many of them are less persistent than Ronstar Liquid. For example, the fellowship project flagged up the potential for Wing-P as an addition to the range of residual herbicides for field-grown stock. However, as noted in the previous report, the approval related issues are unlikely to be unresolved, therefore it is likely that this herbicide will remain unavailable for field-grown HNS producers apart from pre-emergence use in tree seedbeds.

Materials and methods

The trial was laid out in a fully randomised block design with four fold replication. Each plot was 3.5 m wide and 2.4 m long and contained four species of rootstocks, planted in rows spanning all plots within the trial. The rootstock species used were *Malus MM106 (*budded with *Malus domestica* 'Tickled Pink'), *Prunus colt* (budded with *Prunus avium* 'Sunburst'), *Quince A* (budded with *Pyrus communis* 'Doyenne Du Comice') and *Sorbus aucuparia* (budded with *Sorbus aucuparia* 'Joseph Rock'). In March 2013 all plots were over sprayed with the nursery standard treatment Flexidor 125 2.0 L/ha + Stomp Aqua (pendimethalin) 2.9 L/ha, **excluding plots 6, 15, 30 and**

31* which were over sprayed with Flexidor 125 2.0 L/ha + Stomp Aqua 0.98 L/ha prior to the individual treatments applied in addition as part of the trial, both the overspray and the treatments listed below were applied on 19/03/13. Additional standard and novel residual herbicides were applied to the respective plots using a 3.5 m boom sprayer in 400 L/ha over the top of the trees (post heading back, whilst still dormant) on 19/03/13. Note that similar treatments had also been applied after planting the rootstocks in April 2012 except that the nursery standard (treatment 1) was Devrinol 7.0 L/ha + Flexidor 125 2.0 L/ha and treatment 2 was Stomp Aqua 2.9 L/ha. Therefore treatment 2 received Stomp Aqua + Flexidor 125 + Devrinol on both occasions but the control (treatment 1) was Devrinol + Flexidor 125 after planting and Stomp Aqua + Flexidor 125 after heading back.

*The rate of Stomp Aqua was reduced for the Wing–P plots to take account of the pendimethalin content of Wing–P.

The treatment list is shown in table 2.3.1.

Table 2.3.1. Tree field trial treatments applied 19/03/13 in addition to the nursery standard treatment (Flexidor 125 + Stomp Aqua)

Trt no	Product name	Active ingredient	Rate (L/ha or kg/ha)	Approval Status
1	No additional treatment			
2	Devrinol	Napropamide (450 g/L)	9.0 L/ha	Label
3	Ronstar Liquid	Oxadiazon (250 g/L)	4.0 L/ha	Label
4	HDC H30	Confidential		Not approved
5	Gamit 36 CS	Clomazone (360 g/L)	0.25 L/ha	LTAEU
6	HDC H13	Confidential		Not approved
7	HDC H14	Confidential		Not approved
8	HDC H15	Confidential		Not approved
9	HDC H28	Confidential		Not approved
10	Wing-P	Dimethenamid-p + pendimethalin (212.5:250 g/L)	4.0 L/ha	Not approved

The soil type was a medium loam. Due to the exceptionally late spring in 2013 it was decided to delay the 2 WAT score to 4 WAT and to carry out an additional score at sixteen weeks after treatment (16 WAT) to ensure that any potential phytotoxicity was recorded as growth was slow in the early stages of the trial due to the exceptionally low spring temperatures.

Figure 2.3.1. Trees were still dormant on 17 April (4 WAT) because of the low spring temperatures

Results

No phytotoxicity at all was noted in this trial during 2013 (assessments were carried out at 4, 8, 12 and 16 WAT).

Table 2.3.2 shows the mean results of percentage weed cover throughout the trial.

Table 2.3.2. Mean percentage weed cover 4, 8, 12 and 16 WAT.

Treatment	Percentage weed cover 4 WAT	Percentage weed cover 8 WAT	Percentage weed cover 12 WAT	Percentage weed cover 16 WAT
1	0.25	1	13.2	79.2
2	1	1	23.5	86.2
3	0	0.50	1	5.5
4	0.25	0.50	0.8	2.8
5	0.50	1	7	68.8
6	0.25	1	9.2	50
7	0.75	1	10	55
8	0.50	1	16	85
9	0.50	1	8.2	65
10	0.25	1	9.8	54.5
F pr.	0.363	0.023	0.027	<.001
l.s.d (39 d.f)	0.784	0.375	12.14	23.17

Figure 2.3.2. Treatment four, 12 weeks after treatment resulting in good weed control

HDC H30 (along with the overspray treatment) resulted in the lowest mean weed cover with less than 1% at 12 weeks after treatment and less than 3% at 16 weeks after treatment, the second best treatment was Ronstar Liquid with 1% weed cover at 12 weeks after treatment and less than 6% weed cover at 16 weeks after treatment. These were significantly different from the standard overspray treatment and the other treatments assessed (Table 2.3.2).

At 12 weeks after treatment the third best treatment was Gamit 36 CS with 7% weed cover (not significant). Other treatments with less than 10% weed cover at 12 weeks after treatment (listed in order of performance) included: HDC H28, HDC H13 and Wing–P.

Discussion

It was very encouraging that all of the herbicides included within this trial appeared to be safe when applied over budded, field-grown trees on medium loam soils. Applying residual herbicides when stock is still dormant is generally safe as herbicides and not taken up by lignified wood. Problems generally arise when herbicides move down through the soil profile into the rooting zone; this problem occurred in the previous year of the trial when HDC H30 caused a reduction in vigour on all four species within the trial, this did not show until 12 WAT. It is thought that the exceptional levels of rainfall during the spring and summer of 2012 leached this herbicide down the soil profile resulting in root uptake. Significantly less rainfall fell during the summer of 2013, which resembled more of a ‘normal’ growing season, this is likely to be the reason that phytotoxicity (recorded as a reduction in vigour) was not observed in the HDC H30 treatments during the 2013 growing season. The reduction in vigour of the rootstock noted in 2012 did not appear to affect the bud growth in 2013.

Weed pressure on the nursery was higher in 2013 than it was in 2012; this is because the nursery has a policy of controlling emerged weeds with contact herbicides when the spring applied residual herbicides start to run out. The very wet summer of 2012 frequently interrupted the application of contact herbicides to the nursery’s own crops which surrounded the trial plots. This undoubtedly resulted in more weeds setting seed than in a normal year which contributed to higher weed pressure. This situation proved a real test for the residual herbicides during 2013, despite this situation, both HDC H30 and Ronstar Liquid still gave good weed control 16 weeks after treatment, when many of the other residual herbicides were clearly running out. Both HDC H30 and Ronstar Liquid are known to persist for longer than 16 weeks.

Conclusions

Over the two years of this trial, both Ronstar Liquid and HDC H30 have consistently produced the best levels of weed control, these herbicides persist for longer than many of the alternatives which reduces the need to either apply top up treatments of residual herbicides or regular follow-on applications of contact herbicides. Topping up herbicide treatments adds cost to production through additional expenditure on herbicides and labour to apply them. Although Ronstar Liquid is the safer of these two herbicides to the crop, its continued authorisation is not being supported by its parent company in the UK, therefore Ronstar Liquid has a final use date of 30 June 2015.

HDC H30 did cause a reduction in growth in an exceptionally wet summer in the case of *Malus* and a slight reduction in the growth of *Quince, Sorbus* and *Prunus* rootstocks. However, this reduction in the growth of the stocks was not significant. Combined with the fact that this level of stunting would only be expected in an exceptionally wet growing season and that HDC H30 offers weed control that persists for approximately five months, growers may be prepared to tolerate a slight reduction in vigour of stocks in some years. Reductions in vigour in the maiden year however could not be tolerated as a wet season and associated stunting caused by root uptake of HDC H30 could lengthen the time of production which would impact upon crop scheduling. Only a very limited range of species (all belonging to the *Rosaceae* family) have been tested with HDC H30 to date; it would be worthwhile to test this herbicide on other field-grown species over a range of growing seasons. HDC H30 was used under an experimental permit in this trial and it cannot be used over a crop as in this trial. This active has the potential to play a role as a residual herbicide within crop production in the future, an EAMU for outdoor ornamental plant production has the potential to be very useful. Results from Gamit 36 CS were also promising and this herbicide could be readily developed as an adjunct to standard programmes used in field-grown tree production such as Stomp Aqua + Flexidor 125 to provide control of groundsel, willowherb and cleavers.

Objective 2.4 - Vegetable herbicide trial: rocket

Introduction

The control of weeds in short season baby leaf salad crops can be difficult, especially in crops such as wild rocket which are sensitive to a number of commercially available herbicides. Growers use crop rotations and soil sterilants such as Basamid (dazomet) to reduce the weed pressure before drilling a crop of wild rocket. However, a number of weeds can still be problematic, including groundsel which is a particular problem as, due to its similar appearance to rocket, it can be missed during hand weeding leading to contamination and rejections by retailers. Hand weeding is also expensive (c. £150/ha) and with the threat of the possible loss of soil sterilants in the future, alternative herbicides for use in wild rocket are needed. The aim of the trial was to test alternatives to the current standard Devrinol (napropamide), for crop safety and efficacy.

Material and methods

<u>Site 1 - Kent</u>

The trial was carried out on a commercial field crop of wild rocket, cv. Napoli in Kent, drilled 3 June and due for harvest 9 July 2013. The site was non-sterilised, with four major weeds: annual mercury *(Mercurialis annua)*, black bindweed *(Fallopia convolvulus),* common fumitory *(Fumaria officinalis)* and volunteer oil seed rape (*Brassica napus* ssp. *Oleifera)*. There were two identical trials side by side in the same field. One was drilled using non-primed seed, and the other using primed seed. The trials were a fully randomised block design with eight main treatments, and two sub-plot treatments, including an untreated control (Table 2.4.1 and 2.4.2), replicated four times. Each main plot was 6 m long and 1.8 m wide, creating two 3 m lengths for the sub-plots.

Table 2.4.1. Detail of herbicide treatments applied either pre- or post-drilling, to non–primed seed – 2013 (Site 1, Kent)

			Timing 1- Both applied at same date either before or after drilling		Timing 2
Treat 1 Main plot	**Treat 2 Sub-plot**	**Trial split seed treatment**	**Main plot Pre-drilling treatment**	**Main plot Post-drilling treatment**	**Sub-plot Post-emergence treatment**
A1	1	Non-primed	Untreated	Untreated	Untreated
A1	2	Non-primed	Untreated	Untreated	Dow Shield 400 0.25 L/ha
A2	1	Non-primed	Devrinol 0.85 L/ha (incorporated)	-	Untreated
A2	2	Non-primed	Devrinol 0.85 L/ha (incorporated)	-	Dow Shield 400 0.25 L/ha
A3	1	Non-primed	Devrinol 0.85 L/ha (watered in - 12 mm)	-	Untreated
A3	2	Non-primed	Devrinol 0.85 L/ha (watered in - 12 mm)	-	Dow Shield 400 0.25 L/ha
A4	1	Non-primed	Devrinol 0.85 L/ha + Goltix Flowable 1.0 L/ha (incorporated)	-	Untreated
A4	2	Non-primed	Devrinol 0.85 L/ha + Goltix Flowable 1.0 L/ha (incorporated)	-	Dow Shield 400 0.25 L/ha
A5	1	Non-primed	-	Dual Gold 1.4 L/ha	Untreated
A5	2	Non-primed	-	Dual Gold 1.4 L/ha	Dow Shield 400 0.25 L/ha
A6	1	Non-primed	-	Butisan S 1.5 L/ha	Untreated
A6	2	Non-primed	-	Butisan S 1.5 L/ha	Dow Shield 400 0.25 L/ha
A7	1	Non-primed	-	Wing-P 1.25 L/ha	Untreated

Treat 1 Main plot	Treat 2 Sub-plot	Trial split seed treatment	Timing 1- Both applied at same date either before or after drilling		Timing 2
			Main plot Pre-drilling treatment	Main plot Post-drilling treatment	Sub-plot Post-emergence treatment
A7	2	Non-primed	-	Wing-P 1.25 L/ha	Dow Shield 400 0.25 L/ha
A8 (commercial practice)	1	Non-primed	-	Devrinol 0.85 L/ha (watered in - 12 mm)	Untreated
A8 (commercial practice)	2	Non-primed	-	Devrinol 0.85 L/ha (watered in - 12 mm)	Dow Shield 400 0.25 L/ha

Table 2.4.2. Detail of herbicide treatments applied either pre- or post-drilling to primed seed – 2013 (Site 1, Kent)

Treat 1 Main plot	Treat 2 Sub-plot	Trial split seed treatment	Timing 1- Both applied at same date either before or after drilling		Timing 2
			Main plot Pre-drilling treatment	Main plot Post-drilling treatment	Sub-plot Post-emergence treatment
B1	1	Primed	Untreated	Untreated	Untreated
B1	2	Primed	Untreated	Untreated	Dow Shield 400 0.25 L/ha
B2	1	Primed	Devrinol 0.85 L/ha (incorporated)	-	Untreated
B2	2	Primed	Devrinol 0.85 L/ha (incorporated)	-	Dow Shield 400 0.25 L/ha
B3	1	Primed	Devrinol 0.85 L/ha (watered in - 12 mm)	-	Untreated
B3	2	Primed	Devrinol 0.85 L/ha (watered in - 12 mm)	-	Dow Shield 400 0.25 L/ha
B4	1	Primed	Devrinol 0.85 L/ha + Goltix Flowable 1.0 L/ha	-	Untreated

			Timing 1- Both applied at same date either before or after drilling		Timing 2
Treat 1 Main plot	**Treat 2 Sub-plot**	**Trial split seed treatment**	**Main plot Pre-drilling treatment**	**Main plot Post-drilling treatment**	**Sub-plot Post-emergence treatment**
			(incorporated)		
B4	2	Primed	Devrinol 0.85 L/ha + Goltix Flowable 1.0 L/ha (incorporated)	-	Dow Shield 400 0.25 L/ha
B5	1	Primed	-	Dual Gold 1.4 L/ha	Untreated
B5	2	Primed	-	Dual Gold 1.4 L/ha	Dow Shield 400 0.25 L/ha
B6	1	Primed	-	Butisan S 1.5 L/ha	Untreated
B6	2	Primed	-	Butisan S 1.5 L/ha	Dow Shield 400 0.25 L/ha
B7	1	Primed	-	Wing-P 1.25 L/ha	Untreated
B7	2	Primed	-	Wing-P 1.25 L/ha	Dow Shield 400 0.25 L/ha
B8 (commercial practice)	1	Primed	-	Devrinol 0.85 L/ha (watered in - 12 mm)	Untreated
B8 (commercial practice)	2	Primed	-	Devrinol 0.85 L/ha (watered in - 12 mm)	Dow Shield 400 0.25 L/ha

Prior to drilling, the site was marked out and the pre–drilling Timing 1 treatments were applied on 3 June. The treatments were applied to the bed-formed soil using an OPS sprayer and a 2 m boom with 04F110 nozzles, to achieve a medium spray quality at 1000 L/ha. Treatments A2, A4, B2 and B4 were then lightly incorporated into the soil with a rake, and 12 mm of water was applied to treatments A3 and B3 to simulate irrigation using a watering can.

Post–drilling treatments were then applied on the same day, using the same sprayer and boom, to achieve a medium spray quality at 400 L/ha. Treatments A8 and B8 were then watered in with 12 mm of water, applied with a watering can.

Post–emergence treatments were applied on 25 June, when the crop had reached two true leaf stage. Treatments were applied using an OPS sprayer and a 2 m boom, with 02F110 nozzles, to achieve a fine spray quality at 200 L/ha.

Each trial was assessed three weeks after the application of the Timing 1 treatments and at harvest, on 25 June and 9 July. 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 percentage emergence of the crop, and percentage weed cover. Weed species were also recorded. Data was analysed by ANOVA.

Site 2 - Wiltshire

Work was carried out on a commercial field crop of wild rocket, cv. Napoli in Wiltshire, drilled 7 May and due for harvest 20 June 2013. This trial was carried out on soil sterilised with Basamid (dazomet), with five major weeds: field pansy *(Viola arvensis)*, groundsel *(Senecio vulgaris)*, knot-grass *(Polygonum aviculare)*, spear thistle *(Cirsium vulgare)* and volunteer lettuce *(Lactuca sativa)*. There were two identical trials side by side in the same field (Figure 2.4.1). One was drilled using non-primed seed, and the other using primed seed. The trials were a fully randomised block design with seven main treatments, and two sub-plot treatments, including an untreated control (Table 2.4.3 and 2.4.4), replicated four times. Each main plot was 6 m long and 1.8 m wide, creating two 3 m lengths for the sub-plots.

Figure 2.4.1. Trial being drilled after application of pre-drilling herbicides and subsequent weed spectrum – 2013 (Site 2, Wiltshire)

Table 2.4.3. Detail of herbicide treatments applied either pre- or post-drilling, to non–primed seed – 2013 (Site 2, Wiltshire)

			Timing 1- Both applied at same date either before or after drilling		Timing 2
Treat 1 Main plot	**Treat 2 Sub-plot**	**Trial split seed treatment**	**Main plot Pre-drilling treatment**	**Main plot Post-drilling treatment**	**Sub-plot Post-emergence treatment**
A1	1	Non-primed	Untreated	Untreated	Untreated
A1	2	Non-primed	Untreated	Untreated	Dow Shield 400 0.25 L/ha
A2	1	Non-primed	Devrinol 0.85 L/ha (incorporated)	-	Untreated
A2	2	Non-primed	Devrinol 0.85 L/ha (incorporated)	-	Dow Shield 400 0.25 L/ha
A3	1	Non-primed	Devrinol 0.85 L/ha (watered in - 12 mm)	-	Untreated
A3	2	Non-primed	Devrinol 0.85 L/ha (watered in - 12 mm)	-	Dow Shield 400 0.25 L/ha
A4	1	Non-primed	Devrinol 0.85 L/ha + Goltix Flowable 1.0 L/ha (incorporated)	-	Untreated
A4	2	Non-primed	Devrinol 0.85 L/ha + Goltix Flowable 1.0 L/ha (incorporated)	-	Dow Shield 400 0.25 L/ha
A5	1	Non-primed	-	Dual Gold 1.4 L/ha	Untreated
A5	2	Non-primed	-	Dual Gold 1.4 L/ha	Dow Shield 400 0.25 L/ha
A6	1	Non-primed	-	Butisan S 1.5 L/ha	Untreated
A6	2	Non-primed	-	Butisan S 1.5 L/ha	Dow Shield 400 0.25 L/ha
A7	1	Non-primed	-	Wing-P	Untreated

				1.25 L/ha	
A7	2	Non-primed	-	Wing-P 1.25 L/ha	Dow Shield 400 0.25 L/ha

Table 2.4.4. Detail of herbicide treatments applied either pre- or post-drilling to primed seed – 2013 (Site 2, Wiltshire)

			Timing 1- Both applied at same date either before or after drilling		**Timing 2**
Treat 1 Main plot	**Treat 2 Sub-plot**	**Trial split seed treatment**	**Main plot Pre-drilling treatment**	**Main plot Post-drilling treatment**	**Sub-plot Post-emergence treatment**
B1	1	Primed	Untreated	Untreated	Untreated
B1	2	Primed	Untreated	Untreated	Dow Shield 400 0.25 L/ha
B2	1	Primed	Devrinol 0.85 L/ha (incorporated)	-	Untreated
B2	2	Primed	Devrinol 0.85 L/ha (incorporated)	-	Dow Shield 400 0.25 L/ha
B3	1	Primed	Devrinol 0.85 L/ha (watered in - 12 mm)	-	Untreated
B3	2	Primed	Devrinol 0.85 L/ha (watered in - 12 mm)	-	Dow Shield 400 0.25 L/ha
B4	1	Primed	Devrinol 0.85 L/ha + Goltix Flowable 1.0L/ha (incorporated)	-	Untreated
B4	2	Primed	Devrinol 0.85 L/ha + Goltix Flowable 1.0L/ha (incorporated)	-	Dow Shield 400 0.25 L/ha
B5	1	Primed	-	Dual Gold 1.4 L/ha	Untreated
B5	2	Primed	-	Dual Gold 1.4 L/ha	Dow Shield 400 0.25 L/ha
B6	1	Primed	-	Butisan S	Untreated

				1.5 L/ha	
B6	2	Primed	-	Butisan S 1.5 L/ha	Dow Shield 400 0.25 L/ha
B7	1	Primed	-	Wing-P 1.25 L/ha	Untreated
B7	2	Primed	-	Wing-P 1.25 L/ha	Dow Shield 400 0.25 L/ha

Prior to drilling, the site was marked out and the pre–drilling Timing 1 treatments were applied on 7 May. The treatments were applied to the bed-formed soil using an OPS sprayer and a 2 m boom with 04F110 nozzles, to achieve a medium spray quality at 1000 L/ha. Treatments A2, A4, B2 and B4 were then lightly incorporated into the soil with a rake, and 12 mm of water was applied to treatments A3 and B3 using a watering can. Post–drilling treatments were then applied on 8 May, using the same sprayer and boom, to achieve a medium spray quality at 400 L/ha.

