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 086
Project leader:	John Atwood, ADAS UK Ltd.
Report:	Final report, March 2016
Previous report:	March 2015
	John Atwood, Project leader
Fellowship staff:	Lynn Tatnell, Assistant project leader
(“Trainees”)	Harriet Roberts, (fruit) project management (Apr 2011 – Sept 2015) Maria Tzortzi, (weed biology) David Talbot, (ornamentals) Angela Huckle, (vegetables) project management (Oct 2015 - Mar 2016)
Location of project:	ADAS Boxworth
Date project commenced:	April 2011
Date project completed (or expected completion date):	March 2016

DISCLAIMER

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AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

John Atwood

Principal Horticultural Consultant

ADAS UK Ltd

Signature Date: 14 March 2016

Report authorised by:

Dr Barry Mulholland

Head of Horticulture

ADAS UK Ltd

Signature ... .. Date: 14 March 2016......................

CONTENTS

Progress against Objectives

Objectives

Objective	Original Completion Date	Actual Completion Date
1. To develop and mentor 4 staff in weed biology and control	March 2016	March 2016
1.1 Train next generation horticulture consultants with an expertise in weed control	March 2016	March 2016
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	March 2016 Completed but moved to other posts
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
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	March 2013
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

Objective	Original Completion Date	Actual Completion Date
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 5 problems.	Sept 2014	March 2016
1.11 Drafted HDC Project Reports on at least 2 projects.	Sept 2013	Sept 2013
1.12 Submitted to HDC or elsewhere at least 3 proposals on R&D topics supported by growers.	March 2014	Dec 2013
1.13 Drafted an HDC Factsheet on biology and control of specific weed species of horticultural crops in specialist work area.	March 2013	Non chemical control of perennial weed review completed Sept 2015
1.14 Delivered at least 3 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	March 2016
2.1.1 1st pot screening for horticulture weeds set up	Oct 2011	May 2012 (1st set) Feb 2013 (2nd set)
2.1.2 1st pot screening completed	Aug 2012	March 2013
2.1.3 2nd pot screening for horticulture weeds set up	Oct 2014	May 2014
2.1.4 2nd pot screening completed	Aug 2015	Aug 2014
2.2.1 1st container plant screening trial set up	Oct 2012	July 2012
2.2.2 1st container plant screening trial completed	Sep 2013	Nov 2012
2.2.3 2nd container plant screening trial set up	Oct 2013	June 2013

Objective	Original Completion Date	Actual Completion Date
2.2.4 2nd container plant screening trial completed	Sep 2014	Nov 2013
2.2.5 3rd container plant screening trial set up	Oct 2015	June 2014
2.2.6 3rd container plant screening trial completed	Sep 2016	Nov 2014
2.3.1 1st Tree field herbicide trial set up	April 2012	April 2012
2.3.2 1st Tree field herbicide trial completed	June 2013	Sept 2013
2.3.3 2nd Tree field herbicide trial set up	April 2013	Replaced with herbicide trial in stocks for cut flowers completed Sept 2013
2.3.4 2nd Tree field herbicide trial completed	June 2013	Replaced with herbicide trial in stocks for cut flowers
2.4.1 1st vegetable herbicide trial set up	May 2013	March 2013
2.4.2 1st vegetable herbicide trial completed	Aug 2013	Sept 2013
2.4.3 2nd vegetable herbicide trial set up	May 2014	May 2014
2.4.4 2nd vegetable herbicide trial completed	Aug 2014	Aug 2014
2.4.5 3rd vegetable herbicide trial set up	May 2015	May 2015
2.4.6 3rd vegetable herbicide trial completed	Aug 2015	Aug 2015
2.5.1 Top fruit herbicide trial set up	April 2015	March 2015
2.5.2 Top fruit herbicide trial completed	Sept 2015	October 2015
2.6.1 Ground cover trial set up	April 2013	April 2013
2.6.2 Ground cover trial completed (Living mulch in Apple)	Aug 2015	October 2015
2.7.1 Perennial weed trial set up (initial pot tests)	March 2013	April 2013
2.7.2 Perennial weed trial completed (blackcurrant cover crop)	Sept 2015	Sept 2015

Objective	Original Completion Date	Actual Completion Date
3. Set up a working group within the European Weed Research Society	March 2012	Group of contacts identified March 2016

Summary of Progress

A training programme has continued in 2015 with specific technical training. As the remaining trainees are now experienced and BASIS qualified, training has switched from more formal training events to individual coaching on specific aspects of the job. For Angela Huckle 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 Angela Huckle and David Talbot have been able to plan and run weed control experiments, present results at events across all sectors and, for Angela, to develop project proposals outside of the weeds fellowship.

Jessica Sparkes returned to ADAS Boxworth during the latter half of 2014 following maternity leave but subsequently decided to pursue a different career route within ADAS and has moved to ADAS Wolverhampton and will no longer be part of the fellowship project. Maria Tzortzi was promoted from scientific officer to replace Jessica. She participated fully in the fellowship training activities and experiments during 2014 and 2015 but decided to pursue a career in the agrochemical industry by joining BASF as a trials manager in October 2015.

Having participated and contract managed the Fellowship programme from the outset Harriet Roberts also left ADAS in October 2015 to join LRS as a blackcurrant agronomist. The expertise she has gained through the Fellowship programme will continue to be available to blackcurrant growers in the UK, a soft fruit sector which has particular weed control problems. Although not formally part of the Fellowship programme, new ADAS recruits based at Boxworth; Emma Worrall and Chloe Whiteside have been able to take over the work programmes managed by Harriet and Maria and have worked on new weed control projects outside of the Fellowship programme.

The nursery stock experiments under the Fellowship programme were completed in 2014. Follow up container nursery and field nursery stock experiments (HNS PO 192a) were managed by David Talbot in 2015-16 outside of the Fellowship, further developing treatments tested in 2014 into programmes.

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 was continued in 2014 and concluded in 2015 with growth studies, water and nitrogen usage and apple yields.

A residual herbicide trial for newly planted apples (Objective 2.5) was planned and managed initially by Harriet Roberts. Emma Worrall took over the management of the trial during 2015 and it was concluded at harvest autumn 2015.

Building on her contacts with the salad leaf industry, Angela Huckle ran a programme of herbicide trials for improved weed control in salad leaf crops (Objective 2.4) and the use of weed reducing green manure treatments during 2014 and 2015. These trials were based on growers' holdings. Angela Huckle also built on an earlier herbicide screening project for rhubarb with further work in 2015 outside the fellowship project. This work has been particularly well received by the rhubarb industry which has lagged behind in herbicide developments for many years.

At the request of the cut flower industry, an additional project on stocks was included in the fellowship programme of work for 2013. The liaison with the Cut Flower Centre (CFC) Spalding was successful and has led to a spinoff project on cut flower species in 2014 and further work in 2015 (HNS PO 192a) outside of the fellowship managed by Harriet Roberts and more recent recruits to the ADAS team Chloe Whiteside and Emma Worrall.

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. This was developed further in 2014 with field trial on a weed infested fallow site prior to planting blackcurrants. Further work on perennial control included a fallow year herbicide trial completed in 2014 and Maria completed a literature review of non-chemical methods for perennial weed in 2015.

Liaison with researchers in other European countries is proceeding (Objective 3.0) with Angela Huckle and Lynn Tatnell having attended previous European Weed Research Society meetings. Maria Tzortzi attended the European Weed Research Society workshop on "Optimizing herbicide use in an integrated weed management (IWM) context" in Crete in March 2015. David Talbot and John Atwood to visited northern Germany in September to meet Heinrich Loesing (VuB Schleswig-Holstein) and study nursery weed control in the Ellerhoop area north of Hamburg.

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 initially set up a SharePoint web site to share outline details of current research projects, however usage of the site has been limited. 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 in 2014 and 2015 with Heinrich Loesing VuB Schleswig-Holstein, Germany.

Overseas 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, corne.kempenaar@wur.nl

- Vision technology for weed detection
- Herbicide resistance development
- Weed biology in relation to decision support of specific weeds, focus on perennial weeds.
- Control of aquatic weeds
- Control of weed control on pavements
- Weed prevention by soil covering materials
- UV-weed control and other non chemical methods
- Optimization of herbicide doses

Germany

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

Vegetables (Principal contact): Ingeborg Koch, ingeborg.koch@dlr.rlp.de

- control of Poa annua in vegetables, herbs and fruits
- control of Senecio vulgaris in different leafy vegetables

Fruits: Michael Glas

Vines: Friedrich Louis

Ornamentals: Bernd Böhmer

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

Ornamentals: Heinrich Lösing, dr.loesing@vub.sh

- Herbicide screening field grown and container grown nursery stock

Denmark

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

All crops: Peter Hartvig, peter.hartvig@agrsci.dk

- Minor usage herbicide assessments horticulture and agriculture, onions carrots, parsnips, strawberries
- Application techniques

HortAdvice Scandinavia, Grøn Plantebeskyttelse ApS, Hvidkærvej 29 - DK-5250 Odense SV

Nursery stock: Michael Nielsen, mcn@vfl.dk

- Minor usage herbicide assessments

Eire

Tillage Crops KT & Horticulture Development

Teagasc Kildalton College, Piltown, Co Kilkenny

Ornamentals and foliage: Andy Whelton, andy.whelton@teagasc.ie

- Herbicide screening on field grown cut foliage

Container nursery stock: Fred Townsend, fred.townsend@teagasc.ie

- Herbicide screening on container grown nursery stock

France

Astredhor Loire-Bretagne, CDHR CENTRE-VAL-DE-LOIRE, Domaine de Cornay
45590 SAINT-CYR-EN-VAL, France

Container nursery stock: Sophie Bresch, sophie.bresch@astredhor.fr

- Non-chemical weed control in container nursery stock (pot mulches)

USA

North Carolina State University, Raleigh, 27695, North Carolina

Ornamentals: Joe Neal

- Biological and natural products for weed control. Recent research has focused on evaluating *Phoma macrostoma*, MBI-005 (thaxtomin) and Fe-HEDTA (Fiesta) for weed control in turfgrass and landscape plants.
- An assessment protocol for Invasive species
- Longevity of weed control in container nursery crops. Recent research suggests that the herbicide indaziflam remains active in container substrates longer that competing products.
- Ecology and management of Japanese Stiltgrass (*Microstegium vimineum*)
- Control options for recently introduced weeds in nursery crops. The efficacy of herbicides labeled for pre-emergence weed control in container nurseries was compared on several species of newly introduced weeds.
- Dodder host specificity in bedding plants.
- Herbicide Safety on Nursery Crops and Landscape Ornamentals. Research collaborations with the USDA-IR-4 program and product manufacturers. Recent foci of the program have been the development of flumioxazin (Broadstar and SureGuard) and dimethenamid-p (Tower) for weed control in nursery crops; herbicide safety in herbaceous perennials; herbicide safety in ferns; and safety of post-emergence herbicides for nutsedge and broadleaf weed control in ornamentals. Recent research has included phenoxy herbicides effects on seedhead formation in ornamental grasses; Tower herbicide potential for over the top use in woody ornamentals; safety and efficacy of natural products for liverwort control, herbicide safety on herbaceous ornamentals.
- Taxonomy and management of common weeds of nursery crops. Several projects include a comparison of Ranunculus ficaria ssp. distribution and spread in the U.S (manuscript in review); and a taxonomic study of species of Cardamine species found in container nursery crops.

Milestones not reached

The working group of European weed control researchers was not set up as planned. This target was too optimistic but good progress has been made in building links with researchers from the Netherlands, Denmark, France, USA and Germany. It is planned to continue building links with researchers in continental Europe through future projects for example HNS 198 where consultancy from Heinrich Loesing VuB has been included.

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 four years of the fellowship is summarised below:

Maria Tzortzi

- Improved background knowledge of UK agriculture and horticulture
- Experienced in weed resistance testing
- Seedling weed identification
- Researched non-chemical weed control methods
- Attended the European Weed Research Society workshop on “Optimizing herbicide use in an integrated weed management (IWM) context” in Crete in March 2015.