Post–emergence treatments were applied on 7 June, when the crop had reached two true leaf stage. Treatments were applied using an OPS sprayer and a 2 m boom, with 02F110 nozzles, to achieve a fine spray quality at 200 L/ha.

Each trial was assessed four weeks after the application of the Timing 1 treatments and at harvest, on 7 and 20 June. Phytotoxicity was assessed on each plot, using a scale of 0–9, whereby 9 showed no effect, 7 was commercially acceptable stunting/damage, 1 was a very severe effect and 0 was plant death. Plots were also assessed for percentage emergence of the crop, and percentage weed cover. Weed species were also recorded. Data was analysed by ANOVA.

Table 2.4.5. Approval status of herbicides used in the wild rocket experiments

Product name	**Active ingredient**	**Rate (L/ha or kg/ha)**	**Approval Status**
Devrinol	Napropamide (450 g/L)	0.85 L/ha	EAMU
Dow Shield 400	Clopyralid (400 g/L)	0.25 L/ha	EAMU
Goltix Flowable	Metamitron (700 g/L)	1.0 L/ha	EAMU
Dual Gold	S-metolachlor (960 g/L)	1.4 L/ha	EAMU
Butisan S	Metazachlor (500 g/L)	1.5 L/ha	Not approved
Wing-P	Dimethenamid-p + pendimethalin (212.5:250g/L)	1.25 L/ha	Not approved

Results

<u>Site 1 - Kent</u>

In both trials (non-primed and primed seed), plots treated with Dow Shield 400 post–emergence showed an increase in phytotoxicity of between 0.5 and two points when compared to the plots that did not receive a post-emergence spray. Dow Shield 400 caused a slight cupping of the leaves. In the non–primed seed trial, Devrinol incorporated into the soil pre–drilling was the most crop safe method of application giving less crop damage than Devrinol that was watered in pre- or post–drilling, or incorporated with Goltix Flowable (Figure 2.4.3). Devrinol that was watered in post–drilling as per current commercial practice showed less phytotoxicity than Devrinol that was watered in pre–drilling, with and without Dow Shield 400. There was severe damage from Dual Gold, Butisan S and Wing-P, which caused stunting, plant death, and distortion and yellowing of any crop that did emerge (Figure 2.4.2).

Figure 2.4.2. Plots treated with Dual Gold, Butisan S and Wing-P can be clearly picked out as bare due to the phytotoxic effect of these herbicides on the crop – 2013 (Site 1, Kent)

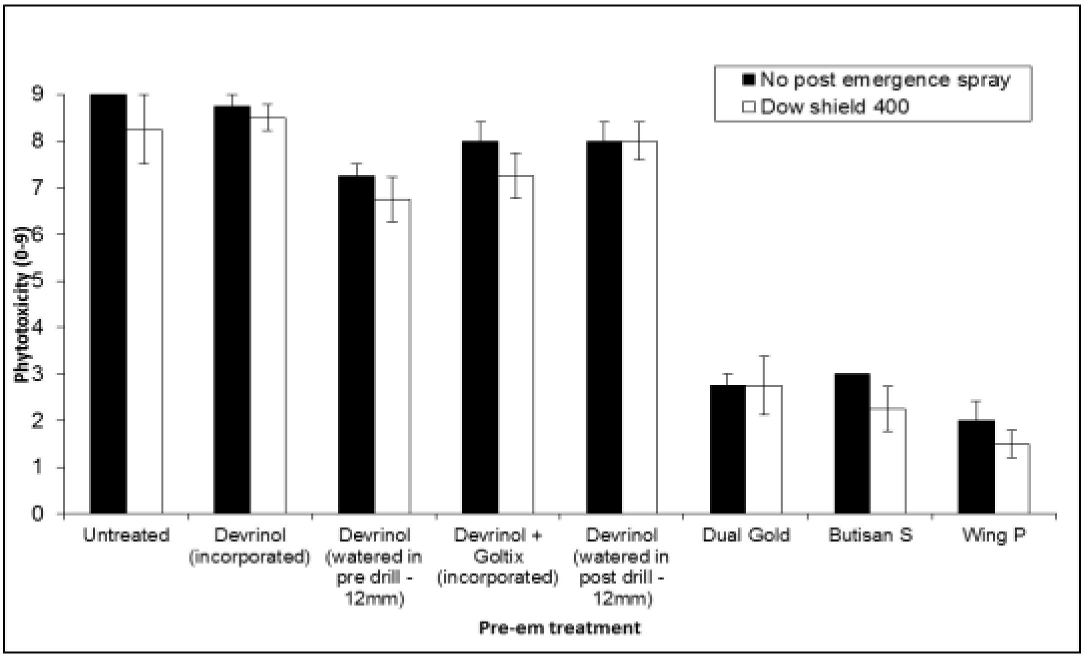


Figure 2.4.3. Phytotoxicity scores for non–primed seed – 2013 (Site 1, Kent) error bars show standard errors. Treatments on the x axis show the pre-emergence applications (either pre-drilling or post). White bars show plots which received Dow shield 400 as a post emergence spray on top of the pre-emergence applications (including the untreated)

For primed seed, there was no significant difference in phytotoxicity between plants in the untreated control, Devrinol incorporated pre–drilling and Devrinol watered in post–drilling plots, all with no post–emergence treatment (Figure 2.4.4). Plots treated with Dual Gold, Butisan S and Wing-P were slightly less affected by these herbicides than in the non-primed seed trial, but scores still fell significantly below the commercial standard required and stunting, plant death, distortion and yellowing were seen as in the non-primed trial. The use of primed seed only gave a slight reduction in phytotoxicity, but didn't improve the safety margin to a point where the crop would become commercially acceptable in the most damaging treatments.

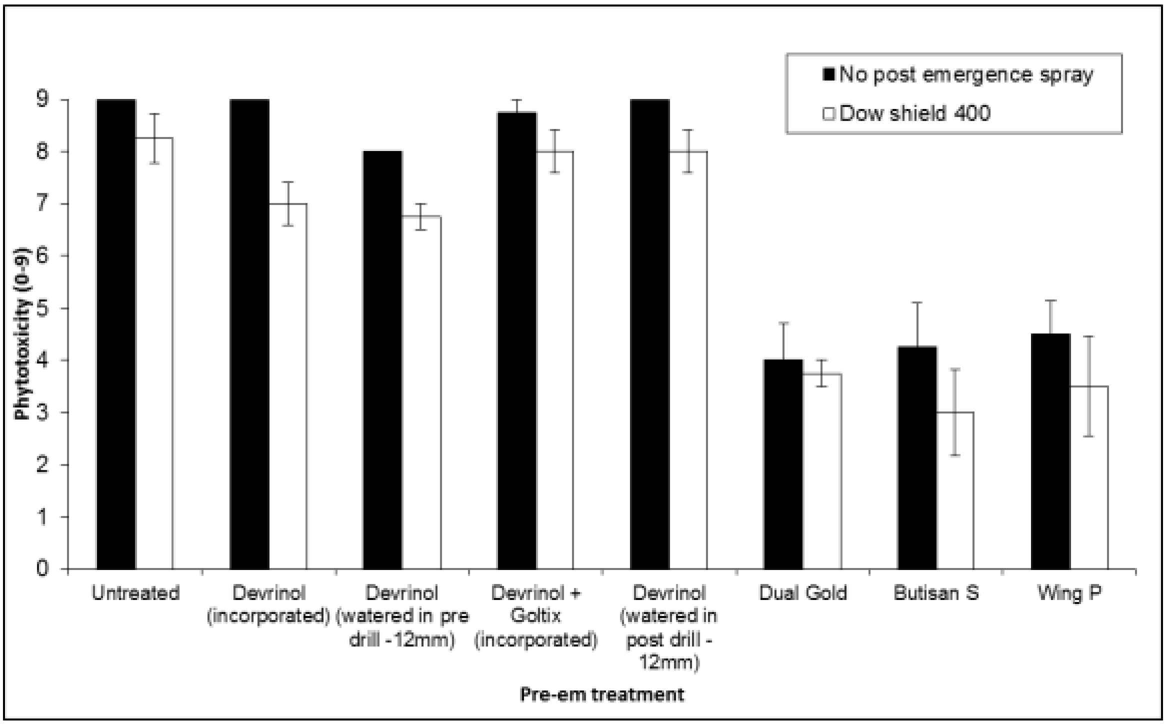


Figure 2.4.4. Phytotoxicity scores for primed seed – 2013 (Site 1, Kent) error bars show standard errors. Treatments on the x axis show the pre-emergence applications (either pre-drilling or post). White bars show plots which received Dow shield 400 as a post-emergence spray on top of the pre-emergence applications (including the untreated)

There was little difference in crop emergence between non–primed and primed seed. For non–primed seed, the application of Dow Shield 400 reduced emergence very slightly in all treatments, apart from Dual Gold (Figure 2.4.5). Plots with Devrinol incorporated into the soil showed equivalent emergence as the untreated control, but in the case of plots where Devrinol was watered in pre–drilling emergence was reduced to 65%. Devrinol watered in post-drilling or applied as a tank mix with Goltix Flowable and then incorporated pre-drilling gave a slight but acceptable reduction in crop emergence. Dual Gold, Butisan S and Wing-P all reduced crop emergence to less than 20%.

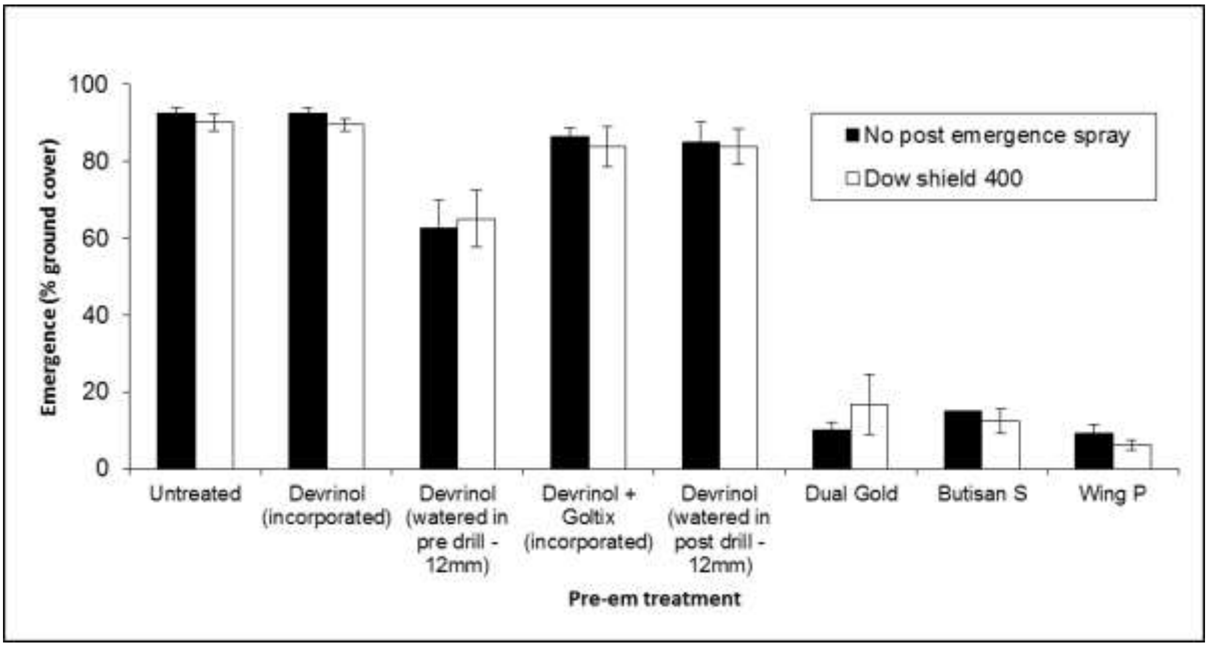


Figure 2.4.5. Crop emergence as a percentage ground cover with non–primed seed – 2013 (Site 1, Kent) error bars show standard errors. Treatments on the x axis show the pre-emergence applications (either pre-drilling or post). White bars show plots which received Dow shield 400 as a post-emergence spray on top of the pre-emergence applications (including the untreated)

In the primed seed trial, plots where Devrinol was used as a tank mix with Goltix Flowable, and where Devrinol was watered in post–drilling showed the highest level of crop emergence, with more than 95% (Figure 2.4.6). As in the non-primed trial, Devrinol watered in pre–drilling reduced crop emergence below 80%. Dual Gold, Butisan S and Wing-P all gave rise to very low levels of crop emergence, with a percentage ground cover of less than 25%.

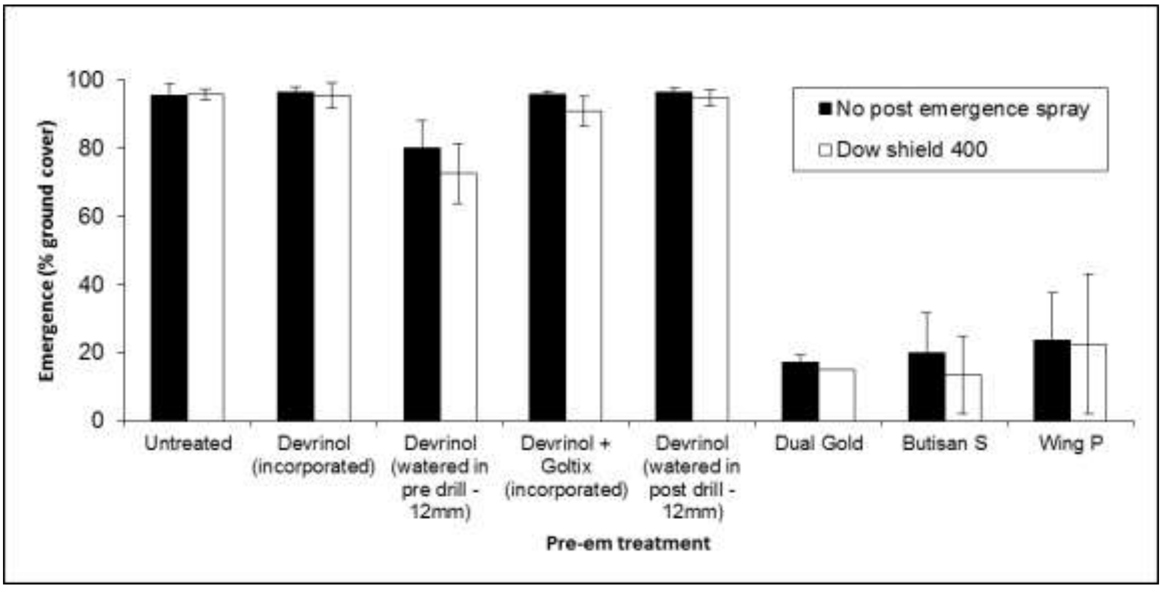


Figure 2.4.6. Crop emergence as a percentage ground cover with primed seed – 2013 (Site 1, Kent) error bars show standard errors. Treatments on the x axis show the pre-emergence applications (either pre-drilling or post). White bars show plots which received Dow shield 400 as a post-emergence spray on top of the pre-emergence applications (including the untreated)

Weed cover was greater in the non–primed than the primed seed trial seed trial at 6.8 to 8.8% cover in the untreated plots. Devrinol incorporated and Devrinol as a tank mix with Goltix Flowable gave a significant reduction in weed cover compared to the untreated control, with less than 4% weed cover (Figure 2.4.7). Dow Shield 400 did not give any consistent extra benefit. Devrinol which was watered in pre–drilling, Dual Gold, Butisan S and Wing-P did not give any significant reduction in percentage weed cover when compared to the untreated control. However, the extra weed cover in the Dual Gold, Butisan S and Wing-P plots could be explained by the lack of competition from the wild rocket crop, due to the effect of these herbicides on crop emergence.

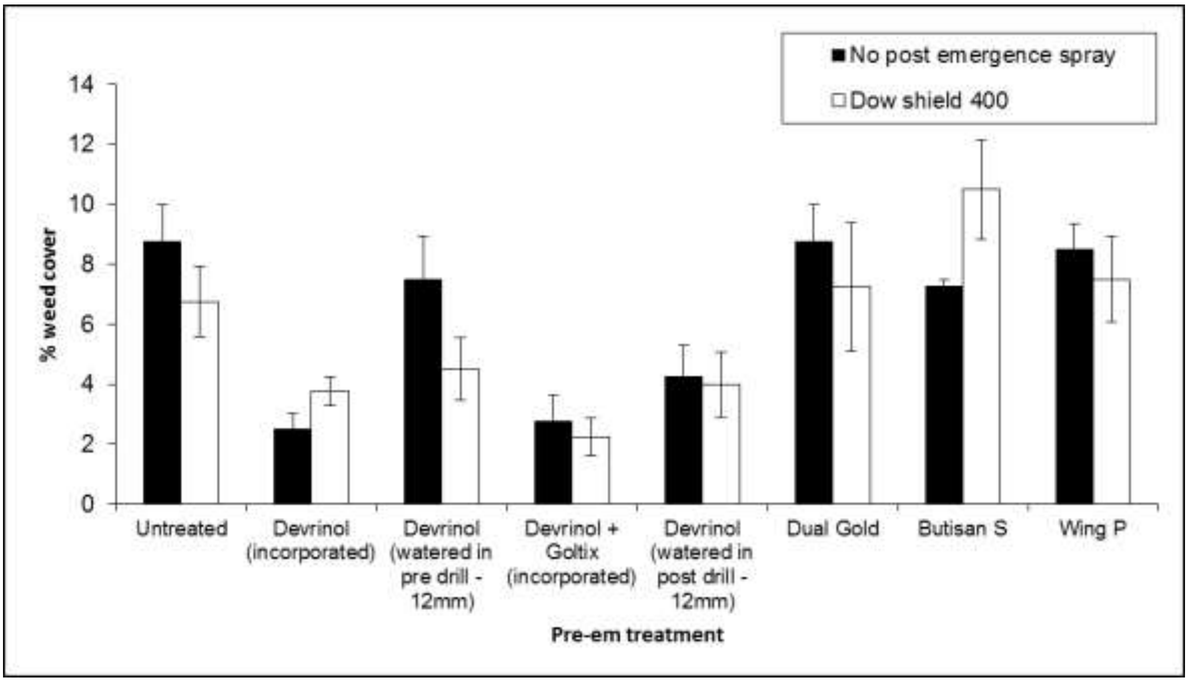


Figure 2.4.7. Percentage weed cover with non–primed seed – 2013 (Site 1, Kent) error bars show standard errors. Treatments on the x axis show the pre-emergence applications (either pre-drilling or post). White bars show plots which received Dow shield 400 as a post-emergence spray on top of the pre-emergence applications (including the untreated)

In the primed seed trial, there were fewer weeds (5.3% cover) in the untreated control compared with the Dual Gold, Wing P and Butisan S treatments (Figure 2.4.8). Devrinol incorporated, Devrinol as a tank mix with Goltix Flowable, and Devrinol watered in post–drilling all gave significantly better weed control than the untreated control. Devrinol which was watered in pre–drilling, Dual Gold, Butisan S and Wing-P gave no significant weed control, and the plots treated with the latter three herbicides all had more weeds than the untreated control. Again, this could be explained by the phytotoxic effect that the herbicides had on the wild rocket crop, reducing crop emergence and thus reducing the competition which would keep weed growth in check.