Harriet Roberts

- Technical writing improved
- Experienced in contract management, protocol development, managing herbicide trials and drafting reports
- Experienced 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
- Gave seminar to staff following visit to EWRS workshop in Spain
- Trained in weed control in vegetables, nursery stock and fruit

- Gained BASIS qualification for Horticulture
- Skilled in giving “on-farm” advice on weed control programmes in speciality vegetable crops
- Developed experiment protocols for vegetable weed control projects in consultation with industry leading producer
- Developed experimental proposal and carried out herbicide screening in rhubarb in consultation with producers and chemical manufacturers

David Talbot

- Networking with researchers at VuB Germany
- Confident and skilled in giving “on-nursery” advice on weed control programmes in nursery stock and protected ornamentals
- Experienced in ADAS quality management systems when running “off-site” experiments
- Consolidated existing skill in identification of seedling weeds
- Attended conference; International advances in pesticide application, Barcelona, Spain in January 2016.

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.

A new area of work – herbicide screening for cut flowers - has been developed as a spin-off from a Fellowship project.

GROWER SUMMARIES

2.4.5. Wild rocket and baby leaf lettuce herbicide screens

Headlines

- H23 is safe to use up ½ the recommended rate in both baby leaf wild rocket and baby leaf lettuce, and gives weed control equivalent to Devrinol
- Wing-P applied at ¼ rate of the EAMU (0.3 L/ha) and incorporated was crop safe on a silty clay loam in the trial, but it was not crop safe on sandy soils

Background

The control of weeds in short season baby leaf salad crops can be difficult, especially in crops such as wild rocket and baby leaf lettuce which are sensitive to a number of commercially available herbicides. Crop rotations and soil sterilants such as Basamid (dazomet) are used to reduce the weed population before drilling a crop. However, a number of weeds can still be problematic, particularly Compositae such as groundsel (*Senecio vulgaris)* and sowthistle *(Sonachus sp.)*, as well as other species such as shepherds purse *(Capsella bursa-pastoris)*, nettles *(Urtica urens)* and fat hen *(Chenopodium album)*. Weed pressure increases through the season, with more problems seen in second or third crops which are drilled during the summer after the first crop has been harvested. Hand weeding the crop before harvest is frequently necessary but is expensive (c. £200/ha) and with the threat of the possible loss of soil sterilants in the future, additional herbicides for use in baby leaf lettuce are needed to increase the range of weeds controlled. When added to a tank mix with Devrinol, Goltix Flo gave control of groundsel in wild rocket in trials carried out under CP 086 in 2013 but when the possibility of an EAMU was investigated, there were issues with gaining approval with regards to operator exposure which gave an obstacle to approval. Therefore options still needed testing, and the pre-drilling incorporation of products containing dimethenamid-P was thought to improve safety to the crop compared with post drilling application, and worthy of investigation.

The main objective of the trial was to assess the crop safety of two herbicides containing dimethenamid-P at a range of rates when applied as incorporated treatments. In addition control of annual weeds in drilled baby leaf lettuce and wild rocket grown for salad leaf was assessed. Products tested were Wing-P (dimethenamid-P + pendimethalin), H41 and a coded product H23 for which incorporation is recommended by the manufacturer.

Summary

The experiments were carried out on three commercial field crops of wild rocket and a red Batavia baby leaf lettuce crop in Wiltshire and Sussex. The crops in Wiltshire were drilled on 19 June with the baby leaf lettuce due for harvest on 14 July 2015 and the wild rocket due for harvest on 22 July 2015. The wild rocket crops in Sussex were drilled on 30 June and 11 August and due for harvest on 28 July 2015 and 15 September 2015 consecutively. The soil at Wiltshire was a sandy loam, while the soil in Sussex was a silty clay loam. The trials were a fully randomised block design with twelve treatments in the first three trials in Wiltshire and Sussex, and eight treatments in the second trial in Sussex (Table 1 and 2). There was a double untreated control and four-fold replication, and each plot was 5 m long and 1.5 m wide. The major weeds at each site are detailed in Table 3.

Table 1. Treatments applied to plots in 400 L water per hectare. Wiltshire and Sussex, 2015.

Treatment no.	Product	Rate
1 + 2	Untreated	-
3 (Standard)	Devrinol	0.86 L/ha
4	H23	1/3 N
5	H23	1/6 N
6	H23	1/9 N
7	H41	Normal rate (N)
8	H41	½ N
9	H41	¼ N
10	Wing-P	1.25 L/ha
11	Wing-P	0.63 L/ha
12	Wing-P	0.3 L/ha

Table 2. Treatments applied to plots in 400 L water per hectare. Sussex 2nd trial, 2015.

Treatment no.	Product	Rate
1 + 2	Untreated	-
3 (Standard)	Devrinol	0.86 L/ha
4	H23	3/4 N
5	H23	1/2 N
6	H23	1/4 N
7	Wing-P	0.63 L/ha
8	Wing-P	0.3 L/ha

Table 3. Major weeds at the experimental trial sites. Wiltshire and Sussex, 2015.

Wiltshire		Sussex	
Weed species	Common name	Weed species	Common name
Capsella bursa-pastoris	Shepherds purse	*Capsella bursa-pastoris*	Shepherds purse
Chenopodium album	Fat hen	*Persicaria maculosa*	Redshank
Diplotaxis tenufolia	Volunteer wild rocket (in baby leaf lettuce)	*Poa annua*	Annual meadow grass
Geranium molle	Crane's-bill	*Polygonum aviculare*	Knot-grass
Poa annua	Annual meadow grass	*Senecio vulgaris*	Groundsel
Polygonum aviculare	Knot-grass	*Solanum nigrum*	Black nightshade
Senecio vulgaris	Groundsel	*Sonchus sp.*	Sow thistle
Solanum nigrum	Black nightshade	*Stellaria media*	Common chickweed
Sonchus sp.	Sow thistle	*Tripleurospermum inodorum*	Scentless mayweed
Tripleurospermum inodorum	Scentless mayweed		
Urtica urens	Small nettle		

After bedforming, the site was marked out and the treatments were applied on 18 June at Wiltshire and 30 June and 11 August at Sussex. The treatments were applied to the beds using an OPS sprayer and a 1.5 m boom with 02F110 nozzles, to achieve a medium spray quality at 400 L/ha. The markers were then removed and the treatments were incorporated by a second pass with the bedformer. The crop was drilled within 24 hours of application and incorporation of the herbicide treatments at all sites. The trial was re-marked out after drilling.

All trials were assessed on at least three occasions; approximately two, three and four weeks after the application of the treatments and at harvest; on 1 July, 6 July, 14 July and 22 July in the baby leaf lettuce and wild rocket trials in Wiltshire. At the Sussex sites assessments took place on 13 July, 21 July and 27 July at the first site, and 26 August, 4 September and 14 September at the second site. Plots were assessed for phytotoxicity effects, percentage emergence of the crop and weed incidence. Weed species were also recorded.

Results

H23 was the most crop safe treatment at both sites and in all trials, but at the sandy loam site in Wiltshire, H23 at 1/3 full rate did cause slight stunting of just a few plants of both baby leaf lettuce and wild rocket (Figure 1). This did not affect all the plots in either of the trials, and an overall score of above seven was recorded which deems H23 crop safe. This slight stunting was not seen on the silty clay loam soil even at the highest rate applied of ¾ of the normal rate of H23. This increased crop sensitivity could be due to herbicides behaviour in the sandy loam soil and consideration of rates may be needed on these soils.

H41 was not crop safe in any of the trials, and caused significant phytotoxicity at both sites and in both crops. Even at the lowest rate of ¼ of the approved rate, and on the silty loam soils, crop emergence was reduced and what did emerge was stunted and deformed, with thickened and twisted leaves.

Crop safety of Wing-P varied with soil type and rates, and was not crop safe at any rates used in the trials on sandy loam soils. However, on the silty clay loam Wing-P applied at ¼ of the EAMU rate to the wild rocket crops was crop safe and gave a commercially acceptable crop. But, care must be taken with rates even on the silt soils as when used at the higher rates of ½ full rate, and at the full EAMU rate the herbicide was not safe. Significant differences were seen in phytotoxicity at these rates and crop losses and deformed plants were recorded.

H23 applied at all the rates tested (1/9 N to ¾ N) exhibited equivalent crop stand to the untreated and the grower standard, Devrinol in the wild rocket crops across the soil types in the trials. In the baby leaf lettuce trial on the sandy loam in Wiltshire, a reduction of 10% plot cover was recorded at 1/3 of the full rate, but this was not a significant reduction and plot cover was on average 85% across the plots. Whereas, there was a significant reduction in crop stand as the rate of Wing-P increased in both soil types in both wild rocket and baby leaf lettuce, when applied at either the full EAMU rate or ½ EAMU rate. At ¼ of the EAMU rate, Wing-P did not significantly reduce crop stand of the wild rocket when applied on the silty clay loams in Sussex or the baby leaf lettuce on the sandy loams in Wiltshire. But, Wing-P at ¼ rate did significantly reduce the crop stand of the wild rocket in Wiltshire by 27% which was commercially unacceptable. Again, this highlights the need for care with the use of Wing-P depending on soil type.

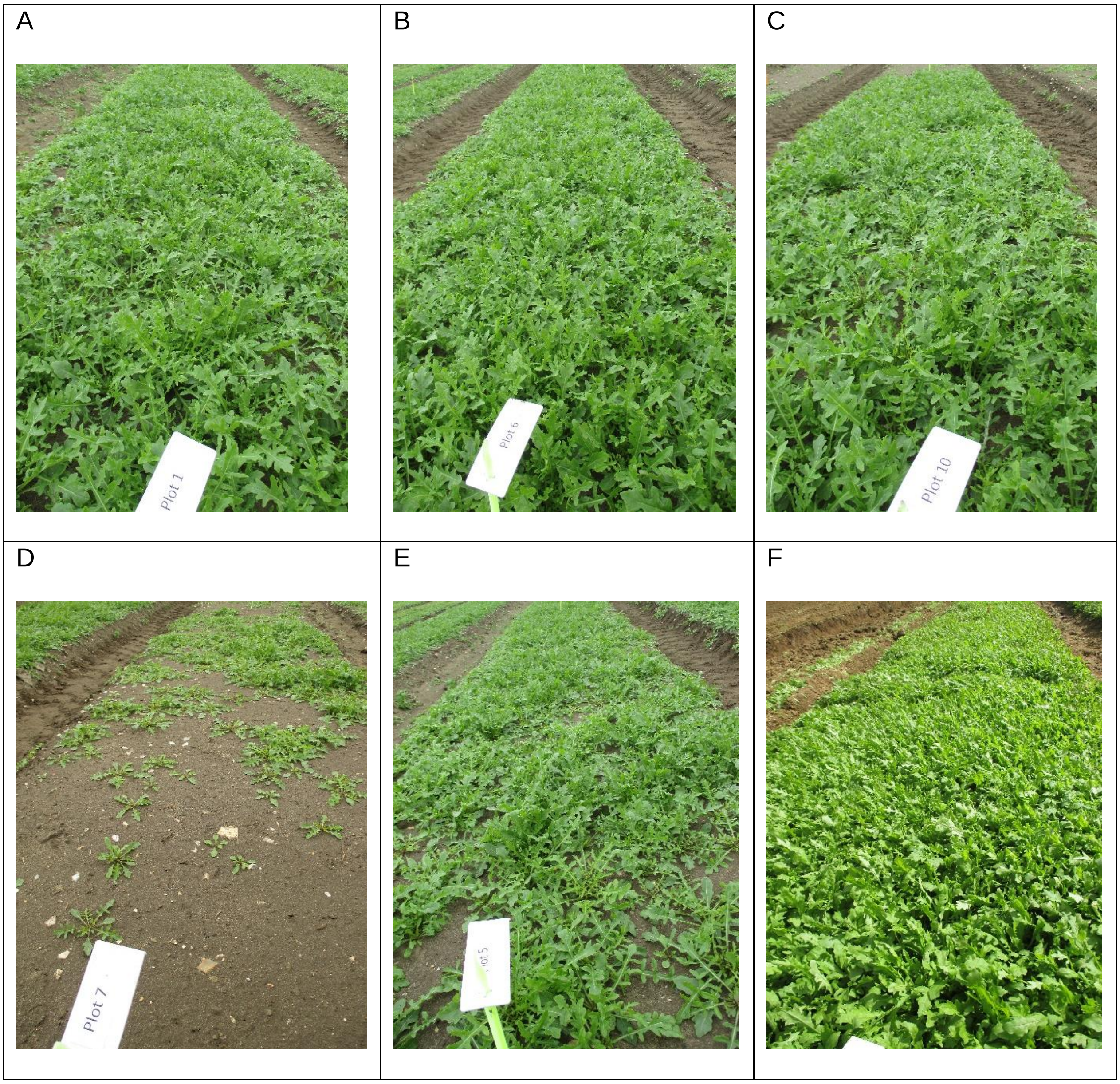

Figure 1. Comparison of crop appearance of A) an untreated plot and B) Devrinol (standard), C) H23 at 1/3 rate, D) H41 at ¼ rate and E) Wing P at ¼ rate on a sandy clay loam, F) Wing P at ¼ rate on a silty clay loam. Wilts and Sussex, 2015.