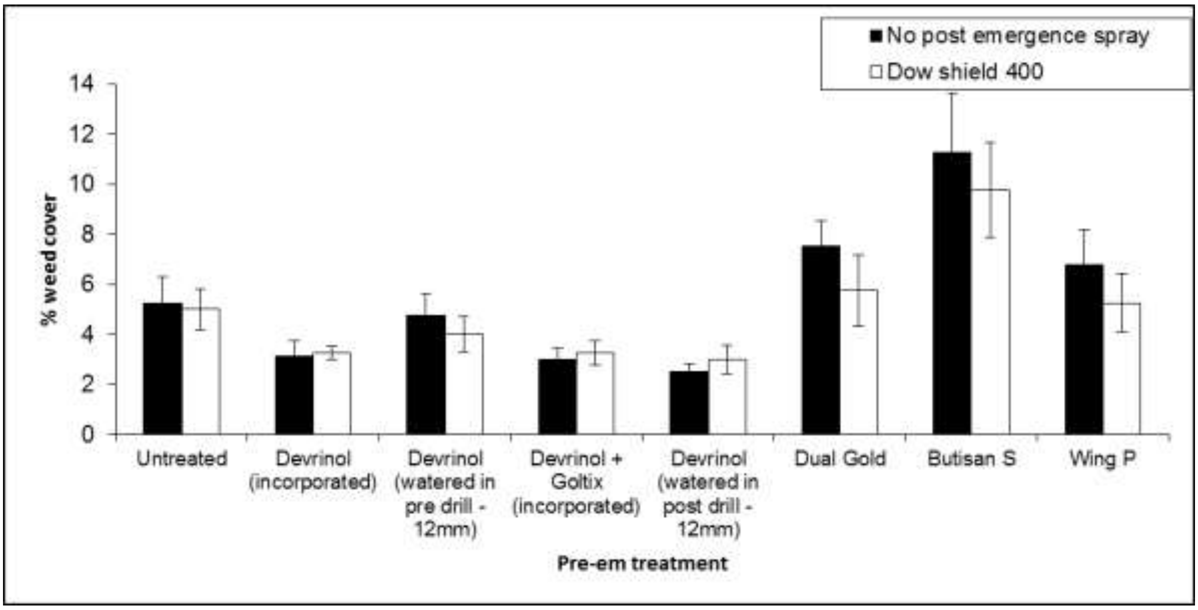


Figure 2.4.8. Percentage weed cover with primed seed – 2013 (Site 1, Kent) error bars show standard errors. Treatments on the x axis show the pre-emergence applications (either pre-drilling or post). White bars show plots which received Dow shield 400 as a post-emergence spray on top of the pre-emergence applications (including the untreated)

Phytotoxicity was slightly more evident in the non–primed seed trial than in the primed seed trial (Table 2.4.6 and 2.4.7). Crop emergence was slightly reduced in the non–primed trial, and the percentage weed cover increased.

Table 2.4.6. Mean scores for phytotoxicity, percentage emergence and percentage weed control using non–primed seed – 2013 (Site 1, Kent)

Trial	Treatment	Phytotoxicity (0-9)	% emergence	% weed cover
Kent (without post-emergence treatment)	1	9.0	92.5	8.8
	2	8.8	92.5	2.5
	3	7.3	62.5	7.5
	4	8.0	86.3	2.8
	5	8.0	85.0	4.3
	6	2.8	10.0	8.8
	7	3.0	15.0	7.3
	8	2.0	9.3	8.5
Kent (with post-emergence treatment)	1	8.3	90.0	6.8

Trial	Treatment	Phytotoxicity (0-9)	% emergence	% weed cover
	2	8.5	89.5	3.8
	3	6.8	65.0	4.5
	4	7.3	83.8	2.3
	5	8.0	83.7	4.0
	6	2.8	16.8	7.3
	7	2.3	12.5	10.5
	8	1.5	6.3	7.5
F pr.		<.001	<.001	<.001
l.s.d (21 d.f)		0.81	9.81	3.05

Table 2.4.7. Mean scores for phytotoxicity, percentage emergence and percentage weed control using primed seed – 2013 (Site 1, Kent)

Trial	Treatment	Phytotoxicity (0-9)	% emergence	% weed cover
Kent (without post-emergence treatment)	1	9.0	95.5	5.3
	2	9.0	96.5	3.1
	3	8.0	80.0	4.8
	4	8.8	95.8	3.0
	5	9.0	96.3	2.5
	6	4.0	17.0	7.5
	7	4.3	20.0	11.3
	8	4.5	23.8	6.8
Kent (with post-emergence treatment)	1	8.3	95.8	5.0
	2	7.0	95.5	3.3
	3	6.8	72.5	4.0
	4	8.0	90.8	3.3
	5	8.0	94.8	3.0
	6	3.8	15.0	5.8
	7	3.0	13.5	9.8
	8	3.5	22.5	5.3
F pr.		<.001	<.001	<.001
l.s.d (21 d.f)		1.38	11.39	3.03

<u>Site 2 – Wiltshire</u>

At this site, a higher level of phytotoxicity was noted in the non–primed trial than in the primed seed trial. In both trials at the Wiltshire site (non-primed and primed) the post-emergence application of Dow Shield 400 significantly increased phytotoxicity in most treatments, especially when applied after Devrinol. The phytotoxicity was seen as a distinct cupping of the leaves and all plots where Dow Shield 400 had been applied scored below the commercial standard of 7 (Figure 2.4.9). In the non-primed trial, Devrinol watered in pre–drilling, without the addition of Dow Shield 400, produced the lowest level of phytotoxicity, giving rise to a commercially acceptable crop. There was severe damage from Dual Gold, Butisan S and Wing-P, which caused distortion, yellowing, stunting and plant death.

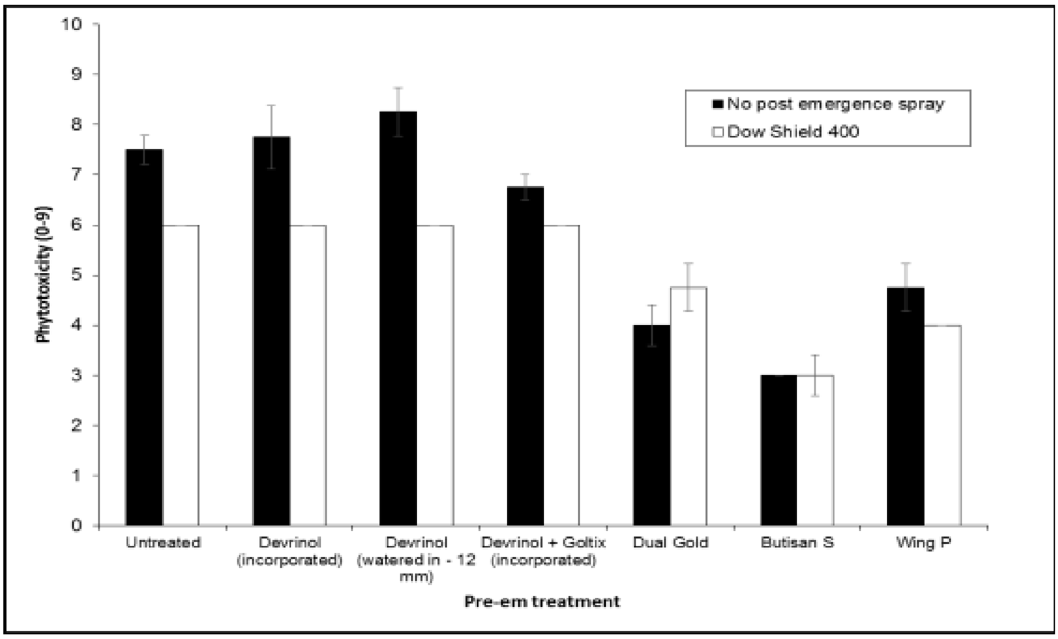


Figure 2.4.9. Phytotoxicity scores for non–primed seed – 2013 (Site 2, Wiltshire) error bars show standard errors. Treatments on the x axis show the pre-emergence applications (either pre-drilling or post). White bars show plots which received Dow shield 400 as a post-emergence spray on top of the pre-emergence applications (including the untreated)

In the primed seed trial, there was less phytotoxicity noted on the wild rocket, and the scores for Dual Gold, Butisan S and Wing-P were correspondingly higher than in the non–primed trial, however they were still below the commercial standard, and distortion, yellowing and stunting of the plants was seen. Dow Shield 400 applied as a post-treatment spray reduced scores by 0.25 to 2.5 across all treatments, and significantly reduced the scores to below commercial standards when applied after a pre-emergence treatment of Devrinol (Figure 2.4.10). Devrinol incorporated in the soil gave rise to barely perceptible crop damage, and plots treated with Devrinol which was watered in or applied as a tank mix with Goltix Flowable were commercially acceptable

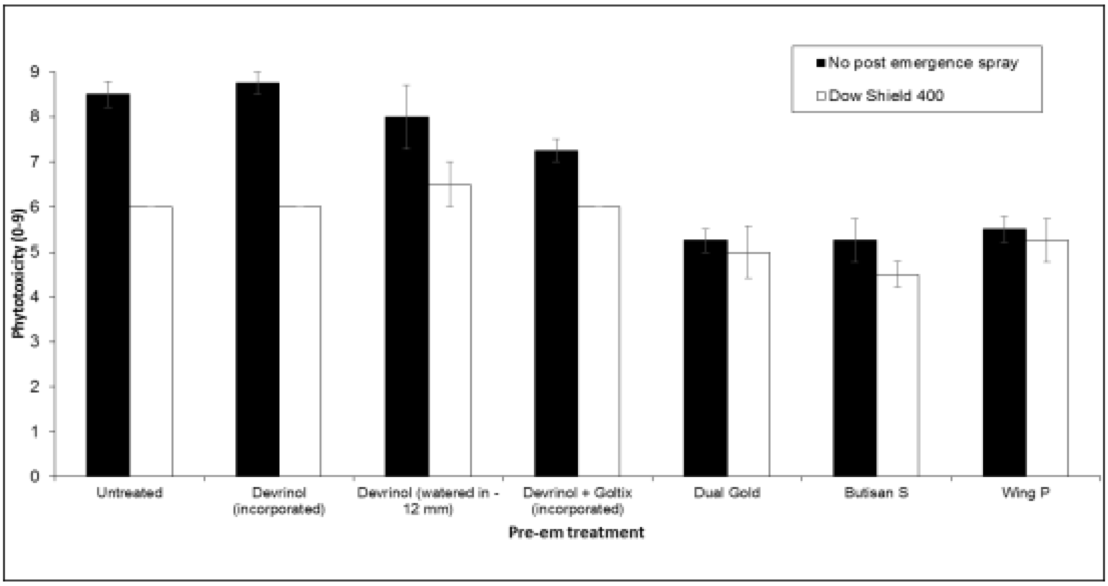


Figure 2.4.10. Phytotoxicity scores for primed seed – 2013 (Site 2, Wiltshire) error bars show standard errors. Treatments on the x axis show the pre-emergence applications (either pre-drilling or post). White bars show plots which received Dow shield 400 as a post-emergence spray on top of the pre-emergence applications (including the untreated)

Crop emergence in the non–primed trial was better in the Devrinol incorporated treatment, and the Devrinol watered in pre–drilling treatment than the untreated control (Figure 2.4.11). Dow Shield 400 reduced crop emergence slightly in all treatments apart from Butisan S. Plots treated with Butisan S were associated with the lowest level of crop emergence - 30%. Dual Gold and Wing-P reduced crop emergence by 50%; Devrinol when tank mixed and incorporated with Goltix Flowable led to a 25% reduction in crop emergence.

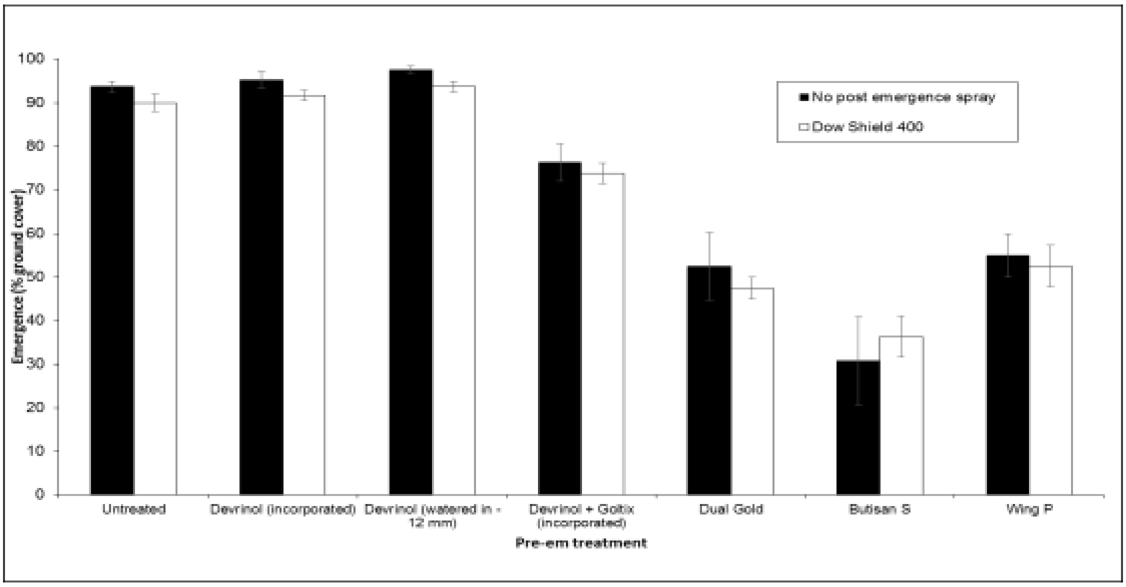


Figure 2.4.11. Crop emergence as a percentage ground cover with non–primed seed – 2013 (Site 2, Wiltshire error bars show standard errors. Treatments on the x axis show the pre-emergence applications (either pre-drilling or post). White bars show plots which received Dow shield 400 as a post-emergence spray on top of the pre-emergence applications (including the untreated)

In the primed seed trial, plots where Devrinol had been incorporated and where Devrinol was watered in pre–drilling showed the highest percentage of crop emergence (Figure 2.4.12). With plots where Devrinol and Goltix Flowable were applied as a tank mix and then incorporated, crop emergence was only slightly reduced, at 88%. The use of primed seed also increased the percentage emergence in the plots treated with Dual Gold, Butisan S and Wing-P pre-emergence, but scores were still significantly lower, with Butisan S giving a crop emergence of 57%. The primed seed improved crop emergence at the Wiltshire site in all the treatments but not to a commercially acceptable level in those treatments where emergence was significantly reduced.

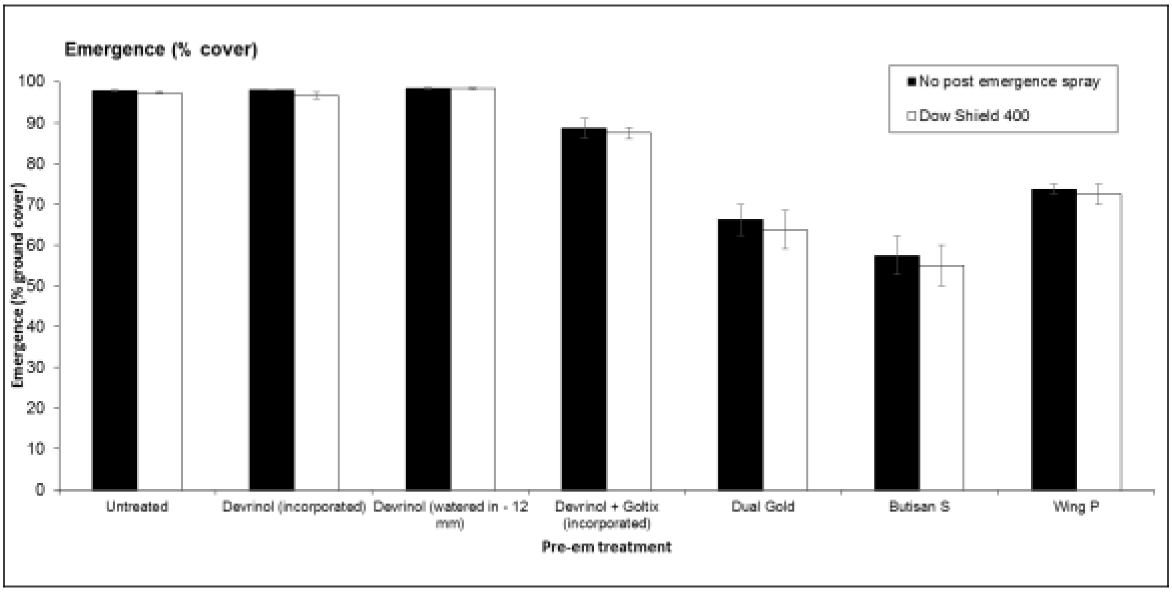


Figure 2.4.12. Crop emergence as a percentage ground cover with primed seed – 2013 (Site 2, Wiltshire) error bars show standard errors. Treatments on the x axis show the pre-emergence applications (either pre-drilling or post). White bars show plots which received Dow shield 400 as a post-emergence spray on top of the pre-emergence applications (including the untreated)

With the exception of the plots treated with Dual Gold, weed cover was relatively low at only 1.5 to 2.5% in the untreated plots in both the non–primed and primed seed trials (Figure 2.4.13). Devrinol applied as a tank mix with Goltix Flowable and Wing P gave significant control of the weeds in the non-primed trial, with the additional treatment of Dow Shield 400 only giving a very slight improvement.

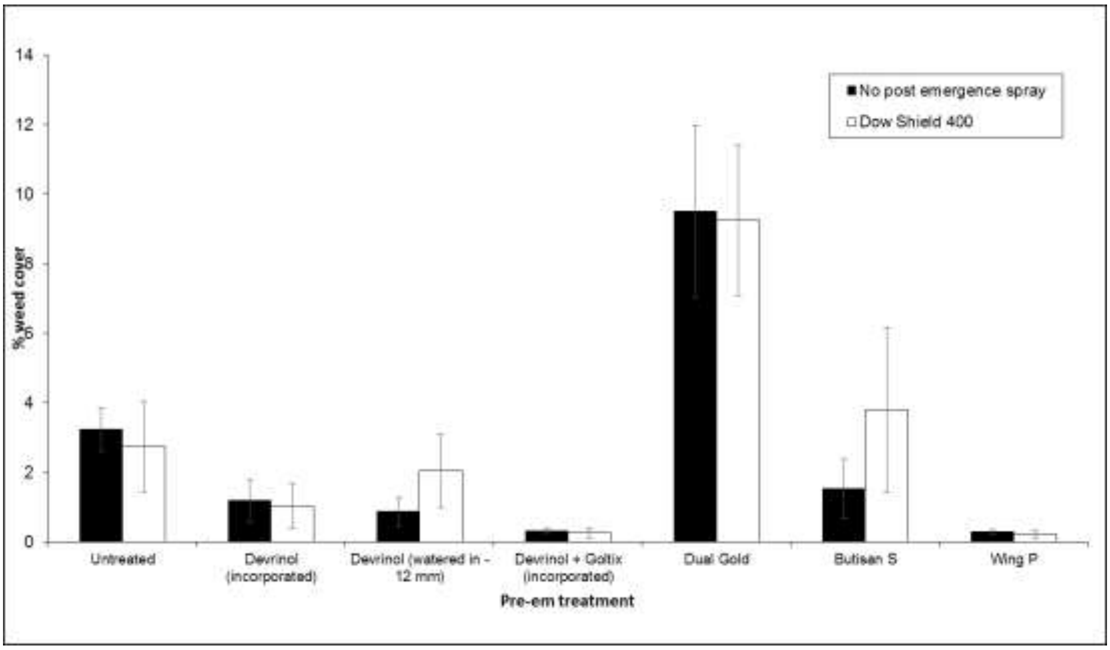


Figure 2.4.13. Percentage weed cover with non–primed seed – 2013 (Site 2, Wiltshire) error bars show standard errors. Treatments on the x axis show the pre-emergence applications (either pre-drilling or post). White bars show plots which received Dow shield 400 as a post-emergence spray on top of the pre-emergence applications (including the untreated)

In the primed seed trial, the highest level of weed cover once again occurred with the Dual Gold treatment, spear thistle being a particular problem, however the addition of Dow Shield 400 reduced this to below the level of the untreated control (Figure 2.4.14). All the treatments, apart from Dual Gold, gave rise to less than 1% weed cover. There were no significant differences in weed control between any of the treatments in the primed seed trial. There was little difference between the performance of the herbicides using non–primed and primed seed, although Butisan S performed much better in the primed trial, alone and with the follow up application of Dow Shield 400, however this could have been simply due to differences in the weed population between the two trials.

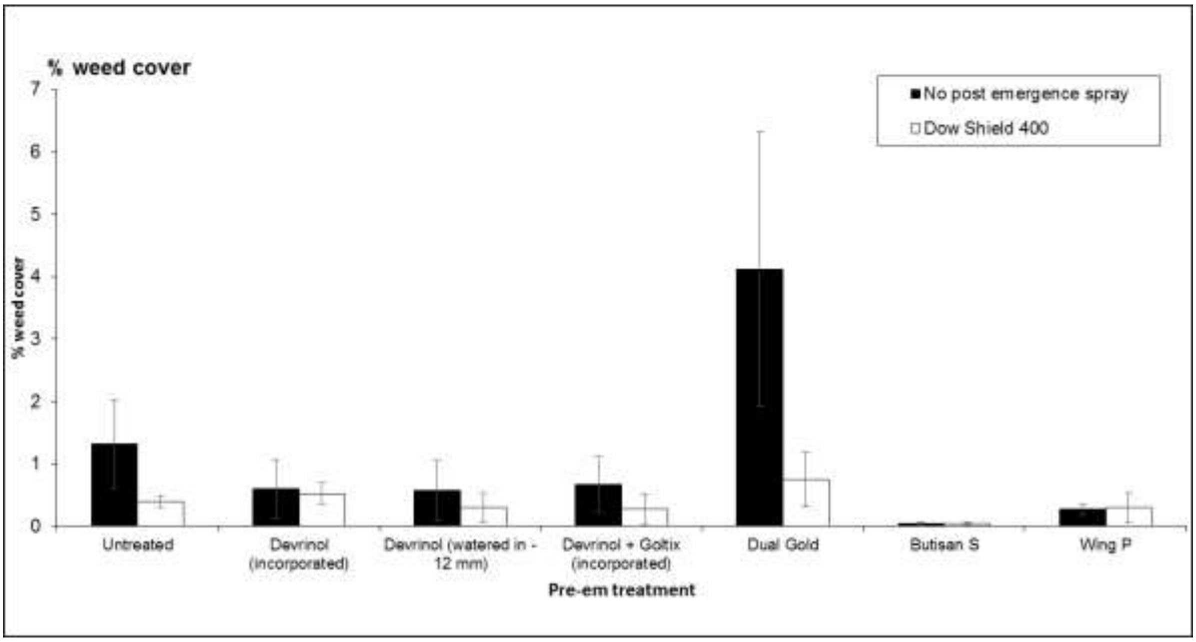


Figure 2.4.14. Percentage weed cover with primed seed – 2013 (Site 2, Wiltshire) error bars show standard errors. Treatments on the x axis show the pre-emergence applications (either pre-drilling or post). White bars show plots which received Dow shield 400 as a post-emergence spray on top of the pre-emergence applications (including the untreated)

Phytotoxicity was more noticeable in the non–primed trial, and crop emergence was slightly reduced (Table 2.4.8 and 2.4.9). The percentage weed cover was similar between the two trials, although weed populations were lower at the Wiltshire site.

Table 2.4.8. Mean scores for phytotoxicity, percentage emergence and percentage weed control using non–primed seed – 2013 (Site 2, Wiltshire)

Trial	Treatment	Phytotoxicity (0-9)	% emergence	% weed cover
Wiltshire (without post-emergence treatment)	1	7.5	93.8	3.3
	2	7.8	95.2	1.2
	3	8.3	97.5	0.9
	4	6.8	76.3	0.3
	5	4.0	52.5	9.5
	6	3.0	30.7	1.5
	7	4.8	55.0	0.3
Wiltshire (with post-emergence treatment)	1	6.0	90.0	2.8
	2	6.0	91.8	1.1

Trial	Treatment	Phytotoxicity (0-9)	% emergence	% weed cover
	3	6.0	93.8	2.1
	4	6.0	73.8	0.3
	5	4.8	47.5	9.3
	6	3.0	36.2	3.8
	7	4.0	52.5	0.2
F pr.		<.001	<.001	<.001
l.s.d (39 d.f)		0.63	8.95	2.42

Table 2.4.9. Mean scores for phytotoxicity, percentage emergence and percentage weed control using primed seed – 2013 (Site 2, Wiltshire)

Trial	Treatment	Phytotoxicity (0-9)	% emergence	% weed cover
Wiltshire (without post-emergence treatment)	1	8.5	97.8	1.3
	2	8.8	98.0	0.6
	3	8.0	98.3	0.6
	4	7.3	88.8	0.7
	5	5.3	66.3	4.1
	6	5.3	57.5	0.1
	7	5.5	73.8	0.3
Wiltshire (with post-emergence treatment)	1	6.0	97.3	0.4
	2	6.0	96.5	0.5
	3	6.5	98.3	0.3
	4	6.0	87.5	0.3
	5	5.0	63.8	0.8
	6	4.5	55.0	0.1
	7	5.3	72.5	0.3
F pr.		<.001	<.001	0.022
l.s.d (39 d.f)		0.72	5.26	1.35

Discussion

Devrinol was the safest treatment examined at both sites, with only slight differences in the level of phytotoxicity noted between the application methods used. When Devrinol was applied alone the crop was of marketable quality at harvest whichever method of application was used. In Kent, incorporation into the soil pre–drilling was the safest method with non-primed seed. Devrinol watered in post-drilling, as per current commercial practice, showed less phytotoxicity than Devrinol watered in pre-drilling, with non-primed seed. There was little difference between the Devrinol treatment application methods for primed seed at the Kent site. However, in Wiltshire, Devrinol watered in pre-drilling showed the least phytotoxicity with non–primed seed. Devrinol incorporated into the soil was the most crop safe method for primed seed. Therefore applying Devrinol as a soil incorporation treatment pre-drilling or (following current commercial practice) and applying the Devrinol pre-drilling and then watering it in are both crop safe to wild rocket.

When Devrinol was tank-mixed with Goltix Flowable and incorporated pre-drilling the combination caused some very slight phytotoxic effects and a reduction in crop emergence, although this was not significant at the Kent site. At the Kent site, all the plots treated with Devrinol and Goltix Flowable were of an acceptable commercial standard, therefore there is a possibility that this combination could be acceptably safe at lower application rates of Goltix Flowable. At the Wiltshire site, the reduction in crop emergence from the addition of Goltix Flowable was minimised where primed seed was used.

Dual Gold, Butisan S and Wing-P all caused significant phytotoxicity to the crop at both sites, with yellowing, stunting, distortion and plant death. Crop emergence was largely reduced, and in Kent, weed cover was higher in plots treated with these products. However, this may have been due to the lack of competition in the sparse crop. In Wiltshire, weed cover was reduced by Butisan S and Wing-P, but Dual Gold was not effective.

The addition of Dow Shield 400 as a post–emergence treatment proved to be phytotoxic on both non–primed and primed seed, at both sites. Leaf cupping was regularly observed. Phytotoxicity was greater in Wiltshire, possibly because the crop was at a later growth stage when the Dow Shield was applied.

The Devrinol treatments gave rise to the highest levels of crop emergence, with little difference between application methods. Devrinol watered in pre–drilling reduced crop emergence in Kent, but not in Wiltshire. In Wiltshire, Devrinol + Goltix Flowable reduced crop emergence by 17% in both the primed and non-primed trials, but in Kent emergence was only reduced by 6% in the non-primed trial and not at all in the primed seed trial. This may be due to the differing soil types and the higher clay content at the Kent site. At both sites, and in all trials, Dual Gold, Butisan S and Wing-P significantly reduced crop emergence (especially so in Kent) where emergence was below 25%. The application of Dow Shield 400 had a slight negative effect on crop emergence.

Weed emergence was higher at the Kent site, with more weeds present in the non–primed trial. However, in both trials, Devrinol or Devrinol as a tank-mix with Goltix Flowable was the most effective at controlling weed populations. Devrinol watered in pre–drilling was slightly less effective. Dual Gold, Butisan S and Wing-P were less effective at controlling weeds in Kent. However, in Wiltshire, Butisan S and Wing-P were just as effective as Devrinol. It is possible that the reduced weed populations at the Wiltshire site may have contributed to this.

The most troublesome weeds at each site were not fully controlled, but their percentage ground cover was reduced by the application of Devrinol, and in the trial at Wiltshire the groundsel was controlled by the application of Devrinol and Goltix Flowable.

Primed seed gave a very slight benefit in terms of improving crop emergence and reducing crop phytotoxicity, notable where Goltix Flowable was used, but possibly not enough to provide justification for use considering the extra cost of the seed. There was little difference in weed cover between non–primed and primed seed trials.

Conclusions

- **Devrinol was the most crop safe treatment used in the trials, either incorporated into the soil pre–drilling, or watered in post–drilling. Goltix Flowable has the potential to improve the control of groundsel when used as a tank mix with Devrinol. At 1 L/ha it slightly reduced the percentage of crop emergence at the Wiltshire site but the effect was minimal where primed seed was used.**
-
- **Dual Gold, Butisan S and Wing-P are not safe to use on wild rocket.**
-
- **Dow Shield 400 is slightly phytotoxic to wild rocket, and no appreciable benefits were seen in weed control when compared to treatments that did not receive a post–emergence treatment and therefore its use is difficult to justify.**

Objective 2.6 – Ground cover trial: living mulches

Introduction

Living mulches are low growing plants established either prior to or at the same time as the main crop. There are many benefits that living mulches can offer to the crop such as enhancing the soil structure (e.g. prevent soil erosion by covering the bare soil, improve fertility levels etc.), habitat creation for beneficial insects and the provision of weed suppression. However, it is very important that the correct living mulch is selected, as it could become detrimental to the crop due as a result of competition for water or nutrients.

This study is the second part of the 2012 preliminary experiment, in which four plant species were assessed for suitability as living mulches in top fruit.

Material and Methods

The study was carried out at in an outdoor pot standing area at ADAS Boxworth and was separated into two different parts. The first part was a full factorial design including four living mulch species being sown at two different sowing densities either singularly or with a second species, plus an untreated control without living mulch (

Table 2.6.1). The second part was also a fully factorial design containing the same treatments as the first part plus two different weed types (Table 2.6.2). Both parts were replicated four times.

Table 2.6.1. Treatment list: living mulch species and sowing density

Treatment	Common name	Scientific name	Sowing density (g/m²)	Seeds per container (g)
1	White clover (Aberherald)	*Trifolium repens*	0.70	0.50
2	White clover (Aberherald)	*Trifolium repens*	1.40	1.00
3	Black medic	*Medicago lupulina*	0.80	0.60
4	Black medic	*Medicago lupulina*	1.60	1.20
5	Creeping red fescue	*Festuca rubra*	3.75	2.70
6	Creeping red fescue	*Festuca rubra*	7.50	5.40
7	Birdsfoot trefoil	*Lotus corniculatus*	0.70	0.50
8	Birdsfoot trefoil	*Lotus corniculatus*	1.40	1.00
9	Creeping red fescue + birdsfoot trefoil	*Festuca rubra* + *Lotus corniculatus*	3.75 + 0.70	2.70 + 0.50
10	Creeping red fescue + birdsfoot trefoil	*Festuca rubra* + *Lotus corniculatus*	7.50 +1.40	5.40 + 1.00
11	Untreated	-	-	

Table 2.6.2. Treatment list: living mulch species and weed interactions

Treatment	Common name	Sowing density (g/m^2)	Weed type
1	White clover (Aberherald)	0.70	Annuals
2	White clover (Aberherald)	1.40	Annuals
3	Black medic	0.80	Annuals
4	Black medic	1.60	Annuals
5	Creeping red fescue	3.75	Annuals
6	Creeping red fescue	7.50	Annuals
7	Birdsfoot trefoil	0.70	Annuals
8	Birdsfoot trefoil	1.40	Annuals
9	Creeping red fescue + birdsfoot trefoil	3.75 + 0.70	Annuals
10	Creeping red fescue + birdsfoot trefoil	7.50+1.40	Annuals
11	Untreated	-	Annuals
12	White clover (Aberherald)	0.70	Perennials
13	White clover (Aberherald)	1.40	Perennials
14	Black medic	0.80	Perennials
15	Black medic	1.60	Perennials
16	Creeping red fescue	3.75	Perennials
17	Creeping red fescue	7.50	Perennials
18	Birdsfoot trefoil	0.70	Perennials
19	Birdsfoot trefoil	1.40	Perennials
20	Creeping red fescue + birdsfoot trefoil	3.75 + 0.70	Perennials
21	Creeping red fescue + birdsfoot trefoil	7.50 + 1.40	Perennials
22	Untreated	-	Perennials

In the case of the annual weeds, 30 seeds were sown for each species; common chickweed (*Stellaria media*), groundsel (*Senecio vulgaris*) and scentless mayweed (*Tripleurospermum inodorum*). The perennial weeds used were common couch (*Elytrigia repens*) and broad-leaved dock (*Rumex obtusifolius*). Root material was used to establish both. A total of 132 containers (30.5 x 23.5 x 15cm) were filled with Kettering loam and were watered to field capacity prior to the sowing / planting date. Weeds were sown / planted in the containers on 19 April 2013 and the living mulches were evenly sprinkled on the top by hand according to the treatment lists. For the first part of the trial, the sowing density of the living mulches was assessed twice on 8 May 2013 and 7 June 2013. After the second assessment, the plant material above the soil surface from all the containers from the second part of the trial (containers with weed) was cut back. A fresh weight assessment of each species was carried out on 6 August 2013. The soil nitrogen content was assessed at the end of the trial from the containers from the first part of the experiment (living mulches in the absence of weeds) by sending soil samples from each treatment for laboratory analysis.

Results

The percentage cover of the living mulches was assessed twice, 8 May 2013 and 7 June 2013 and the data are presented below (Table 2.6.3).

Table 2.6.3. Living mulch percentage pot cover, three and seven weeks after sowing

Treatment	**Sowing density(g/m^2)**	**3 weeks 08 May 2013**	**7 weeks 07 June 2013**
White clover (Aberherald)	0.70	52.50	96.25
	1.40	76.25	100.00
Black medic	0.80	27.50	62.50
	1.60	31.25	62.50
Creeping red fescue	3.75	65.00	97.50
	7.50	75.00	95.00
Birdsfoot trefoil	0.70	37.50	73.75
	1.40	28.75	70.00
Creeping red fescue + birdsfoot Trefoil	3.75+0.70	85.00	95.00
	7.50 + 1.40	73.75	97.50
Untreated	-	-	-
P value		<0.001	<0.001
LSD (df)		18.28	16.34

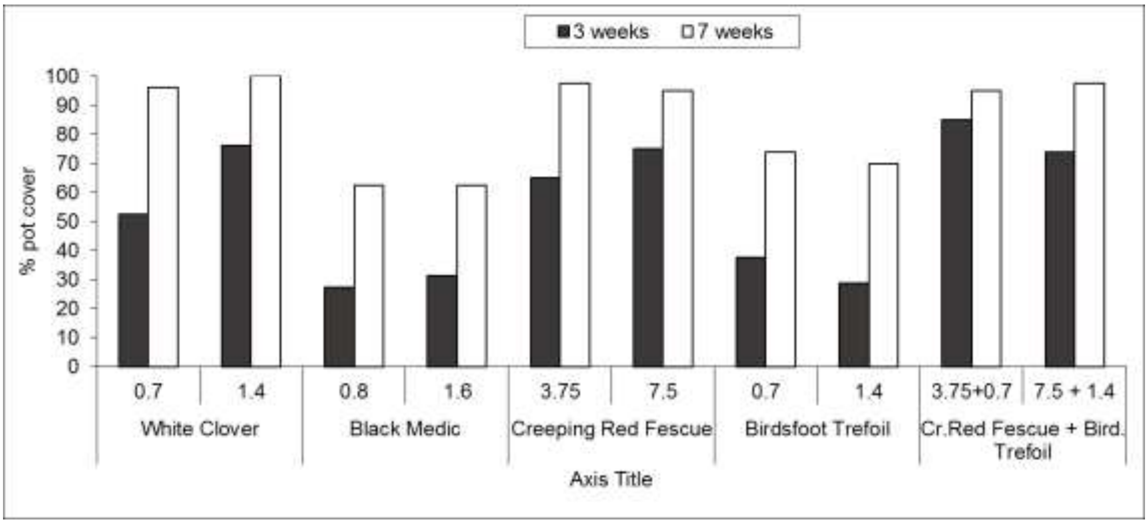


Figure 2.6.1. Living mulch percentage pot cover, three and seven weeks after sowing

The results show that there was no significant difference between the two sowing densities examined. The lower sowing density resulted in the same ground cover as the higher density. The results are shown in Figure 2.6.2.

White clover (0.7-1.4 g/m^2)

Black medic (0.80-1.60 g/m^2)

Creeping red fescue (3.75-7.50g/m^2)

Birds foot trefoil (0.7 – 1.4 g/m^2)

Creeping red fescue-birdsfoot trefoil
(3.75+0.70-7.50+1.40g/m^2)

Figure 2.6.2. Living mulches at different sowing densities

A biomass assessment for the second part of the trial was carried out on 6 August 2013. All the plant material above the soil surface was cut and separated by species. The fresh weight of each species was recorded and presented below.