H41 gave significant reductions of 38% crop stand in the silty clay loam at the lowest rate used, to 99% reduction in crop stand in the sandy loam at the highest rate, and was therefore too damaging to any crop at either site.

The overall weed levels at the Sussex sites were higher than seen in Wiltshire, however significant differences were seen at all sites except the wild rocket trial in Wiltshire. At the latter site the weed levels were very low. At those sites where significant differences were seen, Wing-P and H41 significantly reduced the weed levels when compared to the untreated.

But, as aforementioned H41 was not crop safe, and Wing-P was only crop safe at ¼ rate on heavier soils.

H23 reduced the weed level at all the sites but the amount of reduction varied and was not always significant. In the baby leaf lettuce trial in Wiltshire H23 gave a significant reduction in weeds, and equivalent control to Devrinol but it should be noted that weed levels were low with only six weeds per plot in the untreated. In the rocket trials in Sussex, results were variable with no consistent significant reduction of weeds in the first trial but the predominant weed was shepherd's purse and H23 does not control crucifers, hence the possible poor performance of the product in this trial. However, at 1/9th of the full rate of H23, significant control of weed numbers was seen, which was unexpected considering the higher rates showed poor weed control.

In the second trial in Sussex the rates of H23 were increased and all herbicide treatments significantly reduced weed levels when compared to the untreated (Figure 2), and gave equivalent control to the grower standard Devrinol. But, the percentage reduction in weed cover was not as great as seen at the first site in Sussex. This may have been due to the heavy rainfall after application, which would have moved the herbicide lower in the soil profile and reduced efficacy. Weed levels were reduced by 33% by Wing-P and H23 at ½ of the full rate. All other treatments including the grower standard, reduced weed by 25% compared to the untreated. No treatment was significantly better than another or the grower standard in this trial, and no differences were seen in the range of species controlled.

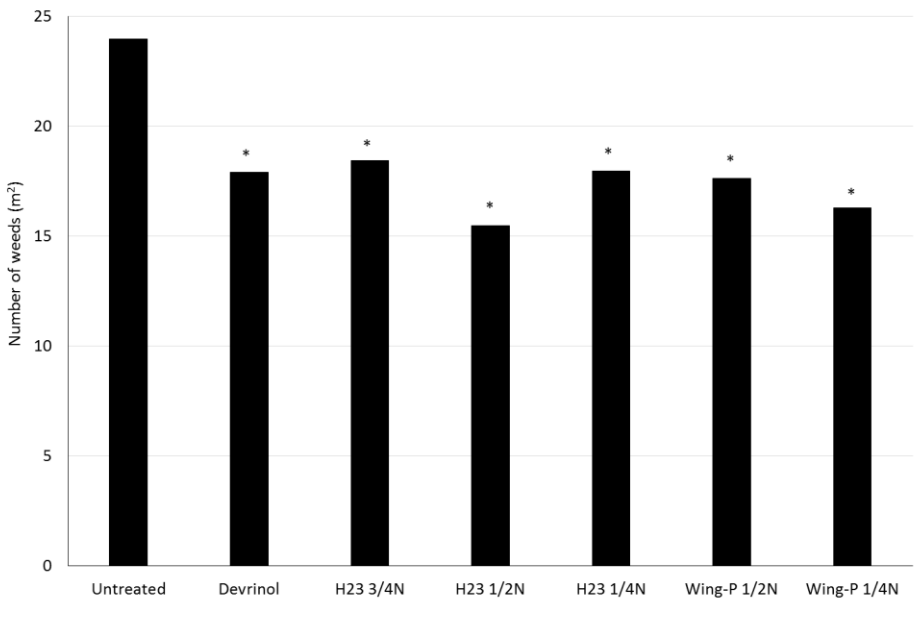

Figure 2. Weed numbers at five weeks after herbicide application, W. Sussex, 2015 (* = significantly different from the untreated).

The most troublesome weeds at each site were not fully controlled, but their percentage ground cover was reduced with by all of the treatments tested in the trials. However, not all of the treatments were crop safe. Further work could determine if combining H23 with the grower standard Devrinol could improve weed control while maintaining crop safety in these sensitive crops. Wing-P at ¼ of the EAMU rate gives an equivalent reduction in weed levels to the grower standard, but is only crop safe on heavier silt soils and even then it would be advisable to test a small area of crop before use on a larger scale as higher rates of Wing-P gave commercially unacceptable stunting and crop loss.

Financial Benefits

Wing-P is approved for use in baby leaf crops under an EAMU and on heavier soils such as silty clay loams it may give greater control of a different range of weeds such as crucifers. Any reduction in time to hand weed crops can make significant cost savings in labour for the grower, and even the extra reduction of just 8% in weed cover between Devrinol and Wing-P could save £30/ha in labour costs based on the percentage of weed reduction in the trial.

Action Points

- The grower standard, Devrinol is effective in reducing weed cover and is safe to wild rocket crops, but is not safe to use on baby leaf lettuce.
- H23 is crop safe across both baby-leaf lettuce and wild rocket up to ½ rate in all soil types, and gives equivalent reductions in weed cover to Devrinol. An EAMU for this product would be useful to give baby leaf growers an alternative mode of action and guard against the development of resistant weed populations.
- Wing-P at ¼ of the EAMU rate (0.3 L/ha) was crop safe on silty clay loams even after heavy showers, but it is not crop safe on lighter sandy soils and consideration of the soil type must be taken into account when using the product to avoid crop loss.
- H41 is not safe to use on wild rocket or baby leaf lettuce crops.

2.5.1. Top fruit (apple) herbicide screen

Headline

- After some initial moderate scorching to buds caused by Butisan S, Flexidor 125 and Sumimax (each applied in a tank mix with Stomp Aqua), there was no phytotoxicity from any of the herbicide treatments on the apple trees and all gave significant weed control up to 24 weeks after treatment.

Background

Weeds in soil grown top fruit systems compete with the trees for light, nutrients, water and space. Therefore, ‘starting clean’ is important to avoid weeds competing with the crop and reducing the crop’s vigour. Weeds can also act as alternative hosts for significant pests of apple trees, e.g. the winged form of rosy apple aphid migrates to *Plantago* species (plantains) in June/July, thus removing alternative host species can help with controlling certain pests.

Starting off with an effective residual herbicide means that growers can reduce the need for follow up, contact acting, herbicides. Up until summer 2015, Ronstar (oxadiazon) was one of the main herbicides used by apple growers for the control of broad leaved weeds and grasses in their orchards. However, after Ronstar was revoked, growers have become reliant on a tank mix of Stomp Aqua (pendimethalin) and Flexidor 125 (isoxaben) as a commercial standard. Although authorised for this use, application to newly planted apple trees is not covered by the label recommendations which refer to use on “established” trees. Relying on one or two active ingredients increases the risk of resistant weeds building up in the plantation.

Herbicides Nirvana (imazamox + pendimethalin) and Sumimax (flumioxazin) already have EAMUs for use in apples with a 365 day harvest interval but have not been tested for safety, others such as Butisan S (metazachlor) and Wing P (dimethenamid P + pendimethalin) have approval in nursery production. Combinations of these herbicides with standards such as Stomp Aqua may also offer better control of weeds and help to reduce this risk of resistance developing when preparing land for fruit crops.

The objective of this trial was to compare a range of novel herbicides with Stomp Aqua + Flexidor 125, and an untreated control, for weed control efficacy and crop safety in a newly planted commercial apple orchard in order to support applications for Extension of Authorisations for Minor Uses (EAMUs).

Summary

This herbicide trial tested six treatments: an untreated control, Nirvana, Wing P, Butisan S + Stomp Aqua, Stomp Aqua + Flexidor 125 and Stomp Aqua + Sumimax for their efficacy and crop safety when applied to a newly planted, soil grown, apple orchard (Table 1). The trial was set up as a randomised block design with four replicates of each treatment. Each plot measured 1.5 m wide and 4.0 m long and consisted of three apple trees.

Prior to the trial herbicide applications, a pre-treatment of Harvest (glufosinate ammonium) at a rate of 5 L/ha was used to clear any weeds that had already germinated. All guard areas and ends of rows were also treated with Harvest as well as the commercial standard treatment (Stomp aqua + Flexidor 125) to avoid excessive weed growth around the trial plots. All treatments were applied on the 2 April 2015 by an OPS knapsack sprayer at a water volume of 200 L/ha.

Weed and Phytotoxicity assessments were carried out 2, 6, 12, 16 and 24 weeks after treatments had been applied.

Table 1. Residual herbicide treatments tested on a newly planted apply orchard (2015).

Treatment number	Product name	Active ingredient	Rate (L/ha)	Timing
1	Untreated	-	-	-
2	Nirvana	imazamox + pendimethalin	4.5	April
3	Wing P	dimethenamid P + pendimethalin	4.0	April
4	Butisan S + Stomp Aqua	metazachlor + pendimethalin	1.5 + 2.0	April
5	Stomp Aqua + Flexidor 125	pendimethalin + isoxaben	2.0 + 2.0	April
6	Stomp Aqua + Sumimax	pendimethalin + flumioxazin	2.0 + 0.1	April

Table 2. List of herbicide treatments used in the apple herbicide trial and their approval status as on 11 February 2016.

Product name	**Approval status**
Nirvana	EAMU 2894/09 (365 day harvest interval)
Wing P	Not approved
Butisan S	Not approved
Stomp Aqua	Full approval but use on newly planted is off-label
Flexidor 125	Full approval but use on newly planted is off-label
Sumimax	EAMU 2881/08 (365 day harvest interval)

None of the herbicide treatments caused any lasting crop damage; however, there was some transient bud scorching on trees noted during an initial assessment two weeks after treatment (16 April). The scorched buds were seen in plots that were treated with Butisan S + Stomp Aqua, Stomp Aqua + Flexidor 125 and Stomp Aqua + Sumimax. The buds grew out of the damage and no further phytotoxic effects were seen at any of the following assessments. There were no significant differences between the treatments on extension growth of the trees. This suggests that none of the herbicide treatments had an adverse effect on the health or growth of the newly planted apple trees.

The weed cover for all of the herbicide treatments was significantly lower than the untreated control plots eight weeks after the treatments had been applied, on 4 June 2015 (Figure 1). All of the tested novel herbicides performed as well as the standard Stomp Aqua + Flexidor 125, with very low weed cover seen up until 16 weeks after treatment (4 August). On this date, the untreated control had the highest percentage cover of weeds, 21.25 %, (Figure 2) and Butisan S + Stomp Aqua and Stomp aqua + Sumimax had the lowest percentage weed cover, both 0.25 % (Figure 3).

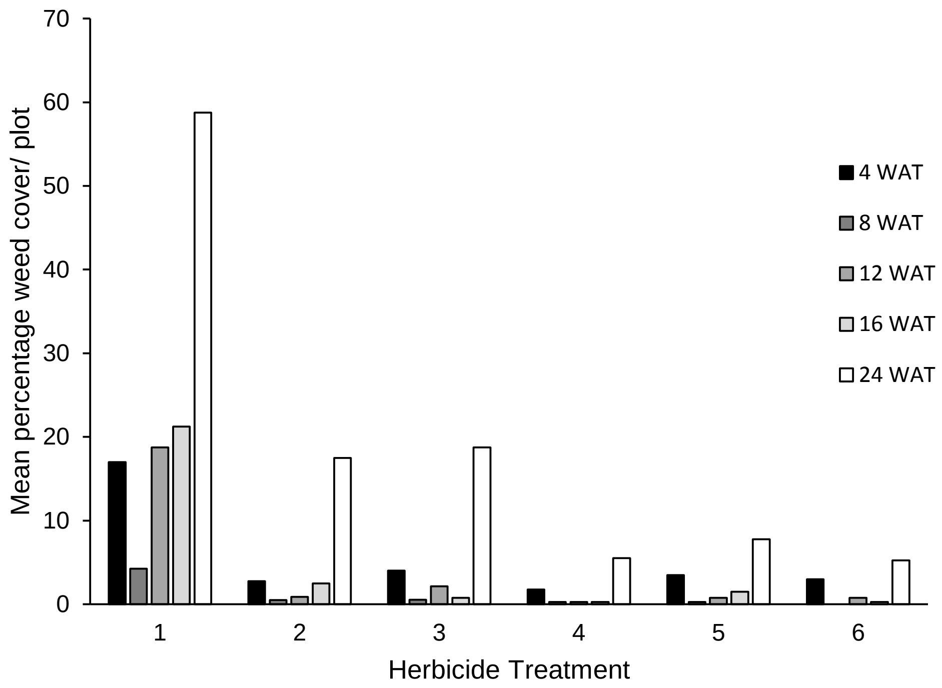

Figure 1. Mean percentage (%) weed cover per treatment plot at four, eight, 12, 16 and 24 weeks after treatment. Treatments: 1 = Untreated, 2 = Nirvana, 3 = Wing P, 4 = Butisan S + Stomp Aqua, 5 = Stomp Aqua + Flexidor 125, 6 = Stomp Aqua + Sumimax.

Figure 2. Untreated plots 16 weeks after treatment - 4 August 2015.

Figure 3. Stomp Aqua + Sumimax 16 weeks after treatment – 4 August 2015.

Financial Benefits

It is believed that growers will be able to make savings by altering their herbicide programme so that they are not just relying on two active ingredients (pendimethalin and isoxaben). Relying on one or two active ingredients would make resistance of the weeds more likely, thus making it harder and more expensive for growers trying to control these weeds in the long term.

Action Points

- There was no significant adverse effect from using Stomp Aqua + Flexidor 125 after planting. This use is authorised but not covered by the label recommendations.
- Growers can safely use Nirvana and Sumimax as part of their herbicide programmes on newly planted apple orchards under EAMU authorisation.
- EAMUs will need to be applied for before growers can use Butisan S or Wing P in apple orchards.

2.6 Living mulches in apple orchards

Headline

- Living mulch treatments were identified that performed as well as the herbicide treatment in terms of weed suppression but apple yields were reduced.

Background

Living mulches are crops established either prior to or at the same time as the main crop, with the main objective of improving soil conditions. In particular, living mulches enhance soil structure, increase organic matter and prevent soil erosion by covering the bare soil whilst also providing an appropriate habitat for beneficial insects and increasing local biodiversity. Within this investigation, however, their ability to suppress noxious weed populations was the prime focus, utilising a low growing weed suppressive living mulch in place of maintaining an herbicide strip. Weed control by herbicide applications could become increasingly difficult as herbicide availability becomes more limited though tightening pesticide legislation and so it is important that alternatives are investigated. It is thought that living mulches could provide an effective alternative method of weed control in top fruit, although it will be essential that the appropriate living mulch is chosen, in order to avoid excessive competition for water and nutrients, which can be damaging to the crop.

Summary

The main objective of the trial was to investigate the potential advantages of sowing living mulches on the herbicide strip in apple orchards. The study focused on weed suppression, soil nutrient status, soil water content, apple yield and diameter, branch extension growth and leaf nutrient content. This was the final year of the two-year study.

The trial was carried out in a commercial apple orchard at Lavender farm, Faversham, Kent by kind permission of David Figgis and Worldwide Fruit Ltd. An undisclosed (confidential) apple variety coming into its third year was selected and a fully randomised block design with seven treatments, including an untreated control, with four replicates was set up (Table 1). Each plot was 1.70 m wide and 2.50 m long and consisted of three apple trees per plot with a 1.25 m gap between plots.

Table 1. Treatment list for living mulches trial – Kent.

Treatment no.	Common name	Scientific name	Sowing density (g/ m^2)*
1	White clover	*Trifolium repens*	2.8
2	Black medic	*Medicago lupulina*	3.2
3	Creeping red fescue	*Festuca rubra*	15.0
4	Birdsfoot trefoil	*Lotus corniculatus*	2.8
5	Creeping red fescue + birdsfoot trefoil	*Festuca rubra* + *Lotus corniculatus*	15.0 + 2.8
6	Untreated	-	-
7	Herbicide treatment**	-	-

** Seed was applied at double the normal rate due to wet conditions at sowing.*

***Details for the herbicide treatment are shown in the Table 2 below.*

Table 2. Herbicide programme (treatment 7) for living mulches trial – Kent.

Herbicide	Active ingredient	Timing	Rate (L/ha)	Water volume (L/ha)
Ronstar liquid	Oxadiazon	March	4.0	300.0
Harvest	Glufosinate-ammonium	March	3.0	300.0

The site was marked out and the living mulch seeds were sown on 8 November 2013. In this final year of the study the herbicide treatment was applied to the respective plots on 27 February 2014. A tank mixture of Ronstar liquid and Harvest, was sprayed using a Knapsack OPS sprayer at a water volume of 300 L/ha. The percentage of living mulch cover per plot was assessed on 15 April 2015, 4 June 2015 and at harvest day 2 October 2015. The percentage weed cover per plot was also recorded on the same dates as the living mulch assessments.

At harvest, on 2 October 2015, the following measurements were recorded: the diameter of 10 apples per plot, the extension growth of five branches per plot and the yield of three trees per plot. Means were then calculated for each treatment. Maturation testing, which included Brix^o, firmness and starch measurements and post-harvest grading for one block of the trial was conducted by Worldwide Fruit Ltd. Firmness is measured using a pressure meter (Psi). Data collected were analysed using one-way analysis of variance.

Soil moisture recording and leaf sampling for analysis was carried out on 4 June. Soil samples were taken at the beginning of the trial and again in June 2014, and also finally in June 2015, to investigate any changes in soil nutrient status.

Results

All of the living mulch treatments had high coverage by harvest on 2 October 2015, ranging from 73.8 % to 96 % cover (Figure 1). They all also had significantly greater weed suppression compared with the untreated control and the herbicide treatment by harvest. This suggests that they were able to out-compete the weeds in the treatment plots.

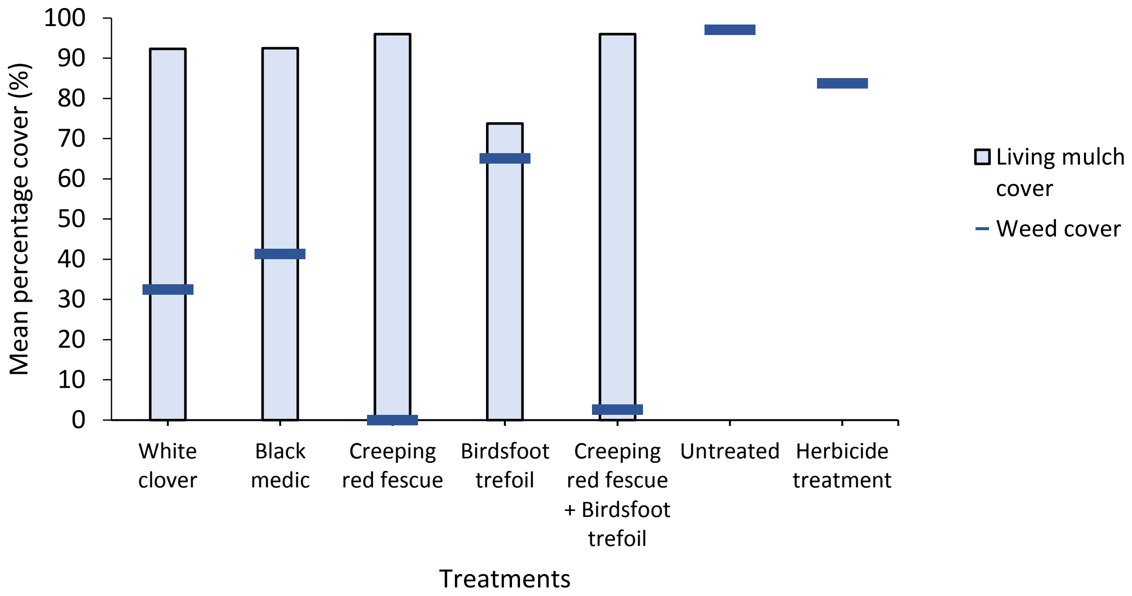

Figure 1. Living mulches percent cover compared with that of weed population, during the final assessment on the 2 October 2015.

In the maturation tests the Psi ranged from 9.86 kg in the white clover treated plots to 13.75 kg in the birdsfoot trefoil treated plots. The lowest Brix content was 11.0 % in the birdsfoot trefoil treated plots and the highest mean was 11. 6 % in the creeping red fescue plots. Starch content ranged from 79.8 % in the untreated plots to 90.3 % in the creeping red fescue/ birdsfoot trefoil treated plots. The Psi and the mean starch percentage were both higher in 2015 than they were in 2014 at harvest, suggesting that the fruit was less ripe when it came to harvest. This may have been as a result of poor growing conditions in 2015, in particular a lower sunshine duration during August.

The leaf nutrient analysis results in 2015 showed more variation compared with those for 2014. Leaf nitrogen content noticeably decreased in 2015 compared with 2014 in all treatments (ranges: 1.26-1.69 % w/w and 1.60-2.17 % w/w respectively). The nitrogen content in 2015 for all of the treatments was lower than the optimum range for apple trees (2.0-2.4 % w/w) (Table 3). Only the plots treated with birdsfoot trefoil had a similar nitrogen leaf content level to 2014, although it was still under the optimal range. The plots containing creeping red fescue had the lowest leaf nitrogen content and had yellowing foliage when the trees were assessed in August 2015 (Figure 2).

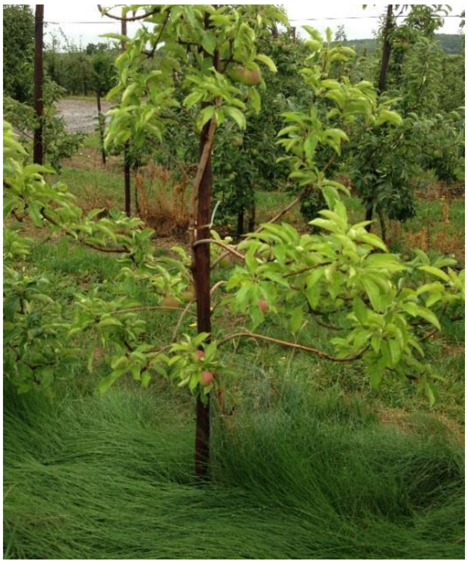

Figure 2. (Left) Apple tree in creeping red fescue plot showing yellowing foliage. (Right) Comparison of apple foliage from creeping red fescue treated plots to herbicide plot August 2015

Available phosphorous, potassium or calcium were within the optimum range for all treatments, although with slightly reduced concentrations when compared with the last year's content levels. All plots, except those with white clover, birdsfoot trefoil or the standard herbicide treatments, had slight magnesium deficiencies. All plots had manganese, iron and zinc concentrations within the acceptable ranges. The leaf boron content was higher in 2015 than in 2014 and the nutrient concentration for all plots was within the optimum range.

Results showed that the pH across all of the plots stayed within a range similar to the starting pH of 7.6 and the treatments were not significantly different to one another. The living mulch treatments did not have a significant effect on any of the soil nutrients. There was no significant difference in the soil water content between the different treatments.

Table 3. Soil and leaf main nutrient status, 4 June 2015.