Table 2.6.4. Annual weeds interaction with living mulch: average fresh weight 6 August

Treatments	Sowing density(g/m^2)	Average of chickweed	Average of groundsel	Average of mayweed
White clover	0.70	25.425	12.600	17.025
	1.40	23.866	10.533	5.525
Black medic	0.80	15.775	2.900	33.350
	1.60	20.050	5.266	24.900
Creeping red fescue	3.75	0.626	-	2.150
	7.50	0.450	0.003	3.112
Birdsfoot trefoil	0.70	51.250	3.400	21.225
	1.40	16.933	5.530	18.175
Creeping red fescue +birdsfoot trefoil	3.75 + 0.70	0.792	0.507	3.650
	7.50 + 1.40	0.453	-	1.283
Untreated	-	18.275	7.675	37.725
P value		<0.001	0.004	<0.001
LSD		16.08	5.135	9.84

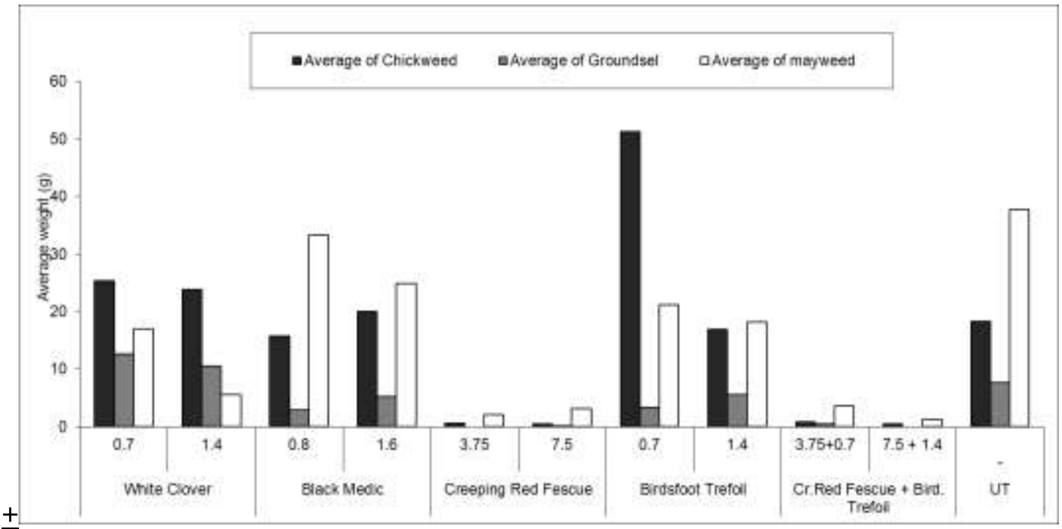


Figure 2.6.3. Annual weeds: average fresh weed weight (g) after five months

The results show that only creeping red fescue and the mixture of creeping red fescue and birdsfoot trefoil significantly controlled all the annual weeds. Chickweed and groundsel were not controlled effectively by the white clover, black medic and birdsfoot trefoil alone. The most promising control results were for the mayweed. All the living mulches successfully suppressed the mayweed population except for the black medic lower sowing density.

Table 2.6.5. Perennial weeds interaction with living mulch: average fresh weight 6 August

Treatment	Sowing density (g/m^2)	Average of couch (g)	Average of dock (g)
White Clover (Aberherald)	0.70	6.18	20.58
	1.40	8.53	3.77
Black Medic	0.80	11.10	8.18
	1.60	8.05	25.15
Creeping Red Fescue	3.75	2.03	5.25
	7.50	2.78	2.39
Birdsfoot Trefoil	0.70	10.28	21.53
	1.40	9.65	12.58
Creeping red fescue + birdsfoot Trefoil	3.75+0.70	2.33	6.13
	7.50+1.40	1.57	2.68
Untreated	-	26.88	26.18
P value		0.016	<0.001
LSD (df)		7.063	8.119

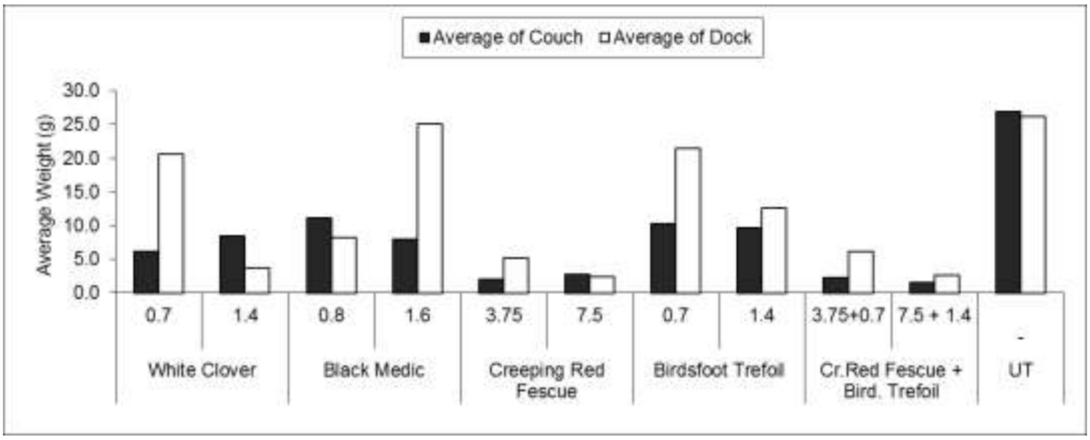


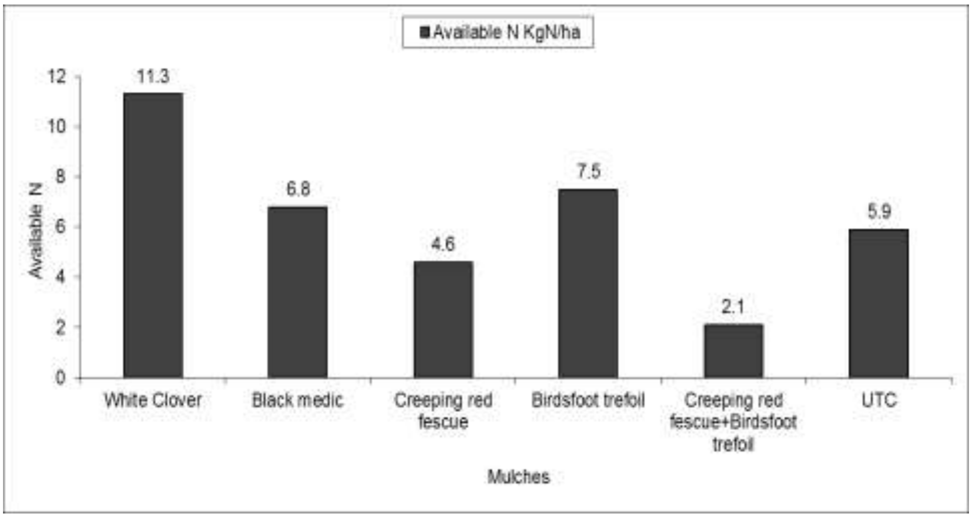
Figure 2.6.4. Perennial weeds: average fresh weed weight (g) after five months

Results show that all the living mulches significantly controlled the growth of common couch. However, they did not all significantly control the dock growth. Dock control varied according to the living mulch species and the sowing density (Figure 2.6.4). Creeping red fescue alone or as a mixture with birdsfoot trefoil significantly supressed both perennial weed species. White clover and birdsfoot trefoil in both sowing densities, significantly supressed couch but only the higher sowing density supressed dock. Interestingly, the black medic lower sowing density better supressed dock than the higher sowing density. Couch was successfully reduced in both sowing rates.

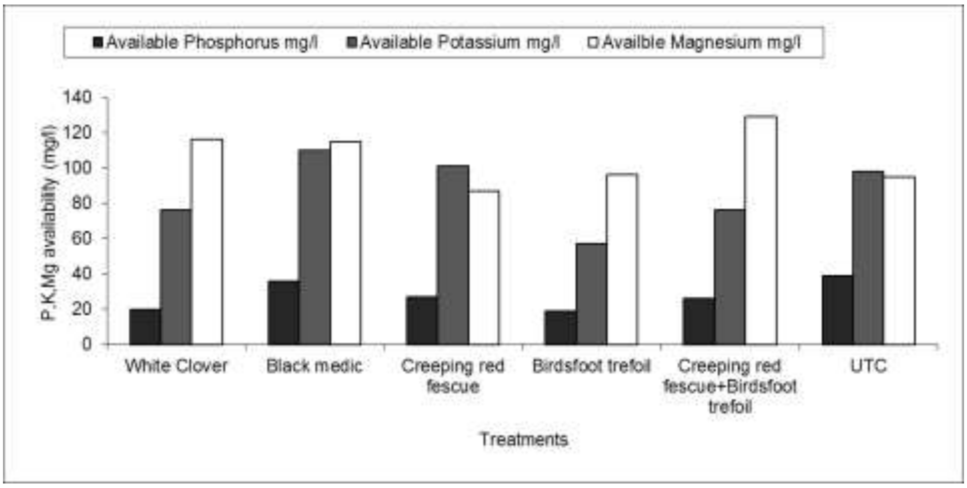
The soil analysis nutrient results varied for all cover crop species (Table 2.6.6).

Table 2.6.6. Soil nutrient values for each cover crop

Treatment	Available N Kg/ha	Available Phosphorus (mg/l)	Available Potassium (mg/l)	Available Magnesium (mg/l)
White Clover	11.3	20.0	76.0	116.0
Black medic	6.8	36.0	110.0	115.0
Creeping red fescue	4.6	27.0	101.0	87.0
Birdsfoot trefoil	7.5	19.0	57.0	96.0
Creeping red fescue +birdsfoot trefoil	2.1	26.0	76.0	129.0
UTC	5.9	39.0	98.0	95.0



Nitrogen availability



Phosphorus, potassium magnesium availability

Figure 2.6.5. Nitrogen, phosphorus, potassium and magnesium availability

The nitrogen availability results were as expected with leguminous species increasing available nitrogen, especially white clover which had the highest concentrations. Creeping red fescue reduced the overall available nitrogen. There were some differences in the availability of the other elements (and their relative levels) dependent upon the plants species, however with only one bulked sample and without statistics it is difficult to draw firm conclusions, further investigations will be made in the field trials in 2014.

Discussion

The results show that there was no difference between the two living mulch sowing densities in terms of ground cover and, for most weeds, efficacy of weed suppression. The majority of the species did suppress the perennial weeds in comparison with the untreated control. Creeping red fescue alone and as a mixture with birdsfoot trefoil were the most suppressive for both perennial and annual weeds. This could be explained by the dense ground cover that creeping red fescue provides. Some of the other living mulch species efficiently suppressed the annual weeds. However it is important to note that, creeping red fescue reduced the nitrogen availability in contrast to the leguminous species. A combination of creeping red fescue and a species which provides high nitrogen availability could be the best option.

Conclusions

At the end of this year’s trial it was shown that creeping red fescue and its mixture with birdsfoot trefoil were the most suppressive living mulches irrespective of sowing densities. However, the nitrogen and the other nutrient availability results should be considered for potential living mulch species mixture to maximise the benefits from leguminous species. Further trials for 2014 will build on these results and include (1) a field trial in an apple orchard with a range of the most successful living mulches investigating weed suppression, nutrient uptake, moisture requirements and apple tree growth and (2) a glasshouse pot trial to investigate the moisture requirements for each of the living mulch species.

Objective 2.7 Perennial weed trial: green manures

Introduction

Cover crops can be used in different field situations as ground cover, green manures and living mulches providing many benefits to the field. Cover crops can enhance the soil fertility and improve the soil structure while controlling the soil erosion. Moreover, cover crops have the ability to suppress the pest population and more importantly to control the weed population. Each cover crop has certain properties that can indirectly control various weed species (e.g. Buckwheat has allelopathic properties while mustard species can produce bio-fumigant gases through their damaged cells).

However, it is very important that cover crops should not be related to the following crop in the rotation in order to avoid creating a pest and disease reservoir. Furthermore, the cover crop choice has to be carefully selected to prevent any potential crop competition.

This trial aimed to investigate the potential of weed suppression from various cover crops when used as a green manure.

Material and methods

The study was a fully randomised block design including four cover crop species, an untreated control without cover crop and three perennial weeds, replicated four times. The treatment list is shown in Table 2.7.1.

Table 2.7.1. Treatment list: Green manure mulch species – weed interactions

Treatment no.	Cover crop species	Sowing density	Seed needed per pot	Perennial weed species
1	Buckwheat (*Fagopyrum esculentum*)	120 kg/ha	8.6 g	Creeping Thistle
2	Buckwheat (*Fagopyrum esculentum*)	120 kg/ha	8.6 g	Broad-leaved dock
3	Buckwheat (*Fagopyrum esculentum*)	120 kg/ha	8.6 g	Field bindweed
4	Caliente 119R	11 kg/ha	0.79 g	Creeping Thistle
5	Caliente 119R	11 kg/ha	0.79 g	Broad-leaved dock
6	Caliente 119R	11 kg/ha	0.79 g	Field bindweed
7	Caliente 61	8 kg/ha	0.57 g	Creeping thistle
8	Caliente 61	8 kg/ha	0.57 g	Broad-leaved dock
9	Caliente 61	8 kg/ha	0.57 g	Field bindweed
10	Caliente 99	10 kg/ha	0.72 g	Creeping thistle
11	Caliente 99	10 kg/ha	0.72 g	Broad-leaved dock
12	Caliente 99	10 kg/ha	0.72 g	Field bindweed
13	-	-		Creeping thistle
14	-	-		Broad-leaved dock
15	-	-		Field bindweed

Root material of each of the weed species was collected from the field in February 2013 and established in pots at ADAS Boxworth ready for replanting for the trial sowing date. Two days prior to the sowing date, 60 containers (30.5 x 23.5 x 15 cm) were filled with loam based soil and watered to field capacity. On 31 May 2013, when the weed root stock was ready, four pieces of each weed species were extracted from the holding pots, cut up using scissors into 10 cm pieces for thistle and bindweed, 2 cm for dock to mimic the effects of cultivation and replanted to the containers at a 5 cm depth. The cover species were then sprinkled by hand on the top and covered with 1 cm soil.

When both cover crops and weed species reached the flowering stage, 1 August 2013, all the plant material above the soil surface was cut, separated by species and the weight of each weed species was recorded (Figure 2.7.1). A similar assessment took place after a further month, 5 September 2013, to assess the re-growth of each weed or cover crop population.

01/08/2013, Before biomass assessment

After biomass assessment

Figure 2.7.1. Trial before and after the first biomass assessment - 1 August 2013

Results

Two destructive biomass assessments were carried out during the trial to investigate any potential weed control from the cover crops and the results are presented below (

Table 2.7.2). There was a poor establishment for the field bindweed.

Table 2.7.2. First biomass and re-growth assessments grams fresh weight

Treatment		Biomass assessment (g) 01/08/2013	Biomass assessment (g) 05/08/2013
Thistle	Buckwheat	1.545	0.000
	Caliente 119R	3.495	8.857
	Caliente 61	1.890	0.387
	Caliente 99	4.440	6.792
	UTC	51.497	25.657
Dock	Buckwheat	1.990	4.840
	Caliente 119R	2.712	9.915
	Caliente 61	2.247	7.962
	Caliente 99	2.840	15.145
	UTC	50.557	20.652
Field bindweed	Buckwheat	0.117	0.107
	Caliente 119R	0.075	0.082
	Caliente 61	0.000	0.297
	Caliente 99	0.000	0.140
	UTC	1.055	0.947
P value		<0.001	<0.001
d.f		42.000	42.000
L.S.D		14.050	10.920

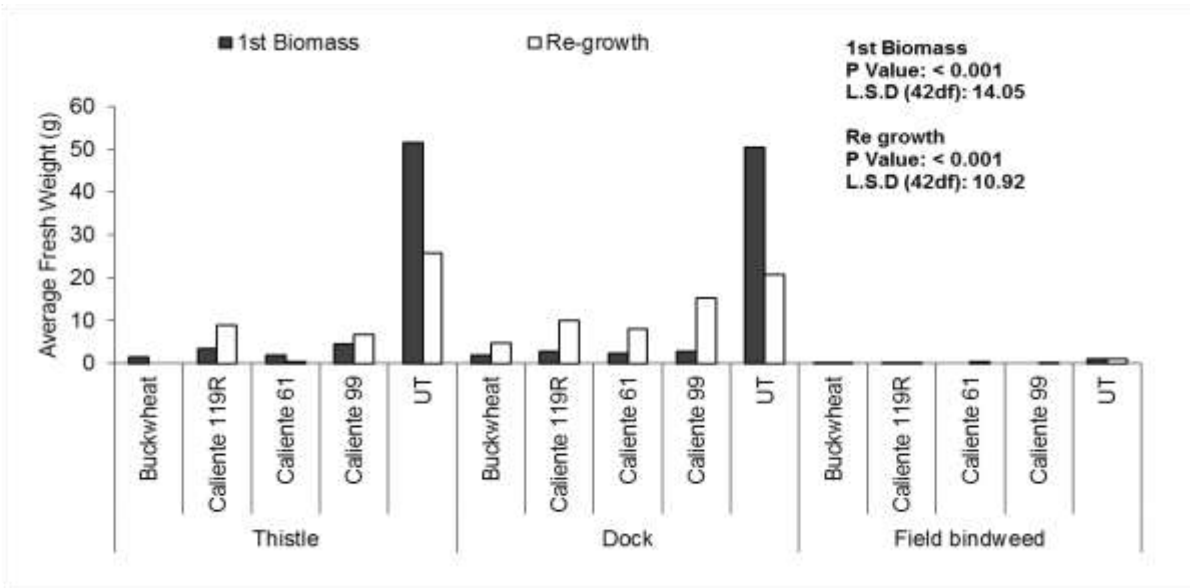


Figure 2.7.2. First biomass and re growth assessment

The results show that all cover crops were able to significantly (p=<0.001) supress each weed species and the re-growth of the weed after cutting was always less than the untreated control. Buckwheat offered the best weed suppression reducing the thistle and dock to a fresh weight of below 2 g, compared to an untreated control fresh weight of over 50 g, with no re-growth for either thistle or dock. This was closely followed by Caliente 61 and then 99 for thistle control. Caliente 99, did not control the dock re-growth as effectively as the other cover crops (Figure 2.7.3).

Creeping thistle untreated

Creeping thistle-Buckwheat

Creeping thistle-Caliente 119

Creeping thistle-Caliente 61

Creeping thistle-Caliente 99

Figure 2.7.3. Creeping thistle establishment before first biomass assessment

Broad-leaved dock untreated

Broad-leaved dock -Buckwheat

Broad-leaved dock -Caliente 119

Broad-leaved dock -Caliente 61

Broad-leaved dock -Caliente 99

Figure 2.7.4. Broad-leaved dock establishment before first biomass assessment

Field bindweed untreated

Field bindweed -Buckwheat

Field bindweed -Caliente 119

Field bindweed -Caliente 61

Field bindweed -Caliente 99

Figure 2.7.5. Field bindweed establishment before first biomass assessment

Discussion

All the green manure cover crops successfully decreased the growth of the weed species examined. Buckwheat suppressed the weed species at the first assessment and also during the re-growth period. This is likely to be the result of both the dense canopy produced and the allopathic effects of the buckwheat that not only smothers the weeds below but also inhibits growth. All the cover crops managed to control the thistle population significantly in both assessments. All cover crops apart from Caliente 99, reduced the re-growth of dock significantly.

Conclusion

All the green manure cover crops tested suppressed the development of creeping thistle and broad-leaved dock. Field bindweed may also be suppressed in a similar manner to thistle and dock, however the establishment of this weed in this experiment was too poor to draw any firm conclusions. Buckwheat was the most suppressive cover crop in this particular experiment, closely followed by Caliente 61 and 99.