Treatment	Mean Soil pH	Mean P (mg/l)	Mean K (mg/l)	Mean Mg (mg/l)	Median Available N (kg/ha)	Leaf N (% w/w)
1. White clover	7.6	80.6	319.3	118.0	216.65	1.47
2. Black medic	7.5	87.9	281.3	119.3	119.35	1.39
3. Creeping red fescue	7.3	83.9	245.3	122.5	18.7	1.26
4. Birdsfoot trefoil	7.5	79.9	250.3	121.0	60.75	1.63
5. Creeping red fescue + birdsfoot trefoil	7.5	83.2	255.0	125.8	27.75	1.31
6. Untreated	7.3	84.2	347.5	118.3	178.15	1.35
7. Herbicide treatment	7.1	87.8	313.5	121.3	203.45	1.69

The lowest marketable yield was from the plots with the creeping red fescue, which was significantly lower than the highest marketable yield in the herbicide treatment. However, the percentage of the marketable yield was not significantly different between any of the treatments. This means that although there was a lower marketable yield overall in the creeping red fescue plots, the proportion that was marketable was still the same as the other treatments.

The mean extension growth for the creeping red fescue and the creeping red fescue/birdsfoot trefoil mix were lower than in the other plots. However, due to large variability within the dataset there were no significant differences between any of the treatments. The creeping red fescue treatment had the lowest total apple yield out of all of the treatments and the herbicide treatment had the highest total yield (Figure 3). There was no significant difference in yield between the herbicide, white clover, black medic and birdsfoot trefoil treatments.

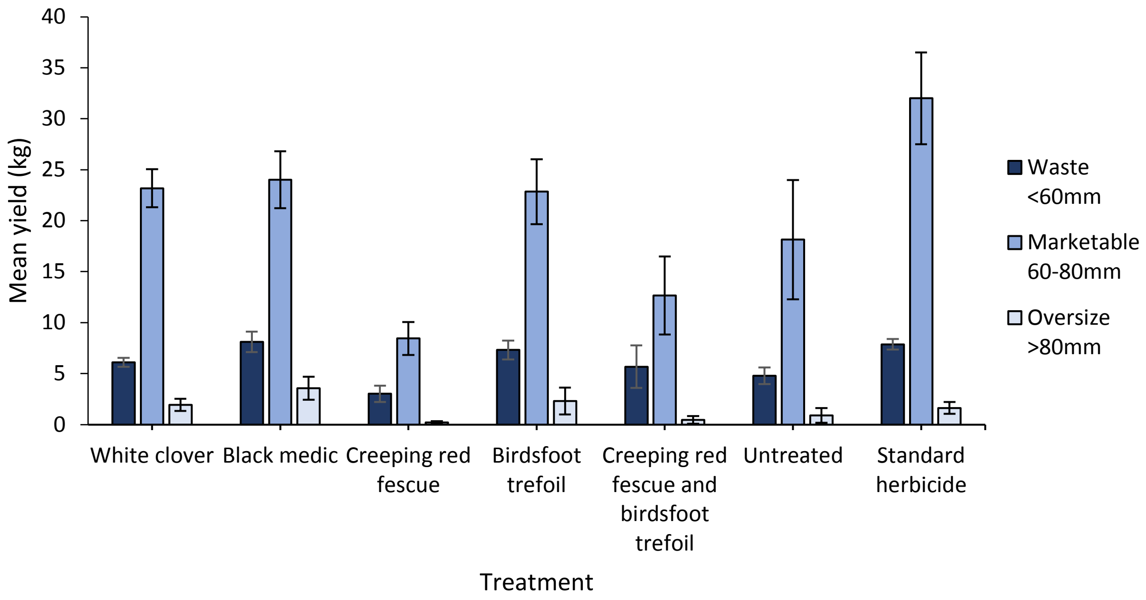

Figure 3. Mean yields for each size range measured on 2 October 2015.

Financial benefits

A basic cost analysis has been performed on the different weed control methods used in this trial. It is estimated that the use of herbicides costs growers around £150 per hectare per annum. This data is based on the use of three applications of Asteroid (glyphosate) per year including the herbicide (£100) and the cost of application – labour and machinery (£50). A comparison of the cost of establishing living mulches showed white clover to be the cheapest of the living mulches at £380 per hectare, whilst creeping red fescue came out as the most expensive of the living mulches at £480 per hectare. Black medic was estimated to cost £440 per hectare and birdsfoot trefoil costed approximately £400 per hectare including the seed and the labour and machinery usage. If written off over five years at 5% the annual cost of the mulches vary from around £88 to £111 per ha per annum which is less than the cost of herbicide use. However the use of living muches caused a yield loss in 2015 ranging from 2.6 kg per tree to 10.6 kg per tree. Because this was an intensive orchard of 3767 trees per ha, the yield loss would have ranged from 9.6 t/ha for black medic to 38.9 t/ha for red fescue. The cost of this yield loss would be around £380 per tonne (typical fruit value less picking and marketing costs) so the cost of yield loss would make this system uneconomic in spite of the small annual saving in maintenance costs.

Action points

- A living mulch of white clover or black medic was effective for weed suppression and gave the smallest yield reduction of the living mulch treatments. However it cannot as yet be recommended as the yield reduction is still too costly in relation to the saving in annual maintenance costs.

2.7 Cover crops for weed suppression prior to planting blackcurrant

Headline

- Cover crops of creeping red fescue (*Festuca rubra)* and black medic (*Medicago lupulina)*, could be used as an alternative method to herbicides for supressing noxious weeds prior to planting blackcurrants.

Background

Perennial weeds cause serious losses in fruit crops each year by reducing yield and fruit quality. Perennial weeds are often harder to control than annual weeds due to their persistent nature and because they spread by vegetative means as well as by seed. Whilst tillage can provide effective control for annual weeds, it will only hinder efforts to control perennial weeds as it will break up the roots, rhizomes and stolons and will spread these parts to other areas of the field or to other fields. Therefore, in a perennial crop, the control of perennial weeds within the row presents a real challenge for growers.

Blackcurrants grow best in moist soils as the fruits require moisture in order to develop. Therefore, any weeds present will compete with the blackcurrants for this moisture which will compromise blackcurrant establishment in young plantations and harvested yields in mature plantations. Perennial weeds, such as thistles, can also cause contamination at harvest and can damage harvesting machinery by getting caught in the mechanisms. Currently perennial weeds are controlled in blackcurrants by hand weeding or by using band sprayer treatments, with glyphosate alongside the crop row. The latter technique, however, does not control weeds directly in the crop row and some broad leaved perennials are moderately resistant. With the issue of resistance and the loss of certain active ingredients in the past five years (e.g. dichlobenil), and future threats to actives due to the Sustainable Use Directive; Water Framework Directive and the endocrine disrupter review, there is a need for the development of alternative mechanisms for the control of perennial weeds in fruit crops.

Cover crops are growing in popularity, particularly in arable systems, as they provide many advantages to soil quality and management through: reducing the risk of soil erosion and diffuse water pollution, improving soil structure, increasing organic matter content, water holding capacity and overall soil health. Moreover, cover crops have the ability to supress certain pest populations and, more importantly for this investigation, to control the weed population. This can either be through physical competition or by chemical action; for example, buckwheat (*Fagopyrum esculentum)* has allelopathic properties where root and shoot exudates can inhibit the growth of other living organisms, whilst mustard species can produce bio-fumigant gases when they are cut and incorporated in to soil. All of these properties will also benefit a perennial crop, such as blackcurrant, particularly at establishment where cuttings need moist, well structured, fertile soils and to be free of competition from weeds.

The objective of this project was to compare three cover crop sowing mixes for their perennial weed suppressant potential when sown prior to blackcurrant planting.

Summary

The cover crops included in the trial were: buckwheat (cv. Kora), rye-grass and red clover mix, creeping red fescue and black medic mix and the grower control (maize game cover). An untreated control was also included in the trial (Table 1). The plot containing buckwheat was split into two subplots, A and B. The buckwheat in subplot A was allowed to die back naturally and re-seed, whilst the buckwheat in subplot B was cut down after flowering and incorporated shallowly. This was done as incorporating buckwheat is meant to increase the allelopathic activity of this species. However, the incorporation was delayed until September 2014 so some re-seeding also took place in subplot B. The study was a non-randomised design, with five 12 m by 48 m large plots sown side by side with a maize cover crop grown all around.

Cover crops were sown by the host grower in 2014 using a grass seed spinner to achieve the sowing density required. The grower then rolled the seeded areas.

Table 1. Cover crop treatment list for blackcurrant trial, sown in May 2014.

Treatment	Species	Sowing density (kg/ha)
1. Untreated control	-	-
2. Buckwheat cv. KORA	*Fagopyrum esculentum*	100
3. Rye-grass/red clover mix	*Lolium multiflorum + Trifolium pratens*	35 + 15
4. Creeping red fescue/ black medic mix	*Festuca rubra + Medicago lupulina*	75 + 8
5. Maize game cover – grower control	Grower standard	Grower's rate

A pre-treatment assessment was carried out prior to sowing the cover crops in order to determine the weed population across the plots. Weed species present included scentless mayweed (*Tripleurospermum inodorum*), annual meadow grass (*Poa annua)*, American willow herb (*Epilobium ciliatum)*, groundsel (*Senecio vulgaris)*, common chickweed (*Stellaria media)* and perennials including: docks (*Rumex spp.*), nettles (*Urtica dioica)* and thistles (*Cirsium arvense*). Weed and cover crop ground cover were assessed in June and again in November 2014. All plots, except subplot A of the buckwheat plot and the maize game cover plot, were mown in September 2014. Figure 1 shows the cover crops in September 2014 after mowing.

Over winter the trial area was shallowly cultivated and the land was prepared for blackcurrants. This involved bed forming and covering these raised beds with woven polythene membrane before sticking blackcurrant cuttings in April 2015. Using GPS coordinates, plot corners were re-placed after planting and two further assessments were carried out in June and August 2015 that were done to assess weed cover in the un-mulched alleyways and blackcurrant growth.

Results in 2014 showed that all of the cover crop species tested can suppress many of the annual weed species present effectively, along with some perennial weeds (Figure 2). Success of the cover crop seems to be determined by the rate of establishment and the density of cover achieved by the cover crop. At both of the June and November assessments, the buckwheat plot was the least suppressive of weeds out of the four cover crops and the two grass legume mixes were the most suppressive. In terms of the perennial weed species controlled, again, the grass mixes tended to show greater suppression (Figure 3) with both the rye-grass/clover mix and the creeping red fescue/black medic mix showing little, or no, nettle or thistle in the quadrat survey. Buckwheat and the maize game cover also showed a reduction in thistle. Buckwheat was also the only cover crop which did not show an increase in the level of docks.

Figure 1. Images of the five treated plots in September 2014.

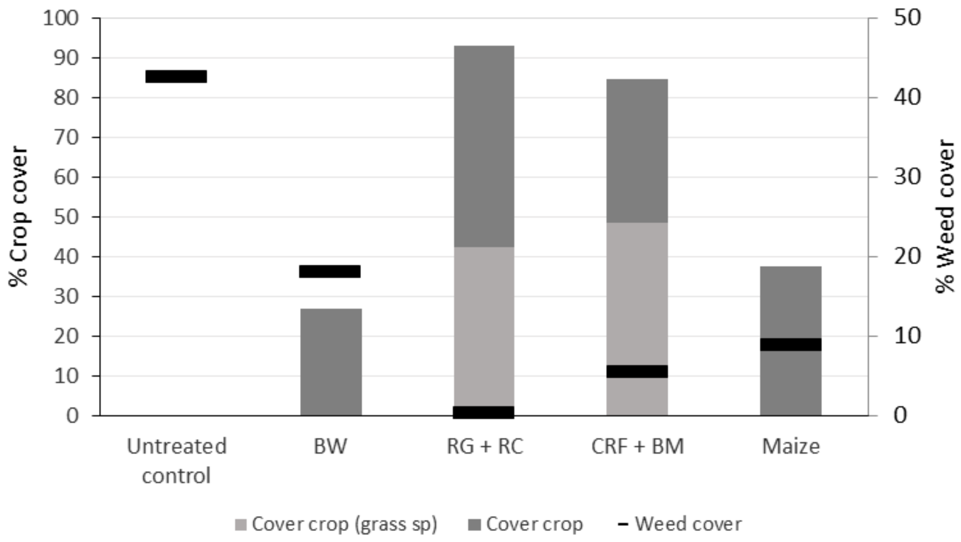

Figure 2. Results from the percentage weed and cover crop assessment (BW = buckwheat, RG + RC = rye-grass + red clover, CRF + BM = creeping red fescue + black medic) - November 2014.

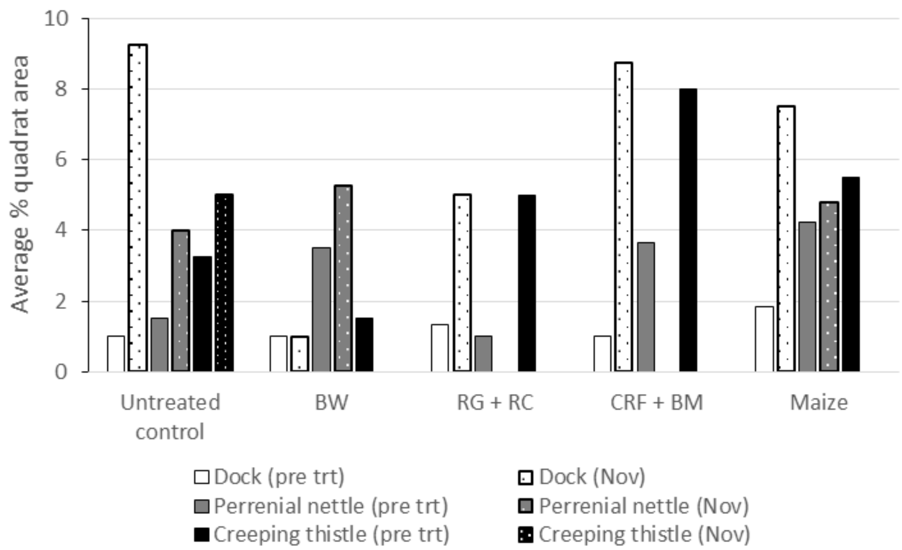

Figure 3. Comparison of the percentage cover of perennial weeds at the pre cultivation/sowing assessment and the November (2014) assessment, six months after sowing (BW = buckwheat, RG + RC = rye-grass + red clover, CRF + BM = creeping red fescue + black medic).

In 2015, the year following the cover crop treatments, at the June assessment, the plot previously sown with the creeping red fescue/black medic mix and the incorporated buckwheat plot had the lowest percentage cover of weeds (Figure 4) and the untreated control plot had the highest percentage of weed cover. On the same date, the rye-grass/red clover mix and the buckwheat incorporated had no creeping thistles in the sampled quadrats, whereas an average of two creeping thistles were found in the maize game cover plots and in the creeping red fescue/black medic mix. The highest number of fat-hen per metre squared was found in the unincorporated buckwheat subplot, 34.5, and the lowest number of fat-hen was found in the rye-grass/red clover mix, 13.3,

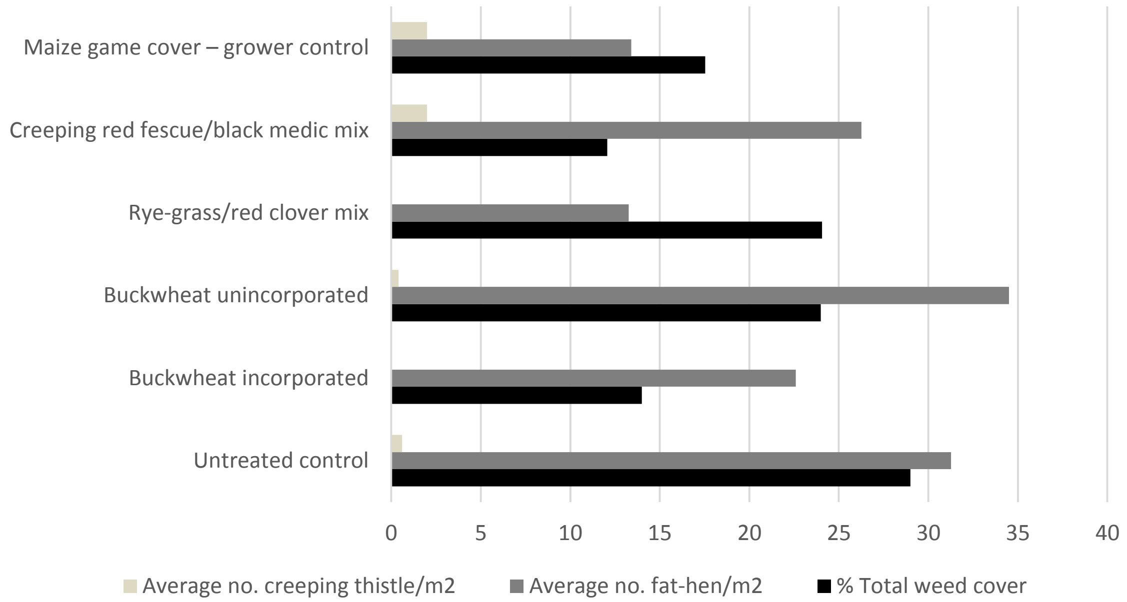

Figure 4. Comparison of mean percentage cover of weeds and mean numbers of individual weed species - June 2015.

There were no significant differences between blackcurrant plant heights at the assessment carried out in August 2015 (Table 2).

Table 2. Average blackcurrant plant height - August 2015.

Treatment	Plant height cm
Untreated control	28.93
Buckwheat incorporated	30.20
Buckwheat unincorporated	32.30
Rye-grass/red clover mix	28.07
Creeping red fescue/black medic mix	35.00
Maize game cover – grower control	35.27
P. value	**0.230**
LSD (69 df)	**7.120**

- All cover crops that were tested showed some suppression of both perennial and annual weeds whilst they were growing in 2014. The grass legume mixes were more suppressive than buckwheat and performed similarly to the maize game cover treatment.
- The following year, once the crop cover had been removed, the residual effect on weeds was harder to assess due to the presence of the pollinator mix that was sown by the grower over all plots after planting.
- Of the weed species present across all plots, there did appear to be differences in number/m^2 with the plots previously sown with buckwheat, creeping red fescue and maize game cover showing fewer weed species in the alley ways than the untreated control and the rye-grass/ clover mix.
- There was clear evidence of volunteer cover crops re-seeding in the alley ways and planting holes, so management strategies after establishment of cover crops prior to crop establishment need to be developed.
- No significant differences in plant height of blackcurrants were observed between the plots in summer 2015.
- The creeping red fescue/black medic mix and the incorporated buckwheat crop covers were the treatments with the best residual effect in 2015 for controlling weeds.

Financial Benefits

Using cover crops as a tool to help control perennial weeds in blackcurrants could reduce labour, harvesting and herbicide treatment application costs. However, a full assessment of the economic benefit cannot be made yet as the longevity of the effect on weed populations and effect on crop yield has not yet been assessed.

Action Points

Growers could consider planting cover crops as an agronomic tool to improve soil structure and health and this could also provide benefit to weed control.

Additional trials

2.8 Alternatives to Basamid in baby leaf salad production

Headlines

- Red clover, the red clover and buckwheat mix and the grass clover mix currently used by the grower all reduced weed cover to 5% during establishment of the cover crops
- The areas that were sown with buckwheat with or without red clover and subsequently colonised by white clover gave the best weed suppression in the 2015 spinach crops.

Background

Weeds are expensive to control in organic salad production systems with few available options to the grower, and all weeds need to be completely removed before harvest to avoid contamination and rejection from retailers. Typical options used are strategically timed cultivations such as stale seed bed technique, hoeing, and weeding just before harvest and appropriate cover crops in the fallow season. In addition in conventional production, the future use of soil sterilants such as Basamid (dazomet) is uncertain and there is increasing interest in the use of alternative methods for weed suppression such as using cover crops.

Cover crops are growing in popularity particularly in arable systems as in addition to their potential for weed suppression, they provide many advantages to soil quality and management through; reduced risk of soil erosion and diffuse water pollution, improving soil structure, organic matter content, water holding capacity and overall soil health. Cover crops are already used in rotation by some salad growers for these latter purposes, including by the grower which hosted the trial. Cover crops can help with weed suppression either directly through physical competition or by chemical action, for example buckwheat (*Fagopyrum esculentum*) has allelopathic properties where root and shoot exudates can inhibit growth of other living organisms, while mustard species can produce bio-fumigant gases when they are cut and incorporated in to soil. However, mustards are not favoured in baby leaf salad rotations due to fears that they may be a host for brassica pests and disease such as club root that can infect wild rocket. Therefore red clover (*Trifolium pratense*) and buckwheat were chosen to be used in the trials as alternatives to the current grass/white clover (*Trifolium repens*) mix that is currently sown.

The objective of this project was to compare the advantages of sowing five different cover crop mixes in an organic salad crop rotation, and assessing their influence on weed suppression and effects on nutrient and organic matter status.

Summary

The work was carried out on a site at a commercial salad grower in Wiltshire on an area of organic land that was being fallowed and sown with cover crops during the summer with the aim to increase soil fertility and also reduce weed burden in the following season. The area is due to be sown with baby leaf spinach in April 2015.

There were five different cover crop species and mixes in total (Table 1), with the area representing current grower practice being sown with a grass/clover ley. Experimental treatments included buckwheat (cv. Kora) and red clover (cv. Formica), and also combinations of these cover crops sown together by intentionally overlapping the application with the spreader. There were no untreated plots. The grass/clover mix and buckwheat was sown by the grower on 17 April using a 24 m fertiliser spreader with spinning discs in areas of one hectare and nearly half a hectare respectively. ADAS staff sowed the red clover on 16 April by hand in an area of 12 m x 50 m. To achieve an area with just red clover in addition to an area with a mix of buckwheat and red clover, ADAS sowed the red clover the day before the buckwheat was sown by the grower and then covered half of the plot with plastic to prevent the buckwheat being over-sown in the red clover only plot. Once sown all the plots were rolled by the grower.

The cover crops were allowed to establish, and then mowed as per current practice in mid-July and again in late August. This is to encourage a mat of material in the grass/clover ley to build organic matter and suppress weeds. It is also done before the cover crop sets seed to prevent problems with volunteers in the commercial spinach crop in the following season.

Table 1. Cover crop treatments and sowing rates – Wiltshire 2014

Treatment no.	Common name	Scientific name	Sowing density (kg/ha)
1	Grass and clover ley Italian Ryegrass cvs. Danergo, Dracar, Fox, Red clover cv. Milvus (grower standard)	Lolium multiflorum +Trifolium pratense	22.5
2	Buckwheat cv. Kora	Fagopyrum esculentum	100
3	Red clover cv. Formica	Trifolium pratense	25
4	Clover and grass/Buckwheat cvs as above	Lolium multiflorum + Trifolium repens/ Fagopyrum esculentum	22.5 + 100
5	Red clover/Buckwheat cvs as above	Fagopyrum esculentum/ Trifolium pratense	25 + 100

During the period of cover crop establishment five randomly selected areas were marked so that progress of establishment could be recorded in the same areas on 6, 19, and 30 May. Percentage of weed species and percentage weed cover were also recorded at these assessments. A final assessment to record cover crop establishment, percentage of weed cover and weed species present was then made on 4 July in five randomly selected areas using a 0.25 m^2 quadrat. Biomass of the cover crops was assessed on 30 October before the cover crops were mown.

A soil sample was taken from the whole trial area before the cover crops were sown to measure soil mineral nitrogen (SMN) to 90 cm in 30 cm increments and pH, P, K, Mg and organic matter (OM) were also measured. Once the cover crops had been mown and incorporated in October, these soil analysis were then repeated from each cover crop area in November to assess the effects of the cover crops on these parameters. The soil sampling will be repeated in April 2015 to assess the effects of the cover crops on spring levels of SMN, pH, P,K, Mg and OM.

The weed species were assessed before the site was cultivated and common chickweed (*Stellaria media*) was the major weed occurring at 75% when considered as a proportion of all the species seen. Other species included amsinkia (*Amsinckia intermedia*), shepherd's purse (*Capsella bursa-pastoris*), fat hen (*Chenopodium album*), volunteer wild rocket (*Diplotaxis tenufolia*), willowherbs (*Epilobium* sp.), crane's bill (*Geranium molle*), pineappleweed (*Matricaria disciodes*), annual meadow grass (*Poa annua*), knot-grass (*Polygonum aviculare*), groundsel (*Senecio vulgaris*), volunteer spinach (*Spinacia oleracea*), sow-thistle (*Sonchus* sp), scentless mayweed (*Tripleurospermum inodorum*), small nettle (*Urtica urens*) and common field-speedwell (*Veronica persica*).