Column stocks herbicide screen

Introduction

There are a limited range of herbicides that are safe for use on column stocks produced for cut flowers, and there is a need for crop safety information on current and new herbicides for use on the newer ‘Figaro’ varieties desired by the retailers. The trial re-evaluated herbicides with approval for use in ornamental plant production; HDC H29 and Butisan S, alongside newer herbicides recently developed for brassica production such as Wing-P and Dual Gold. The newer varieties of column stocks are thought to be more susceptible to herbicide damage than the older varieties and so both were compared in the trials.

Materials and methods

The experiment was carried out on a commercial crop of column stocks (*Matteola incana*), at the Cut Flower Centre in Lincolnshire, between April and July 2013. Plants were grown in a polythene tunnel in soil which had either been steam sterilised two or three years ago. The trial was split, with two blocks in each soil treatment, so that any possible differences between the soil sterilisation timing could be noted. Two varieties were used in the trial; ‘Figaro Lavender’, which is a less vigorous variety, and ‘Fedora Deep Rose’, which is a vigorous variety. The crops were planted by nursery staff on 26 April. The trial was a fully randomised block design with seven treatments, including an untreated control (Table (stocks) 1), replicated four times. Two 38 m beds were used for the trial, with each plot measuring 2.7 m long and 1 m wide.

Table (stocks) 1. Detail of herbicide treatments applied either pre- or post-planting 2013

Treatment	Pre-planting	Post-planting	
1	Untreated	Untreated	
2	HDC H29	Butisan S	1.5 L/ha
3	HDC H29	Wing-P	3.5 L/ha
4	HDC H29	Dual Gold	0.78 L/ha
5	-	Wing-P	3.5 L/ha
6	-	Butisan S	1.5 L/ha +
		HDC H31	
7	-	Butisan S	1.5 L/ha +
		Dual Gold	0.78 L/ha

Table (stocks) 2. Approval status of herbicide treatments used on stocks 2013

Product	Active ingredient	Approval status	
		Outdoor	Protected
Butisan S	Metazachlor (500 g/L)	Approved	Not approved*
Dual Gold	S-metolachlor (960 g/L)	Approved	Not approved
HDC H29		Approved	Not approved
HDC H31		LTAEU	Not approved
Wing-P	Dimethenamid-p (212.5 g/L) + pendimethalin (250 g/L)	Approved pre planting only	Not approved

*Some metazachlor products can be used on protected crops as unlike Butisan S they do not contain a label warning stating not to use on protected crops

The site was marked out and the pre–planting treatments were applied on 25 April. The treatments were applied using an OPS sprayer and a single nozzle handheld lance, with 3.00E+80 nozzles, to achieve a medium spray quality at 400 L/ha.

Post–planting treatments were applied on 2 May, using the same sprayer and boom, to achieve a medium spray quality at 400 L/ha.

The trial was assessed for phytotoxicity on 15 May (2 WAT), 29 May (4 WAT), 11 June (6 WAT), 26 June (8 WAT) and 8 July (10 WAT). Phytotoxicity was assessed 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 crop vigour. At harvest on 9 July, plants were assessed by the grower and given a marketability score. Data was analysed by ANOVA.

Results

Wing-P had the most phytotoxic affect, with plants consistently scoring below the commercial standard of 7 (Figure (stocks) 1). HDC H29 followed by Wing-P and Butisan S + HDC H31 both had an effect on the plants, producing yellowing and some stunting. However, the plants did improve and by harvest, plants treated with Butisan S + HDC H31 were at a commercially acceptable standard. HDC H29 followed by Butisan S, HDC H29 followed by Dual Gold and Butisan S + Dual Gold had less of a phytotoxic effect and although there was some slight yellowing in the first four weeks after planting, the plants grew away from this and by harvest all three were the same quality as the untreated.

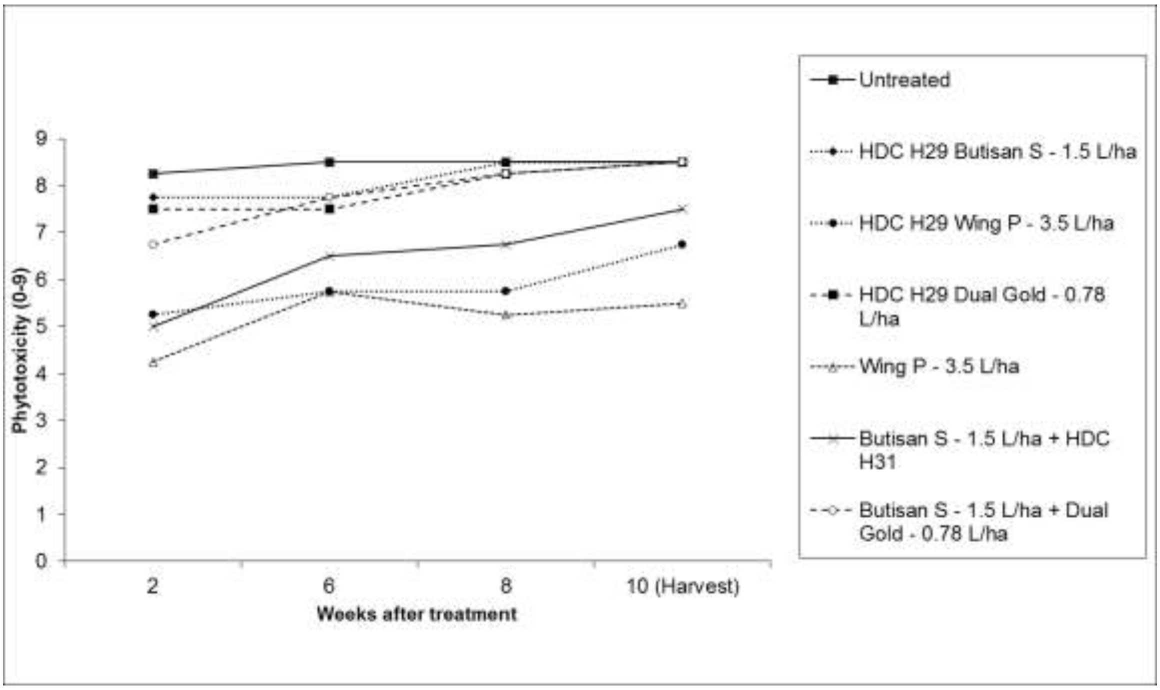


Figure (stocks) 1. Phytotoxicity scores for each treatment combined for both varieties, up until harvest 2013

Crop vigour was not greatly affected by HDC H29 followed by Butisan S or HDC H29 followed by Dual Gold, with vigour remaining similar to the untreated (Figure (stocks) 2). Crop vigour in all treatments fell slightly at six weeks after treatment, but had improved by harvest (Table (stocks) 3), this may have been due to a transient irrigation or climatic influence but does not appear to have caused a longer term effect. Plants treated with Butisan + HDC H31 had the lowest vigour score at two weeks after treatment but showed recovery and grew away from the treatment effect. Vigour was generally comparable to the untreated control except in the plots treated with Wing-P where vigour decreased in the weeks after treatment, recovering only slightly by harvest. The plots which received a pre-planting application of HDC H29 before Wing-P, showed greater vigour than those treated with Wing P alone although vigour was still significantly reduced compared with the untreated control.

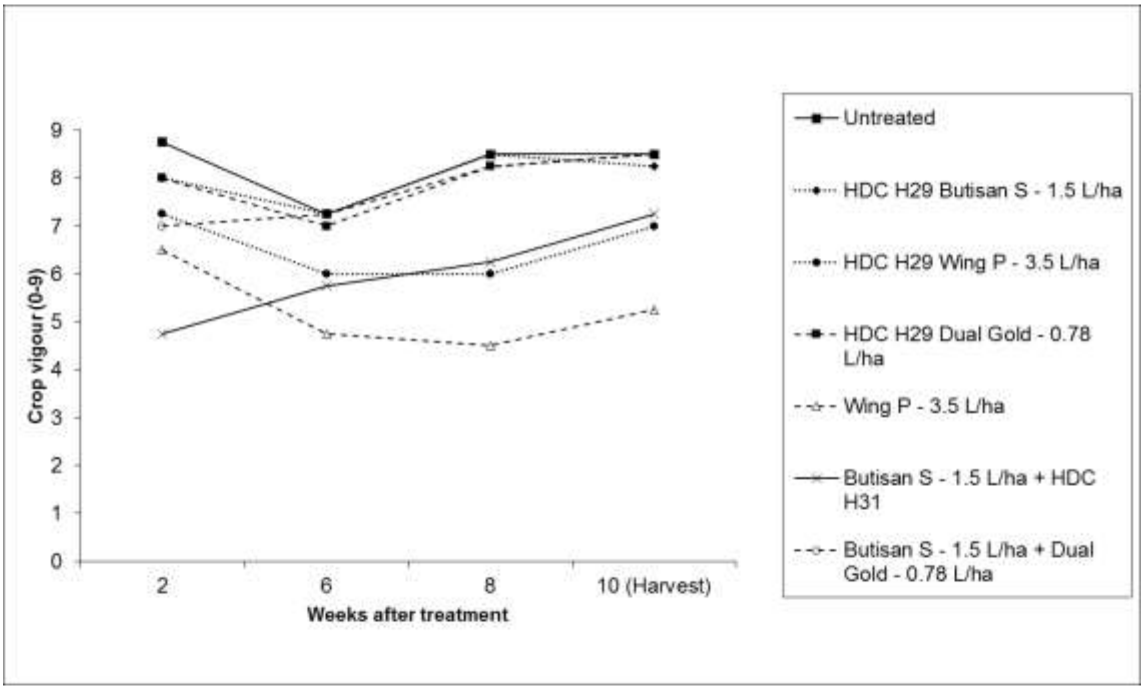


Figure (stocks) 2. Crop vigour for each treatment - both varieties combined, up until harvest 2013

Table (stocks) 3. Mean phytotoxicity and vigour for each treatment 2013 – Both varieties combined

Treatment	Phytotoxicity (0-9)	Crop Vigour (0-9)
1	8.5	8.5
2	8.5	8.3
3	6.8	7.0
4	8.5	8.5
5	5.5	5.3
6	7.5	7.3
7	8.5	8.5
F pr.	<.001	<.001
l.s.d (18 d.f)	1.11	1.15

'Fedora Deep Rose' was more vigorous than 'Figaro Lavender', 59% of the plants were recorded as marketable in the untreated plots, compared to 26% for the latter variety (Figure (stocks) 3). Where phytotoxicity symptoms were not observed, plants were scored as unmarketable mainly because they didn't reach the required height/length specification of 45 cm required by consumers, this was much more apparent in the Figaro variety and a consequence of growing in unsteamed ground. A UK grower would expect 20-30% marketable stems of Figaro in un-steamed soils and 70-80% marketable stems of Fedora in un-steamed soil in a glasshouse.

For both varieties, marketability was greatly diminished by a post-planting treatment of Wing-P, with only 8% of 'Figaro Lavender' and 25% of 'Fedora Deep Rose' suitable for market (Table (stocks) 4).

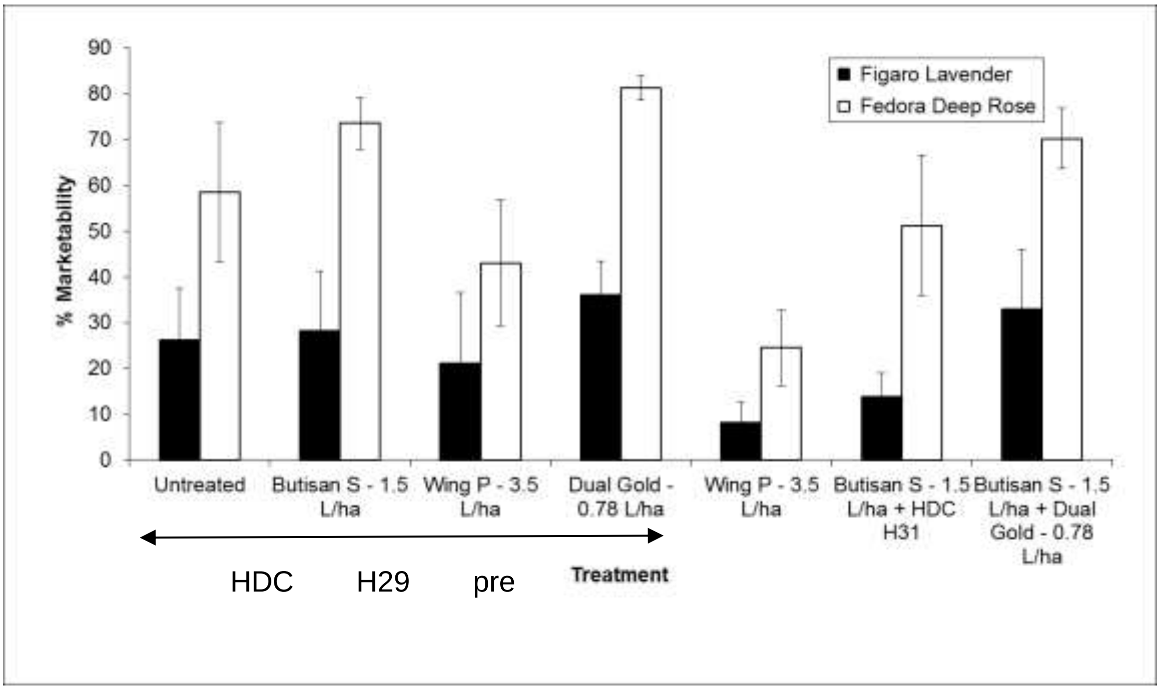


Figure (stocks) 3. Percent marketable stems of both stocks varieties at harvest 2013

Table (stocks) 4. Percentage of plants suitable for market 2013

	% marketability	
Treatment	**Figaro Lavender**	**Fedora Deep Rose**
1	26.2	58.5
2	28.2	73.5
3	21.0	43.0
4	36.0	81.2
5	8.2	24.5
6	13.7	51.2
7	33.0	70.2
F pr.	0.400	0.016
l.s.d (18 d.f)	28.56	30.85

Discussion

Results show that ‘Figaro Lavender’ does not grow well on non-steamed soil the exact reason for this is unknown but is likely to be due to some extent *Fusarium* spp effecting plant growth. ‘Fedora Deep Rose’ grew much better, which was expected being a stronger variety, and appeared better able to grow away from any phytotoxicity effects caused by some of the herbicide treatments.

The application of HDC H29 as a pre-planting treatment had little phytotoxic effect on the plants even when it was followed by a post-planting treatment of Butisan S or Dual Gold. These two treatments were not detrimental to crop vigour, and resulted in good levels of marketability.

Most plots which did not receive a pre-planting application of HDC H29 appeared to suffer more in terms of increased phytotoxicity and reduced crop vigour from the post-planting herbicide treatments than those that did. It is possible that the HDC H29 treatment may have hardened the plants and made them more resistant to subsequent herbicide applications. The exception was treatment seven, where plants treated with Butisan S + Dual Gold (without a prior HDC H29 treatment), which recovered well from early phytotoxic symptoms.

Wing-P was quite phytotoxic on its own or following a pre-planting treatment of HDC H29, reducing crop vigour. It also resulted in reduced marketability with both varieties.

Therefore, results indicate that a pre–planting treatment of HDC H29 followed by a post–planting treatment of Dual Gold and/or Butisan S appeared to be crop safe in this trial. However, caution must be advised with the use of Butisan S as damage has been known to occur in some commercial situations. During the course of the project it was announced that the approval for HDC H29 would be revoked with use up of existing stock by 30 June 2015. Alternative herbicides do not have as wide a range of activity. Herbicides found to be crop safe such as Dual Gold may need to be mixed depending on the weed spectrum at the grower site, and this product is only approved for application during May.

Conclusions

- **'Figaro' varieties grow poorly on non-steamed soil, while the stronger variety, 'Fedora Deep Rose' was able to grow away from any early phytotoxic effects.**
-
- **Dual Gold was generally safe when used as a post-planting treatment, based on the results of this one year trial. However, it is only authorised for use on crops uncovered at the time of application.**
-
- **Wing-P is too phytotoxic for use post-planting on stocks.**
-
- **Use of a pre-planting application of HDC H29 followed by an application of Dual Gold or Butisan S appeared to be crop safe with no effect on crop vigour or marketability in this trial and could be used to aid weed control without damage to the crop. However, caution should be taken with Butisan S as damage has been known to occur in some commercial situations.**

Peony herbicide screen

Introduction

Weed control within a long-lived perennial crop such as peony is a considerable challenge and, with few herbicide options available to growers, the control of perennial weeds such as creeping thistle (*Cirsium arvense*) growing within and between the rows is virtually impossible without removing them out by hand or damaging the crop. Control currently relies on directed sprays of Roundup (glyphosate) and hand removal. The objective of this project was to compare directed herbicide treatments for peonies for crop safety and control of creeping thistle.

Materials and methods

Table (peony) 1. Treatments applied to peony trial site – Winchester growers 2013

Trt no.	Treatment	Active ingredient	Rate	Approval
1	Untreated			
2	HDC H19 *	Confidential		Not approved
3	HDC H20 *	Confidential		Not approved
4	HDC H21 + adjuvant *	Confidential		Not approved
5	Dow Shield 400	Clopyralid (400 g/L)	0.5 L/ha	On label
6	HDC H30			Not approved
7	HDC H15	Confidential		Not approved
8	Callisto	Mesotrione (100g/L)	1.5 L/ha	Not approved
9	Titus	Rimsulfuron (25% w/w)	50 g/ha	Approved
10	Callisto + Titus	Mesotrione (100g/l) rimsulfuron (25% w/w)	1.5 L/ha + 50 g/ha	Not approved EAMU
11	Peak + Butryflow	Prosulfuron (75% w/w) bromoxynil (402g/l)	20 g/ha + 1.0 L/ha	Not approved Not approved[1]
12	Florasulam	Florasulam (4.54% w/w)	0.15 L/ha	Not approved[2]

*** Applied twice, initially same timing as the other treatments then again 14 days after**

[1]Approved post flower harvest for bulbs

[2]Similar product Barton has an EAMU for use on outdoor ornamentals

The trial site was selected in a peony field with a known high thistle population at Winchester Growers, Pinchbeck. A fully randomised block design with 12 treatments including an untreated control replicated three times was laid out. The peonies were grown in 75 cm rows with 45 cm between plants within the row. Plots consisted of 1 m length of row, with treatments applied up to the base of the crop on either side giving a width of 3 m. Plots were selected to ensure that the thistle population was as uniform as possible within a block, this meant that individual blocks were not situated directly next to one another. Data was analysed by analysis of variance.

No other herbicides were applied by the Winchester Growers staff on the plot areas, however the alley ways were mowed as is the routine to allow for harvesting. Other routine treatments (insecticides and fungicides) were applied as normal.

The first treatment was applied on the 2 May 2013 when thistles were at the rosette stage and were approximately 10-15 cm across. Treatments two, three and four were applied twice, with the second application on the 22 May 2013. Treatments were applied using a handheld lance sprayer with spray boards used to shield the peonies from the herbicides. In block three the peonies were deliberately over sprayed with each treatment to determine crop safety. This was done at the second spray timing. All treatments were applied at 400 L/ha water volume with a medium spray quality.

Prior to the treatment application the thistle population was recorded in each plot recording the number and percent cover of thistles per plot. Assessments were made approximately two, six and 12 weeks after the first treatment application. At each recording date, phytotoxicity symptoms on the crop were recorded on a 0-9 scale where 9 is no effect, 7 is commercially acceptable, 1 is a very severe effect and 0 is complete kill of the crop.

Thistle control was assessed by recording percentage cover at two, six and 12 weeks after treatment. Thistle vigour was also recorded on the six weeks after treatment assessment to capture the sub lethal herbicide effects on the thistle that were being observed.