In 2015 the weed levels were then assessed in the spinach crops subsequently established in each of the areas where the cover crop treatments had been grown in 2014. Within each treatment area weed species and number were recorded within 20 randomly selected areas using a 0.25 m^2 quadrat.

Results

In the first year of the trial, cover crop establishment was one of the key aspects that was measured and all of the cover crop treatments germinated and established well, reaching at least 70% ground cover by 4 July 2014 at 11 weeks after sowing. Red clover sown with buckwheat was the quickest to establish by the end of May (six weeks after sowing) reaching 81% cover, and red clover alone was second quickest reaching 71% cover at the same date The clover and grass mix was initially slower to establish in the first six weeks but, by 4 July 2014 the grass/clover mix had established the greatest percentage of ground cover at nearly 100%, with the red clover and buckwheat mix also giving greater than 90% ground cover (Figure 1).

Grass clover mix (grower standard)

Grass clover mix/buckwheat

Buckwheat/grass clover mix

Buckwheat

Buckwheat/red clover

Red clover

Figure 1. Appearance of cover crop treatments on 4 July 2014 at flowering and just before mowing, Wiltshire, 2014.

The cover crops were all mown in mid-July and again at the end of August to prevent the cover crops reaching seed, which is done to avoid volunteers germinating in the following commercial organic spinach crop. Due to this mowing, the buckwheat failed to re-establish and white clover grew extensively in its place. In hindsight a different mix could have been used as it does not respond well to being mown before it seeds. Nevertheless, there were still treatment differences in weed emergence noted when areas were assessed in 2015 after the commercial spinach crops were drilled.

Biomass was measured in October and the treatments containing the greatest proportion of clover gave the highest fresh weight per quadrat equating to 23.9 to 40.8 tonnes/ha of material.

The percentage of weed cover was assessed during establishment of the cover crops and red clover gave the best weed suppression, slightly better than the current clover grass mix used by the grower, but not significantly so. Buckwheat did not significantly suppress weeds compared to the other cover crop treatments during the first month of establishment, but once it had established a good canopy through June, competition for light and possible allelopathic effects meant that weed cover was reduced from 75% at the 30 May assessment to 15% at the 4 July assessment (Figure 2). The red clover and buckwheat mix also gave very slightly better weed suppression than the clover-grass mix. By the time the cover crops were ready for incorporation the successive periods of mowing had encouraged a mat of organic matter to form at the soil surface, which suppressed all weed growth in October in all treatments. This appeared to be greatest in the treatments with a higher proportion of grass. This would be due to the higher carbon: nitrogen ratio that grass has compared to clover, meaning that breakdown of the remaining debris is slower.

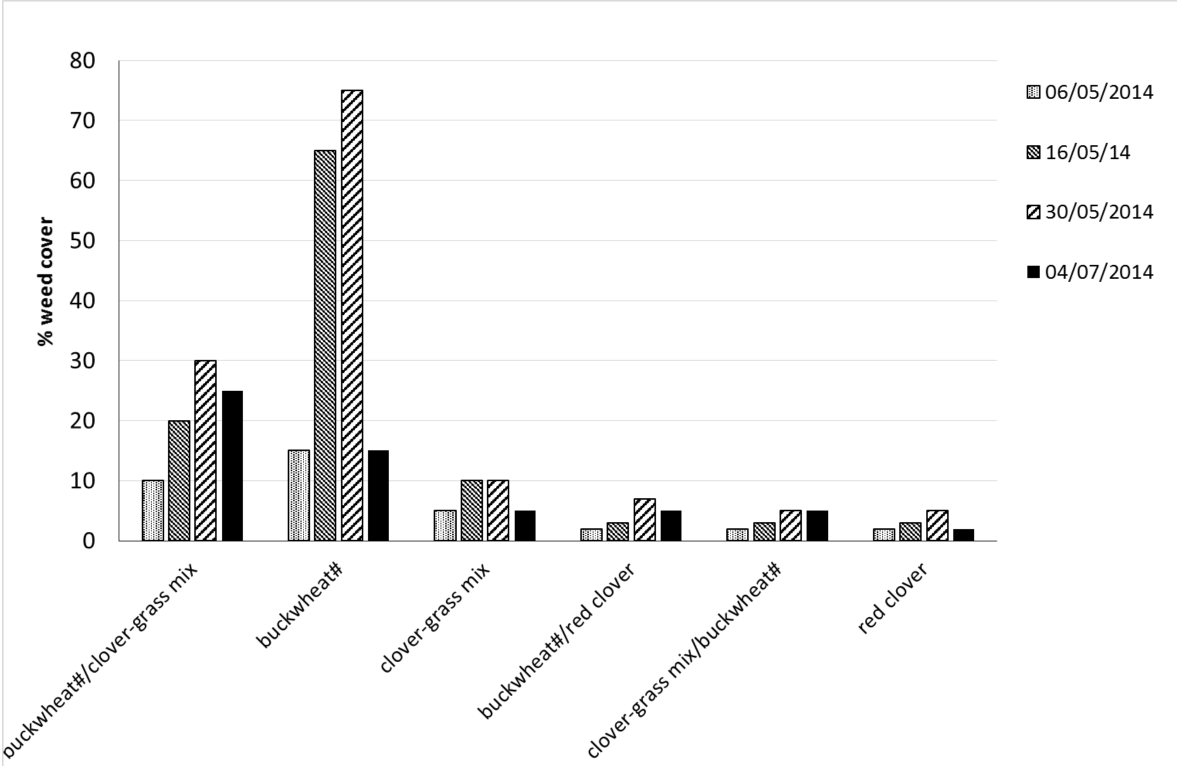

Figure 2. Percentage weed cover between the six cover crop treatments from May to July, Wiltshire, 2014. (# buckwheat was replaced by white clover after 4 July as it failed to re-establish).

Measurements taken to consider the nutrient uptake and influence of the cover crops on soil fertility showed no significant differences in N uptake between the original treatments that were sown, but the buckwheat plots had the lowest SMN in November (Table 2). This could be an advantage as the highest risk to leaching in winter is nitrogen left in soil rather than crop residues.

Table 2. Soil available N, P, K or Mg content (Index in brackets) and pH results in November after incorporation, 2014 and in soil available N in spring 2015. (Soil Index in brackets)

Treatment	pH	Organic Matter (%)	Available SMN Autumn 2014 (kgN/ha)	Available SMN Spring 2015 (kgN/ha)	P (mg/L)	K (mg/L)	Mg (mg/L)
Grass and clover ley (grower standard)	7.4	3.8	131.8 (4)	75.1 (1)	103 (6)	490 (4)	91 (2)
Buckwheat cv. KORA	7.1	4.4	47.1 (0)	138.5 (4)	104 (6)	468 (4)	102 (3)
Red clover cv. FORMICA	7.3	4.7	112.4 (3)	132.3 (4)	108 (6)	602 (5)	106 (3)
Clover and grass/Buckwheat	7.3	5.0	46.1 (0)	105.5 (3)	104 (6)	577 (4)	98.5 (2)
Buckwheat/clover and grass	7.0	4.8	56.6 (0)	124.9 (4)	106 (6)	589 (4)	105 (3)
Red clover/Buckwheat	7.2	4.4	69.4 (1)	120.7 (3)	115 (6)	575 (4)	110 (3)

In the second year of the trial (2015) the effects on weeds in the following crop was recorded. Buckwheat (subsequently colonised by white clover) alone and red clover with buckwheat (subsequently colonised by white clover) gave best overall weed suppression in the spinach crops drilled in spring/summer 2015 (Figure 3). This was due to improved suppression of small nettle and volunteer clover, but the suppression of chickweed remained equivalent to the current grower standard. This indicates that even though the buckwheat failed to re-establish after topping, the possible allelopathic qualities of the species may have still suppressed the growth of some susceptible weeds.

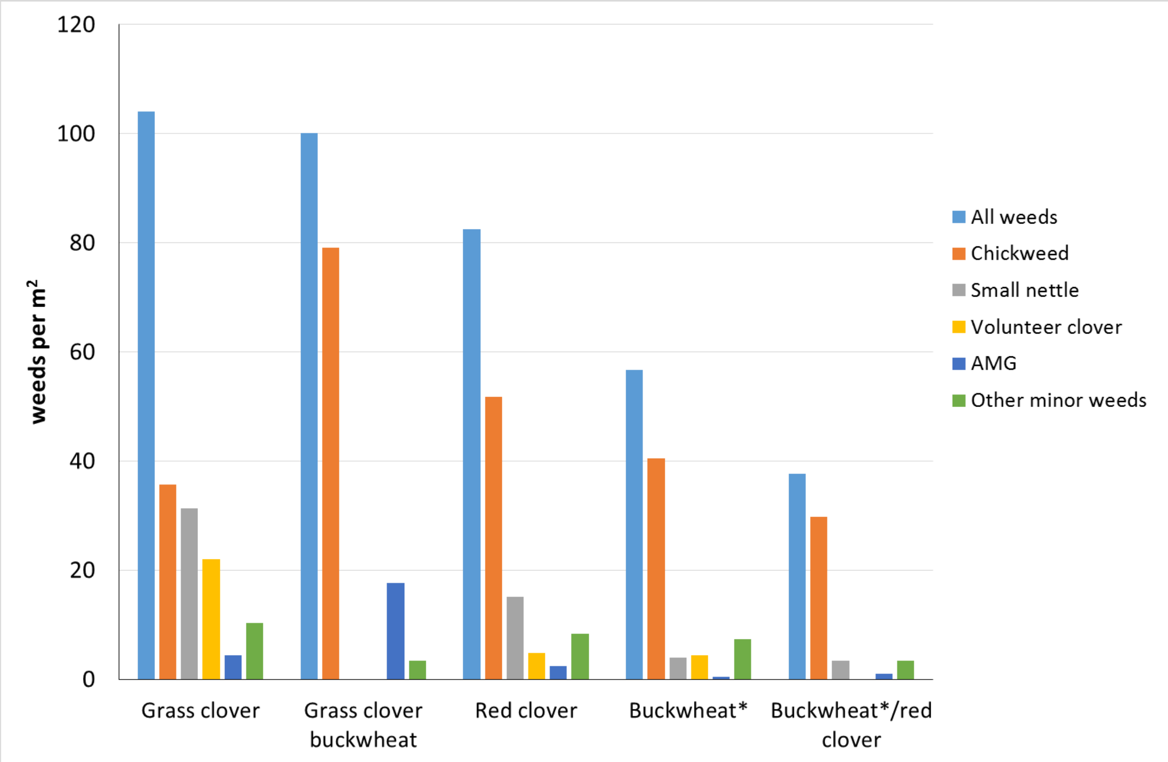

Figure 3. Comparison of weeds per m^2 weed cover in the subsequent spinach crops drilled in the areas after the cover crop treatments. June, Wiltshire, 2015. (* buckwheat was replaced by white clover after 4 July 2014 as it failed to re-establish).

There was also an increase in the amount of available SMN in spring 2015 (Table 2) in the areas which were sown with the cover crops which contained a larger proportion of clover, with increased nitrogen remaining when compared with the grower standard grass/clover ley. Although there was clover in the grass/clover ley, this was predominantly a grass ley and as grass has a higher carbon:nitrogen ratio it would breakdown slower with less readily available N in spring in comparison to the clover cover crops which release N at a quicker rate. This increased SMN would be useful for the following spinach crops, and would allow the grower to reduce rates of manufactured fertiliser. However, the amount of SMN may vary year on year with overwinter rainfall, and in the 2014/15 winter the rainfall was lower than average in the area where the trial was carried out. This indicates that it would be prudent to test for SMN to rooting depth before drilling a following crop to take account of the correct levels of SNS where cover crops have been used.