Results

Table (peony) 2 shows average percentage thistle cover by treatment over the course of the trial. No one treatment stood out as giving a high level of thistle control, and the level of thistle was variable between plots although to some extent this could be mitigated by the pre-treatment assessment made for each plot. Up to six weeks after treatment HDC H30 appeared to be having some effect on thistle growth. 12 weeks after treatment Dow Shield 400, Peak + Butryflow, HDC H15 and HDC H30 showed the lowest percentage thistle cover per plot on average.

Table (peony) 2. Average percentage thistle cover per plot through the duration of the trial – Winchester growers 2013

	Average percentage thistle cover				
Treatment	**Pre trial**	**2WAT**	**4WAT**	**6WAT**	**12 WAT**
Untreated	2.89	7.83	25.00	36.67	18.33
HDC H19	3.67	15.33	32.50	44.17	26.67
HDC H20	3.39	10.00	19.17	27.50	19.17
HDC H21	4.98	14.50	16.50	23.17	24.17
Dow Shield 400	6.07	16.67	21.67	29.17	11.67
HDC H30	3.61	12.83	12.50	19.17	15.33
HDC H15	3.05	12.50	28.67	34.50	16.67
Callisto	4.85	20.83	53.33	56.67	35.83
Titus	3.36	15.83	32.50	40.83	34.17
Callisto + Titus	3.67	18.67	28.33	39.17	27.50
Peak + Butryflow	4.57	13.67	22.00	20.33	15.00
Florasulam	2.43	12.83	20.50	28.33	19.17
p value (21df)	**0.040**	**ns**	**0.011**	**0.071**	**ns**
p value pre-trial values as a covariate	**-**	**ns**	**ns**	**0.056**	**ns**
LSD	**1.973**	**7.307**	**18.340**	**23.420**	**19.680**

Table (peony) 3 shows the increase in percentage thistle cover through 12 weeks for all treatments. This shows Dow Shield 400, Peak + Butryflow, HDC H15, HDC H30 and HDC H21 to be the treatments that restricted the development of thistle cover the most. However, once again the very variable stand of thistles skews this data so that clear conclusions are not possible to draw.

Table (peony) 3. Averaged percentage increase in thistle cover – Winchester growers 2013

	% increase 2 WAT	% increase 4 WAT	% increase 6 WAT	% increase 12 WAT
Untreated	4.94	22.11	33.77	15.44
HDC H19	11.66	28.83	40.50	23.00
HDC H20	6.61	15.78	24.11	15.78
HDC H21	9.52	11.52	18.19	19.19
Dow Shield 400	10.60	15.60	23.10	5.60
HDC H30	9.22	8.89	15.56	11.72
HDC H15	9.45	25.62	31.45	13.62
Callisto	15.98	48.48	51.81	30.98
Titus	12.47	29.14	37.47	30.81
Callisto + Titus	15.00	24.66	35.50	23.83
Peak + Butryflow	9.09	17.43	15.76	10.43
Florasulam	10.41	18.07	25.91	16.74
P. value	ns	0.009	0.055	ns 0.218
LSD (11df)	6.872	17.19	21.75	19.06

Thistle vigour was assessed on two occasions.

Table (peony) 4. Average thistle vigour scored on a zero to nine scale – Winchester growers 2013

	Thistle vigour 0-9 scale (0 = dead, 9 = healthy)	
Treatment	**2 WAT**	**4 WAT**
Untreated	9.00	8.33
HDC H19	8.00	7.67
HDC H20	8.00	6.00
HDC H21	6.67	3.67
Dow Shield 400	6.00	7.00
HDC H30	6.33	6.67
HDC H15	6.33	6.33
Callisto	7.33	8.00
Titus	7.00	6.67
Callisto + Titus	6.67	6.00

	Thistle vigour 0-9 scale (0 = dead, 9 = healthy)	
Treatment	**2 WAT**	**4 WAT**
Peak + Butryflow	5.67	5.67
Florasulam	7.00	6.00
p value	**0.052**	**0.079**
LSD (11 df)	**1.87**	**2.557**

Phytotoxicity was assessed in one of the three blocks by spraying the herbicides over the crop and assessing crop damage on three occasions, results are shown in Table (peony) 5.

Table (peony) 5. Crop phytotoxicity scored on a zero to nine scale. Treatments applied to one block only, not replicated – Winchester growers 2013

	Crop Phytotoxicity 0-9 scale (0 = dead, 9 = healthy)		
Treatment	**4 WAT**	**6 WAT**	**12 WAT**
UTC	9.00	9.00	9.00
HDC H19	8.00	9.00	9.00
HDC H20	7.00	8.00	9.00
HDC H21	2.00	1.00	2.00
Dow Shield 400	6.00	7.00	7.00
HDC H30	5.00	4.00	8.00
HDC H15	6.00	5.00	7.00
Callisto	7.00	6.00	7.00
Titus	9.00	6.00	7.00
Callisto + Titus	7.00	5.00	5.00
Peak + Butryflow *			
Florasulam	8.00	7.00	9.00

- ***It was not possible to collect phytotoxicity data for this treatment as the plot was damaged by farm machinery**

Discussion

Due to the very dense and locally variable stand of thistle within and between plots, a clear interpretation of the results is difficult. It appears that no treatment significantly reduced thistle to an acceptable level. The commercial standard Dow Shield 400, HDC H15, Peak + Butryflow, HDC H30 and HDC H21 all reduced the level of thistle to some extent.

All but Callisto, HDC H19 and to a lesser extent Dow Shield 400 caused some reduction in thistle vigour compared with the untreated control.

The HDC H21 treatment produced the greatest level of damage on the thistle causing browning and die back of tissues.

HDC H21 and Callisto + Titus caused the most lasting damage to the crop, causing necrosis and chlorosis to the peony foliage respectively. All other treatments caused only transient effects and the crop was commercially acceptable at 12 weeks after treatment.

Conclusions

- **No one treatment reduced thistles to an acceptable level. However, Dow Shield 400, HDC H15, Peak + Butryflow, HDC H30 and HDC H21 all gave some control of thistle.**
-
- **Of the treatments that gave the best control of thistles, Dow Shield 400 was the least damaging to the peony crop. HDC H21 and Callisto + Titus caused the most lasting damage to the peony foliage, causing necrosis and chlorosis respectively.**
-
- **Further herbicide screening is required to help develop strategies for effective thistle control in this crop.**
- **Hot foam applications in horticulture: scoping trials**

Introduction

The continuing loss of herbicide approvals means that growers are having to look for alternative options to attain weed control, especially if they wish to avoid the costly and timely process of hand weeding. This experiment explored the possibility of using Foamstream to control weeds in three different horticultural situations. Foamstream is a new thermal weeding technology which has been developed for weed control in the amenity sector. The technology works by denaturing proteins and destroying enzymes within plant tissues using hot water with foam. The natural foaming agents provide an insulating layer to retain heat for longer and provide a greater level of weed control.

Trials were carried out in summer 2013 to investigate the potential of using Foamstream technology in three different horticultural situations; hardy nursery stock, strawberries and organic field vegetables. For each situation the host grower was consulted on where the

Foamstream technology may be of most use in their sector and this was used to help decide upon areas for treatment.

Materials and methods

Trials were carried out on three different sites. Darby Nursery Stock (Broad Fen Site) hosted the hardy nursery stock trial. H&H Duncalfe hosted the strawberry trial (varieties included 'Sonata' and 'Fenalla'). Stephen Briggs (Whitehall Farm) hosted the organic field vegetables. Vegetables used to trial the new technology included brassicas (calabrese) and leeks.

At each site, assessments of weed species, size, and percentage cover were made pre-treatment. Treatments were applied on 25 and 26 July 2013. Time taken to apply treatment and size of area were recorded. Trials were assessed one, two, four and six weeks after treatment. Weed species, size, and percentage cover were all recorded.

Hardy Nursery Stock

Treatments were applied to pot standing areas outdoors, in polytunnels and in glasshouses. The pots were stood on sand, gravel and mypex. Foamstream was also sprayed over empty beds and in, around and over container-grown plants. Treatments were focussed on liverwort and small annual weeds.

Strawberries

Strawberries were grown on raised soil beds with polythene covering. The treatment was applied to the alleyways to annual weeds, perennials and strawberry runners between beds. There were two different aged crops and a non-cropped area that were treated. One was an established crop post-harvest, where Foamstream was used for runner control. The second was a newly planted crop, Foamstream was used here for general weed control. The headland area was also treated for general weed control. Crop safety was assessed.

Organic field vegetables

Inter-plant and inter-row application was applied to control annuals and perennial weeds which cannot be mechanically removed. Foamstream was applied to both the non-cropped and cropped area in the calabrese. Treatment was applied within rows for leeks and the headland plot was also treated.

Results

<u>Hardy Nursery Stock</u>

Trial area 1 – Outdoor sand bed

This started off with 95 % weed coverage (Figure (Foamstream) 1). Treatment was applied on 25 July 2013. Very impressive levels of weed control could be seen one week after treatment. Liverwort (*Marchantia polymorpha*) was killed. Spore heads and leaves turned brown. Percentage weed cover for the treated was less than 1 % compared to 95 % weed coverage for the untreated control. Two weeks after treatment the liverwort was dead and brown, however some regrowth had occurred towards the back of the bed. Four weeks after treatment, liverwort was re-growing and weed coverage was back up to 30 % in the treated area although still substantially reduced compared to 100 % for the untreated area. Six weeks after treatment liverwort showed vigorous regrowth. Shepherd's purse (*Capsella bursa-pastoris*) and sow thistle (*Sonchus oleraceus*) were also noted. The treated area reached 40% weed coverage but this was still considerably lower than the 100% weed coverage observed in the untreated control.

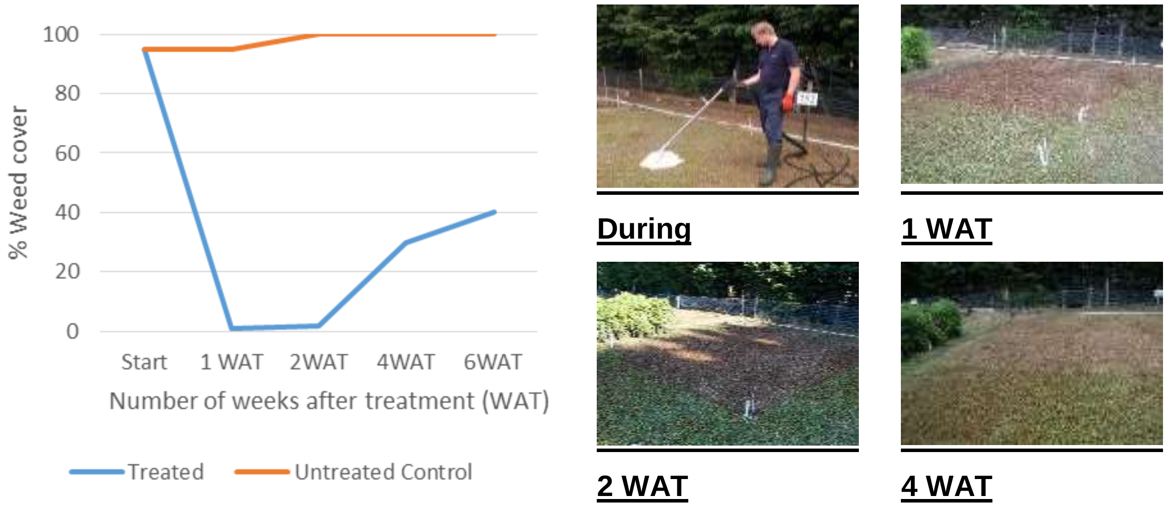


Figure (Foamstream) 1. Change in percentage weed cover for treated and untreated control for empty sand bed over 6 weeks, images of the treated area over the course of the trial. Weeks after treatment (WAT)

Trial area 2 - Prunus pendula rubus - Tree standing area - poly bag pots

At the start of the trial the tree standing area had 100% coverage of liverwort and moss and a few broad leaved weeds including coltsfoot and groundsel. After one week liverwort had been reduced to less than 1% (Figure (Foamstream) 2). The untreated control remained at 95% weed coverage. Six weeks after treatment there was 50% weed coverage on the treated plot and 90% weed coverage on the untreated control. The liverwort and moss regrowth was rapid. No effect was observed to the pots or plants.

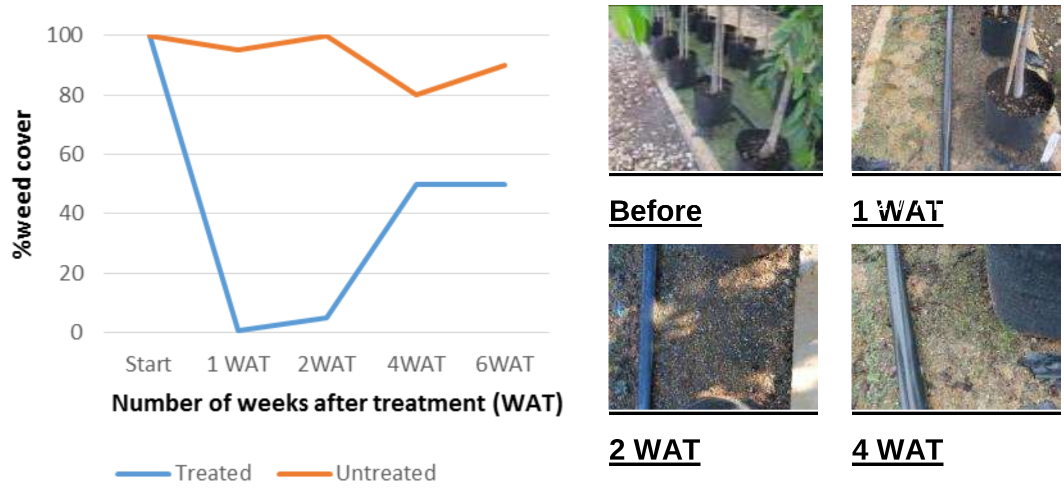


Figure (Foamstream) 2. Change in percentage weed cover for treated and untreated control for tree pot standing area over 6 weeks, images of the treated area over the course of the trial. Weeks after treatment (WAT)

Trial Area 3 - Empty bay, prepared sand bed

This area had been cleared of pots, skimmed and had received a treatment of Jet 5 and Flexidor 125, the aim of treating this area was to see if any additional benefit of the hot foam was possible in terms of algal control assessed by recording percentage surface area showing algae. At the beginning of the trial there was 5% liverwort coverage and 1% sow thistle coverage. One week later there was clear sand, zero weed coverage for the treated plot compared to 40% weed cover for the UTC (Figure Foamstream 3). Six weeks later 5% weed cover was observed for the treated plot compared to 15% weed cover on the UTC and there appeared to be less algal growth over all.

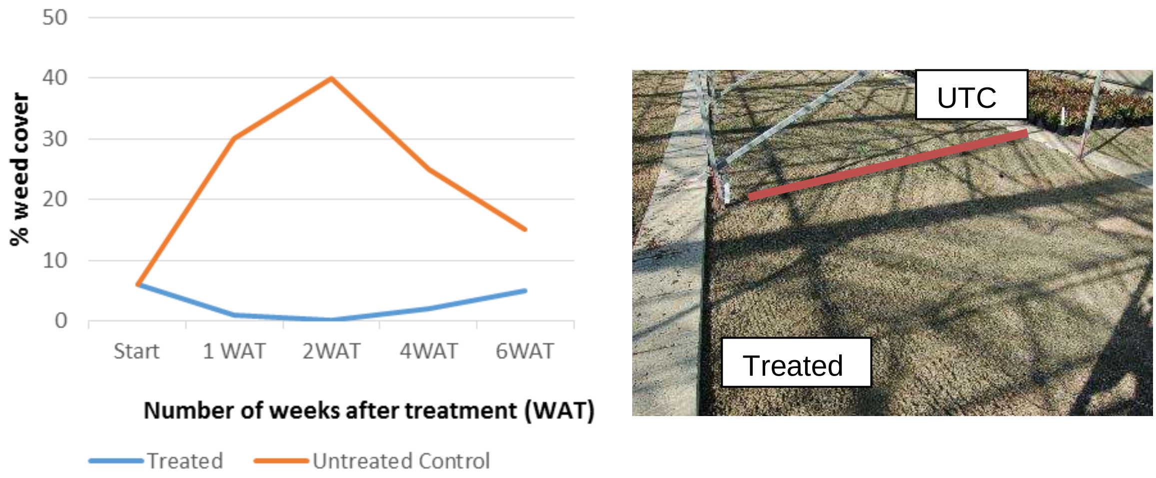


Figure Foamstream 3. Change in percentage weed cover for treated and untreated control for an empty sand bed bay in a glasshouse over 6 weeks, image of plot 4 weeks after treatment (untreated area above the red line)

Trial area 4 - Mypex beds in glasshouse

These again were cleared beds. Prior to treatment there was less than 1% liverwort coverage (Figure (Foamstream) 4). Four weeks later there was slightly more liverwort and moss on the untreated control compared to the treated plot. Six weeks later the trial area was filled with pots and there was slightly less new liverwort and moss regrowth for the treated area compared to untreated control but the difference was slight.

Figure (Foamstream) 4. Change in percentage weed cover for treated and untreated control for an empty Mypex covered bed in a glasshouse over 6 weeks

<u>Strawberries</u>

Amelia field – 'Sonata' - headland plot

The headland plot had a very high percentage cover of weeds prior to treatment (Figure (Foamstream) 5). Creeping thistle, shepherds purse and annual meadow grass (*Poa annua*) each had 25% coverage prior to treatment. One week later there were no weeds on the treated plot, whereas 90% remained on the UTC. By 6 WAT percentage weed coverage had increased to 20%. Weeds present included: thistles, fine grasses, cow parsley (*Anthriscus sylvestris*), annual meadow grass and small nettle (*Urtica urens*). This was considerably less than the untreated control which had 60% weed coverage. The untreated control was largely infested with common poppies (*Papaver rhoeas*).

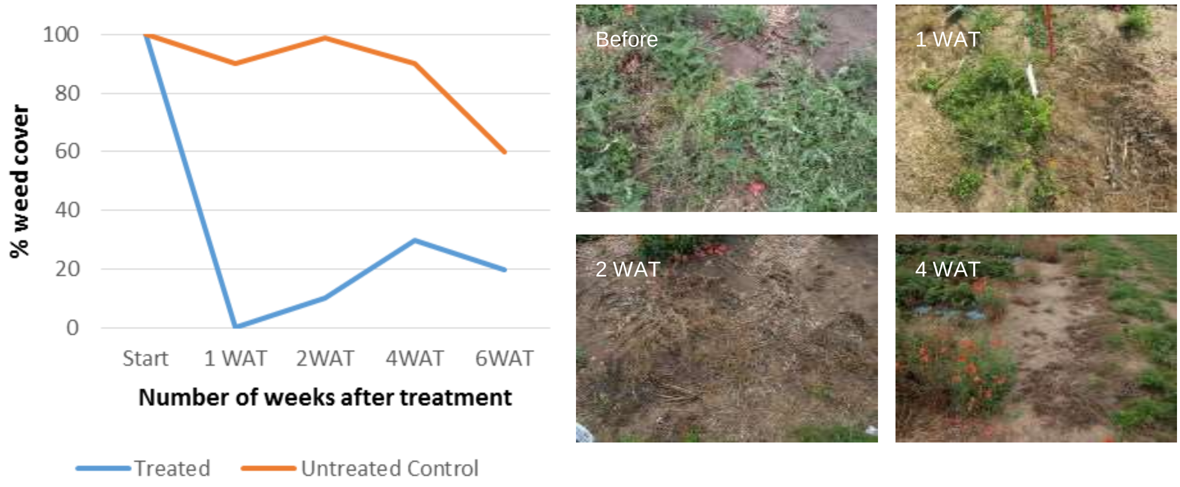


Figure (Foamstream) 5. Change in percentage weed cover for treated and untreated control for the strawberry headland plot, over six weeks

Strawberry alley way treatment over straw – Sonata mainseason

Prior to treatment this plot had a total of 20% weed coverage (Figure (Foamstream) 6). One week later this had decreased to zero weed coverage. This could be compared to 30% weed coverage in the untreated control. Six weeks after treatment weed cover had only crept up to 5% in the treated plot, whereas the untreated control had 50% weed coverage. In the treated plot, runners were controlled and there was also good control of cereals, shepherds purse, small nettle, common poppy and wild oats (*Avena fatua*). Three plants were treated one over the top and two around the base. There was some recovery from the treated plants, one cut crown (plant treated over the top) showed some vascular staining.

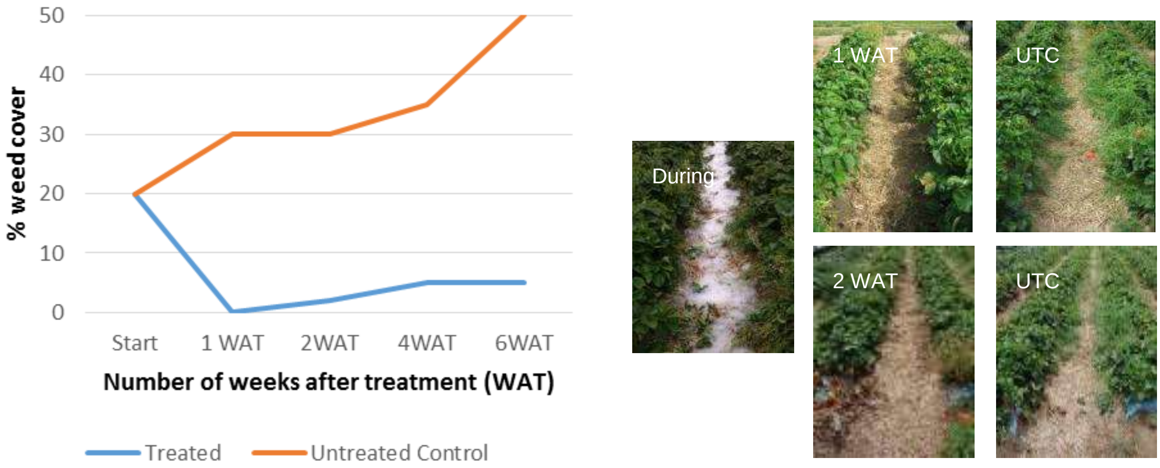


Figure (Foamstream) 6. Change in percentage runner cover for treated and untreated control for inter row strawberry treatment over straw, over 6 weeks

Strawberry alley way treatment over soil 'Fenella' – 60 day crop planted June

Prior to treatment plots had 13% weed coverage (Figure (Foamstream) 7). One week later the treated plot was left with 1% weed coverage and weeds were dead where they had been treated. After four weeks weed coverage remained at 1%. The untreated control had 50% weed coverage. At six weeks there was no weed coverage for the treated plot and 40% weed coverage for the untreated control. Unfortunately no effect was observed on groundsel seed which began germinating two weeks after treatment.

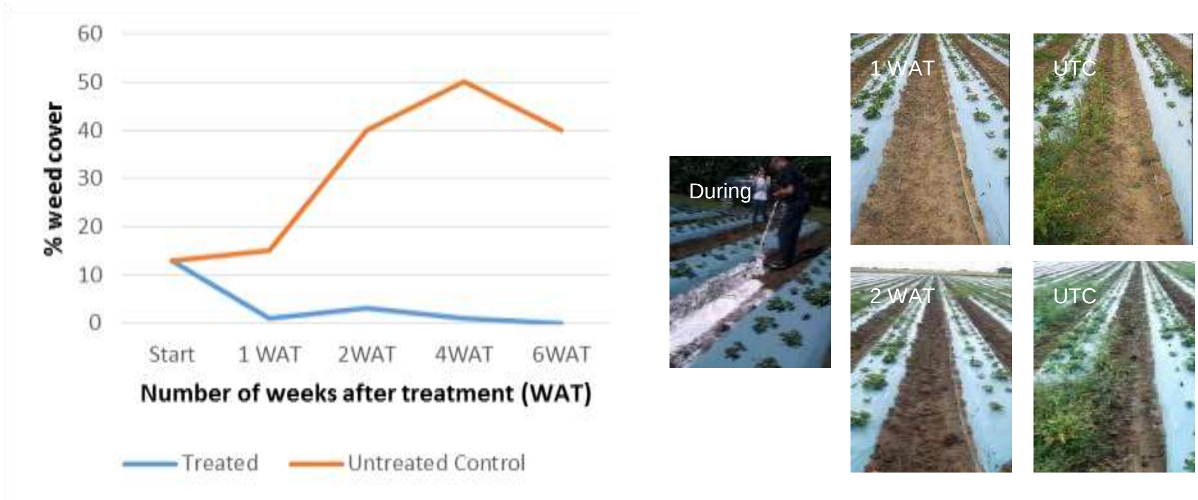


Figure (Foamstream) 7. Change in percentage weed cover for treated and untreated control for Strawberry alleyway treatment over soil over 6 weeks.

<u>Organic Field Vegetables</u>

Brassica field - non cropped area

This area started off with 30% weed coverage (Figure (Foamstream) 8). One week after treatment this had been reduced to 1% weed coverage in the treated area compared to 40% in the untreated control. After four weeks weed coverage had increased to 40% in the treated area and 90% in the untreated control.

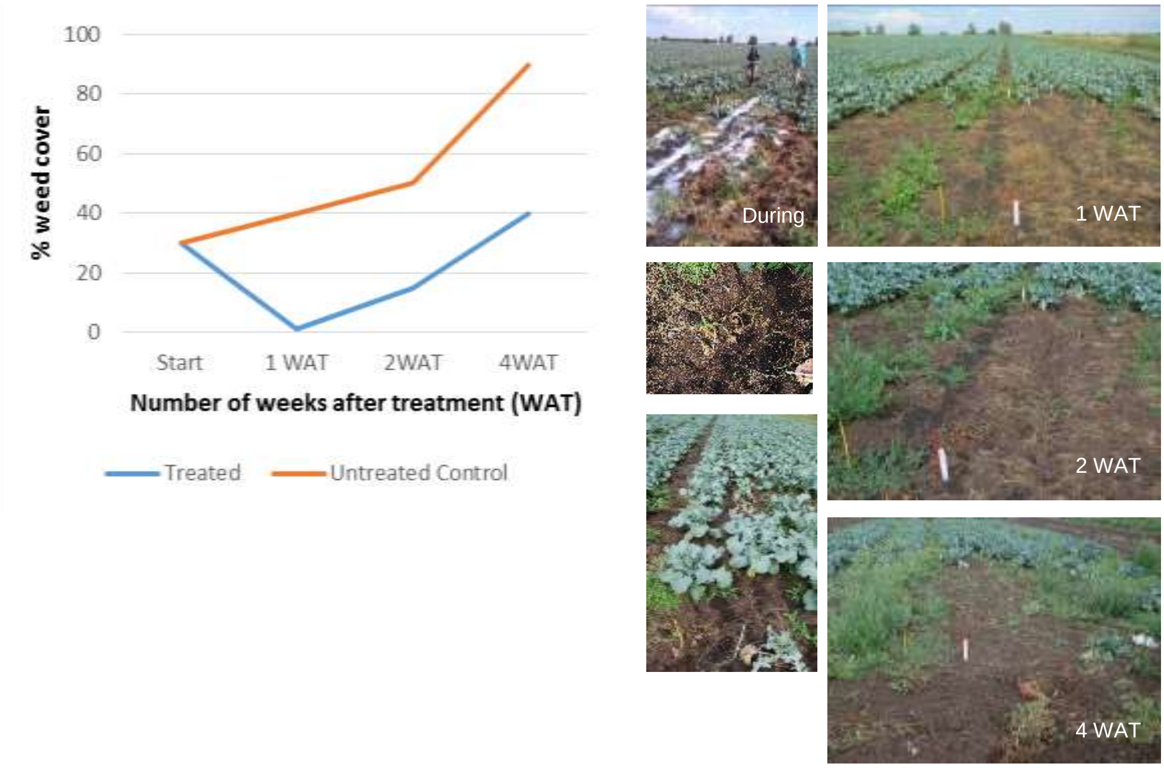


Figure (Foamstream) 8. Change in percentage weed cover for treated and untreated control for brassica field, non-cropped area, over 6 weeks.

<u>Brassica field - calabrese in situ</u>

This plot had 35% weed coverage prior to treatment (Figure (Foamstream) 9). One week after treatment this decreased to 10%, two weeks after treatment there was 20% weed coverage and by four weeks this had risen to 30% weed coverage. This was half the percentage of weed coverage relative to the untreated control (60%). The foam controlled polygonums, fat hen (*Chenopodium album*) and creeping thistle. Weed control was good, however where the hot foam flowed close to the calabrese some crop damage was observed.

Figure (Foamstream) 9. Change in percentage weed cover for treated and untreated control for brassica field calabrese, in situ, over 6 weeks. Image of crop damage observed

Leek field - leeks in situ

Weed coverage in the leek field started off at 60% (Figure (Foamstream) 10), at one WAT this had declined to 40% coverage for the treated area, whereas the untreated control had 75% weed coverage. Better control was not achieved because it was not possible to contact all weeds in and around the leeks without harming the leeks. After four weeks weed coverage on the treated area had risen to 50%. However, this was much lower than the UTC which had 95% weed coverage.

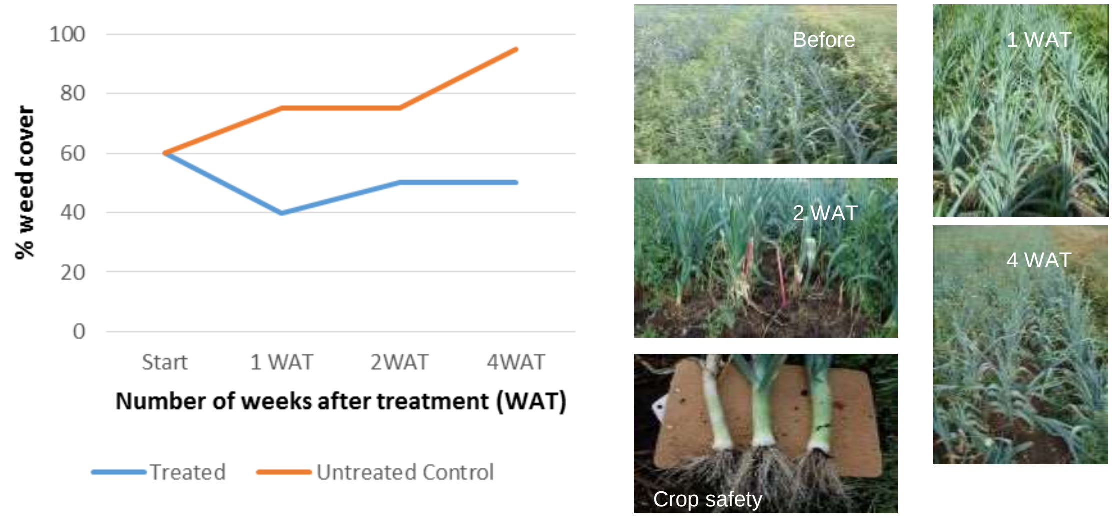


Figure (Foamstream) 10. Change in percentage weed cover for treated and untreated control for leek field, leeks in situ, over four weeks.

Discussion

Hardy nursery stock

Foamstream provided very effective weed control for up to four weeks controlling virtually all weed, moss and liverwort species it came in contact with. The water and foam flowed well around the pots and caused no damage to pots or the plants contained within them. The speed of knock down and the ability to use the technique in any weather coupled with the good environmental and health and safety credentials of the technique meant that the host grower was very keen to replace any conventional herbicide with this equipment. However, Foamstream lacked persistence, and was slower than conventional spray systems to apply. Changes that could help improve the product would include a lance head that was adaptable to the situation i.e. a narrower head. The equipment also needed to be improved by making the flow of foam adjustable. A faster flow of foam could be used to increase speed of application and reduce labour cost. Finally, if the equipment could be downsized a smaller version would be more suitable to treat smaller areas as small and medium sized nurseries wouldn't have large enough bed areas for the current sized equipment. From conversation with our host grower if the cost of application was similar to or less than hand weeding (£6.93/hour) then he would be interested in trialling it on a larger scale in combination with the use of residual herbicides.

Strawberries

Foamstream provided very effective weed control up to four weeks. However by six weeks there were many annual weeds germinating in the Foamstream treated area and also thistles, fine grasses and cow parsley re-growing from rhizomes. There were still however many more weeds in the untreated rows than in the treated. For the inter-row area treatment, application of Foamstream caused runners to immediately wilt and provided good control of weeds. After six weeks no regrowth from the runners was observed. The Foamstream also offered good control of cereals, shepherd's purse, nettle, poppy and wild oats. There was some recovery from the deliberately treated strawberry crop plants, the plant where the hot foam was applied directly over the crown was cut open and showed some vascular staining and a corky outer cuticle but overall remained a fairly healthy looking. This could mean that Foamstream has potential as a dormant season treatment or even as a post-harvest treatment to the crop.

The comment from the host grower was that the technology killed the weeds present regardless of species or size, however it would need repeating regularly, therefore either a lower dose or higher speed would be required, or the incorporation of a residual herbicide into the programme. This could be in the water used for the treatment (however there would probably be too many legislative hurdles even if the chemical was unaffected by temperature), or more likely by a separate pass with an inter-row sprayer. Using the latter method, then the Foamstream application cost would have to be less than the cost of the contact herbicide to be appealing for growers. To make this technology into a commercially viable operation, the steam boiler, tanks, mixer etc. would need to be tractor mounted. The rig would need to be capable of covering at least 1.5 ha/hour and filling time should be included in this. It should be automated to provide for one man operation.

For soft fruit the rig would need to be of a size and weight to make it capable of being handled by an 80 bhp. tractor and the outfit be manoeuvrable enough to facilitate easy turning at the headland.

The grower had concerns over the weight and bulk of a machine capable of producing the required output, as well as the fire risks associated with having a large heat source on a moving tractor, at times in dry conditions. Despite these reservations it was felt that the system was useful giving immediate results and no toxicity and would have a place in organic and amenity situations.

Organic field vegetables

For the brassica field, a similar general pattern was observed - the Foamstream worked very well killing some fairly large weeds including polygonums, fat hen and creeping thistle.

For the brassica field with the calabrese in situ, the foam flowed nicely around the crop plants but needed careful application to ensure treatment reached all the surrounding weeds. Initially most of the weeds in the treated plot were killed but by six weeks there were quite a few species of weeds that were germinating. There was also some damage to the calabrese where the plants were treated close around the base, about 10% of plants were stunted or killed by the treatment.

In the leek field, it was hard to get between leeks because of the spacing and so as a result weeds remained within the rows un-touched.

In both vegetable situations the equipment was not really at a stage to be able to make a good comparison with standard methods, but there was an impressive level of knock down of a large and dense weed population. The crop damage observed is a concern and tractor mounting and speed of application would need to be improved.

Conclusions

- **Foamstream provided immediate weed control of all the species tested and it can be used in any weather, with no associated toxicity or residues. However, weed control was not long lived for thistles, liverwort and it had no effect on surface germinating seeds (four to six weeks).**
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- **Investigation of optimal timing and integration with herbicide programmes could make this a very useful tool as herbicide options become more limited. In the longer term, adaptations to flow rates and application equipment would be necessary to commercialise it for intensive horticulture.**

Knowledge and Technology Transfer

- **Presentation on narcissus weed control to SW narcissus growers forum 22 May 2013 (Jessica Sparkes).**
- **Presentation to stocks cut flower growers CFC 1 August 2013 (Angela Huckle).**
- **Presentation to Vitacress Ltd weed control in wild rocket 12 July 2013 (Angela Huckle).**
- **Presentation at European Weed Research Society conference Turkey June 2013 (Lynn Tatnell).**
- **Presentation at HDC Studentship/Fellowship conference 10 September 2013 (Harriet Roberts).**
- **Data from fellowship nursery stock experiments included in container-grown nursery stock weed control workshops 2, 10, 30 October, 28 November 2013 (John Atwood and David Talbot).**
- **Presentation to amenity weed forum 11 and 20 February 2013 – electric weed control and Foamstream applications in commercial horticulture (Harriet Roberts).**

Appendices

Training logs 2013-14

Angela Huckle

Date	Training activity	Trainer
5/6/13	ADAS Boxworth Open Day – demonstration of SCEPTRE and fellowship trials.	Various (ADAS)
12/7/13	Presented wild rocket trials data at Vitacress salads. Weed control in outdoor leafy salads – update on trials work, discussion of problems and priorities, farm walk which covered weed ID, understanding of growing systems and weed control issues.	Various (ADAS and Vitacress, Graham Clarkson, Shaun Clarkson, David Lindley and Andy Elworthy)
25/6/13	Attended and presented at the asparagus growers' agronomy day – update on international growing systems, diseases, farm walk covering growing and harvesting systems and weed control. Pesticide availability update.	Jon Barfoot, John Bakker (Michigan Advisory Board), Viv Powell, Andy Allen, Nathan Dellicott, Neil Cairns, and Dr Robert Simmons
27/6/13	Attended and presented at the SCEPTRE weed open day on the SCEPTRE vegetable weed control trials carried out in association with ABC.	Cathy Knott and Andy Richardson
2/7/13	NIAB salads open day.	Jerry Knox, Dr Rob Simmonds, Syngenta
1/8/13	Attended and presented the results of the Fellowship stocks herbicide screen at the cut flower open day.	
2/10/13	British Carrot Growers Event, range of sprayers and techniques demonstrated.	Various
10/10/13	Elsoms Seeds Brassica Open Day, demonstrated SCEPTRE disease trial.	
12 – 14/11/13	Attended PowerPoint presentation training session.	Chris Bowerman

Date	Training activity	Trainer
12/12/13	Attended and presented at RDPE workshop on salad residue reduction.	
28/1/14	RDPE workshop on cultivations, soil and nutrient management in brassicas including cover crops.	Ken Smith and Clive Rahn

Harriet Roberts

Date	Training Description	Trainer
12/7/13	Weed control in outdoor leafy salads – update from Angela on trials work, discussion of problems and priorities, farm walk which covered weed ID, understanding of growing systems and weed control issues.	Vitacress, Wiltshire
Spring Summer	Regularly shadows agronomy visits to soft fruit holdings with colleagues.	John Atwood and Janet Allen
Autumn /winter2013	Attended RDPE workshop events on rhubarb, raspberry, asparagus, stone fruit production this autumn – included sections on weed control.	Various
10/9/13	Presented the fellowship results at the HDC studentship conference.	
11/2/14	Presented novel weed control trial results to the amenity forum.	

Jessica Sparkes

Date	Training activity	Trainer
14-15/03/13	Field vegetable visits – brassica.	Mark Tinsley
1-2/05/13	Technical writing.	Various speakers
22/05/13	HDC Narcissus Technical Seminar.	Various speakers

<u>David Talbot</u>

Date	Training activity	Trainer
12/07/13	Training visit to Vitacress, Wiltshire to discuss 2013 trials and problem weeds, view production systems and the scale of production.	Angela Huckle
10/09/13	Attended HDC Fellowship conference.	Various
02/10/13	Presented results from fellowship trials at HDC Weed control workshop.	John Atwood
04/12/13	Fellowship meeting to discuss outcomes of 2013 work and plan 2014 work.	John Atwood