Financial Benefits

Using cover crops as a tool to help control weeds in salad crops could reduce fertiliser, labour and soil sterilant treatment application costs. Soil sterilisation costs £2000/ha even before the cost of application, but as it is carried out only every 3 years this works out to £666/ha per year (not including application costs). Depending on the seed chosen, establishing a cover crop costs £340/ha for the grower standard grass/clover mix, £350/ha for the red clover, and £580/ha for the buckwheat cover crop. The best treatment was the buckwheat/red clover mix which would cost £730/ha for the seed and establishment. Although this is an equivalent cost to sterilisation, at least 100 kg N/ha was available to the following spinach crop in spring, and therefore this would save approximately £100/ha.

Ground preparation = £200/ha

Grass/White clover at 22.5 kg/ha costs £140/ha

Red clover at 25 kg/ha costs £150/ha

Buckwheat at 100kg/ha costs £380/ha

Together = £530/ha

Action Points

Growers could consider planting cover crops as an agronomic tool, especially in organic rotations to improve soil structure, increase organic matter and also provide weed suppression in the fallow and subsequent year of drilling.

2.10 Leek contact herbicide screen – alternatives to Totril in programmes

Headlines

- At six weeks after treatment all treatment combinations were crop safe, but it should be noted that the herbicides were applied when risk of scorch to the crop would be lowest
- The greatest level of phytotoxicity was seen when Buctril (bromoxynil) was tank mixed with Afalon (linuron)
- Buctril gave a similar level of weed control to Totril both as a standalone product and in tank mixes

Background

The control of weeds in leek crops in the early part of the season soon after crop emergence is challenging. This is because the crop is sensitive to a number of herbicides before the leeks reach two true leaves. At this stage weeds are suppressed as long as possible by pre-emergence residual herbicides and low doses of contact herbicides. It's not until after this growth stage that combinations of stronger contact herbicides can be used to gain control of troublesome weeds such as groundsel (*Senecio vulgaris)*, mayweed *(Tripleurospermum inodorum)*, field pansy *(Viola arvensis)* and chickweed *(Stellaria media).* Previously Totril (ioxynil) was used in combination with other contact herbicides such as Starane 2 (fluroxypyr), Afalon (linuron) or Basagran SG (bentazone) at this later stage to gain effective control of more troublesome weeds that escape control from the earlier herbicide applications. However, ioxynil will be withdrawn at the end of August 2016 leaving a gap in programmes. Bromoxynil (Buctril) has gained approval in alliums and is aimed at a similar place in grower programmes but it's crop safety and weed spectrum is different to ioxynil, and therefore growers require information on the efficacy and crop safety of bromoxynil to allow them to use the product safely and effectively.

The main objective of the trial was to assess the crop safety and efficacy of Buctril alone and in typical grower programmes with commonly used tank-mix partners such as Starane 2, Afalon and Basagran SG.

Summary

Work was carried out on a commercial field crop of leeks cv. Pancho. The crop was drilled on 30 April and the crop would have been due for harvest in November 2015. The soil is a sandy loam and the major weeds were groundsel, volunteer oilseed rape *(Brassica napus ssp. oleifera),* mayweed and red dead-nettle *(Lamium purpureum).* Fat hen *(Chenopodium album)*, sow thistle *(Sonchus* spp*.)*, black bindweed *(Fallopia convolvulus)*, common chickweed, willowherb *(Epilobium* spp), annual meadow grass (*Poa annua)*, charlock *(Sinapsis avensis)*, Canadian fleabane *(Conyza canadensis)*, and crane's-bill *(Geranium molle)* also appeared in many plots in the trial but not as frequently.

The trials were a fully randomised block design with nine main treatments including an untreated control, and included a grower practice control of Totril in a tank mix with Starane 2 and Basagran SG. The same treatments were applied twice as per grower practice. (Tables 1 and 2). There was four-fold replication, and each plot was 5 m long and 3 m wide.

Table 1. Treatments applied to plots in 200 L water per hectare. Lincolnshire, 2015.

Treatment no.	Product	Rate
1	Untreated	-
2	Buctril	0.89 L/ha
3	Buctril + Afalon	0.53 L/ha + 0.3 L/ha
4	Buctril + Basagran SG	0.53 L/ha + 0.3 kg/ha
5	Buctril + Basagran SG + Starane 2	0.53 L/ha + 0.3 kg/ha + 0.3 L/ha
6	Totril	0.3 L/ha
7	Totril + Afalon	0.3 L/ha + 0.3 L/ha
8	Totril + Basagran SG	0.3 L/ha + 0.3 kg/ha
9 (Standard)	Totril + Basagran SG + Starane 2	0.3 L/ha + 0.3 kg/ha + 0.3 L/ha

The crop in the trial area was managed as per commercial practice, including herbicide applications, until two true leaves was reached. At this leek growth stage the site was marked out and the experimental treatments were applied on 15 June. Weeds in the plots were at the growth stages of cotyledon to two true leaves at the time of application. The same experimental applications were applied again on 30 June, and at this point the crop had reached four true leaves. The treatments were applied to the beds using an OPS sprayer and a 3.0 m boom with 02F110 nozzles, to achieve a medium spray quality at 200 L/ha, and sprays were applied early morning.

The trial was assessed at each spray application timing and on three occasions post treatment; approximately two, four and six weeks after the application of the treatments; on 15 June, 30 June, 8 July, 29 July and 16 August. Plots were assessed for phytotoxicity effects, percentage weed cover, numbers of weeds per m^2 and weed species were also recorded.

Results

Buctril has been approved recently for use on leeks to fill the gap that will be left in programmes when the approval for Totril is lost in August 2016. There were crop safety issues in alliums with another form of bromoxynil which led to approvals on alliums being withdrawn by the manufacturer due to crop safety issues. All of the treatment combinations showed no or little phytotoxic effects to the leeks by six weeks after the 2nd application (Table 3), and no significant differences were seen between treatments. However, we took care to spray early morning before weather got too hot, and in a practical commercial situation operators would not always be able to avoid spraying in higher risk situations such as midday in hot sun, to take advantage of spray opportunities when windows of application are restricted. This may have highlighted more differences or given greater phytotoxicity.

Table 3. Mean scores for phytotoxicity, weed count and weed cover in leek herbicide screens six weeks after the 2nd herbicide applications – Lincs, 2015.

Treatment	Phytotoxicity (0-9)	weed count (m^2)	weed cover (%)
Untreated	9.0	89.0	45.0
Buctril	8.7	61.0	35.3
Buctril + Afalon	7.7	71.7	21.5
Buctril + Basagran SG	8.3	71.3	23.3
Buctril + Basagran SG + Starane 2	7.7	46.3	14.9
Totril	8.3	60.0	19.3
Totril + Afalon	7.7	64.3	21.8
Totril + Basagran SG	8.5	72.7	24.3
Totril + Basagran SG + Starane 2	8.5	38.7	17.2
F pr.	NS	NS	NS
l.s.d (24 d.f)	-	-	-

Nevertheless, some differences in crop safety were seen at two and four weeks after the final spray applications. Those plots treated with Buctril and Afalon, and Totril alone showed damage below a commercially acceptable standard which was exhibited as stunting and yellowing by the former combination, and thinner plants when treated with Totril alone. The combination of Buctril, Basagran SG and Starane 2 and Buctril alone were also only just at an acceptable level of phytotoxicity at two weeks post application. The slight damage from this combination was mainly exhibited as stunting to the plants. At four weeks post-application, only the plots treated with Buctril and Afalon or Buctril, Basagran SG and Starane 2 showed continuing effects as yellowing and stunting but were recovering to a nearly commercially acceptable appearance at this point.

When comparing the two products, Buctril and Totril used alone gave similar results in phytotoxic effects. But when Buctril was combined in a tank mix with either Afalon, or Basagran SG and Starane 2 then there was a slight increase in phytotoxicity scores at 4 weeks after treatment, and length taken to recover from the sprays when compared to the tank-mixes with Totril. Scores were reduced to 6.75 to 7.25 for leeks treated with these Buctril tank-mixes, compared to scores of 7.75 and 8.25 for the Totril tank-mixes at this assessment. But, as aforementioned the affected plots recovered and grew through this effect over the following month.

No significant differences in weed control were seen at assessments completed at least two weeks post-application. Germination of weeds in the trial were low due to the dry weather through June and July, but increased in August when showers returned and gave a flush of weeds at the final assessment. There were no significant differences at the final assessment, but the data shows a trend by all treatments for a reduction in weed numbers, with the 3-way tank mixes of Totril or Buctril in combination with Basagran SG and Starane 2 giving the lowest weed counts at the final assessment (Table 3). The level of weed control given by Buctril and the Buctril tank-mixes was similar when compared with Totril and the Totril tank-mixes which it is replacing.

Financial Benefits

Growers may not see much immediate change in financial benefit, but the loss of crop due to herbicide scorch can be mitigated by a greater confidence in careful use of Buctril as a replacement for Totril. This would be by considering timing of application and selection of tank-mixes to avoid crop scorch.

Action Points

- Growers can be reassured that if applied early morning when the risk of scorch is low all treatment combinations were crop safe and no commercially unacceptable effects were seen at six weeks after application
- Applying the Buctril treatments in hot weather or full sun should be avoided as the crop safety of the treatments was not tested in these situations and crop losses could still occur
- The greatest level of phytotoxicity was seen when Buctril was tank mixed with Afalon (linuron)
- Buctril gives a similar level of weed control to Totril both as a standalone product and in tank mixes, and the 3-way tank mixes of Basagran SG and Starane 2 with Totril or Buctril gave the greatest reduction in weeds but this was not significant

SCIENCE SECTION

2.4.5. Wild rocket and baby leaf lettuce herbicide screens

Introduction

The control of weeds in short season baby leaf salad crops can be difficult, especially in crops such as wild rocket and baby leaf lettuce which are sensitive to a number of commercially available herbicides. Crop rotations and soil sterilants such as Basamid (dazomet) are used to reduce the weed population before drilling a crop. However, a number of weeds can still be problematic, particularly Compositae such as groundsel (*Senecio vulgaris)* and sowthistle *(Sonchus sp.)*, as well as other species such as shepherds purse *(Capsella bursa-pastoris)*, nettles *(Urtica urens)* and fat hen *(Chenopodium album)*. Weed pressure increases through the season, with more problems seen in second or third crops which are drilled during the summer after the first crop has been harvested. Hand weeding the crop before harvest is frequently necessary but is expensive (c. £200/ha) and with the threat of the possible loss of soil sterilants in the future, additional herbicides for use in baby leaf lettuce are needed to increase the range of weeds controlled. When added to a tank mix with Devrinol, Goltix Flo gave control of groundsel in wild rocket in trials carried out under CP 086 in 2013 but when the possibility of an EAMU was investigated, there were issues with gaining approval with regards to operator exposure which gave an obstacle to approval. Therefore options still needed testing, and the pre-drilling incorporation of products containing dimethenamid-P was thought to improve safety to the crop compared with post-drilling application, and worthy of investigation.

The main objective of the trial was to assess the crop safety of two herbicides containing dimethenamid-P at a range of rates when applied as incorporated treatments. In addition control of annual weeds in drilled baby leaf lettuce and wild rocket grown for salad leaf was assessed. Products tested were Wing-P (dimethenamid-P + pendimethalin), H41 and a coded product H23 for which incorporation is recommended by the manufacturer.

Materials and methods

Site 1 and 2 - Wiltshire

Work was carried out on a commercial field crop of wild rocket of Shamrock standard SSC variety and a crop of red Batavia baby leaf lettuce cv. Redbat. Both were drilled on 19 June 2015 with the baby leaf lettuce due for harvest on 14 July 2015 and the wild rocket due for harvest on 22 July 2015. Soil sterilisation has been used at the site and the soil is a sandy loam. Major weeds were; sow thistle and groundsel in both trials, with small nettle also a major weed in the wild rocket trial, and volunteer wild rocket and crane's-bill *(Geranium molle)* a major problem in the baby leaf lettuce trial. Shepherds purse *(Capsella bursa-pastoris)*, knotgrass *(Polygonum aviculare),* black nightshade *(Solanum nigrum)*, annual meadow grass *(Poa annua)* and fat-hen also appeared in many plots in the baby leaf lettuce trial but not as frequently.

Site 3 – Sussex

Work was carried out on a commercial field crop of wild rocket cv. Torino drilled 30 June and due for harvest 28 July 2015 and the soil is a silty clay loam. There was a different spectrum of problem weeds at this site including; shepherd's purse, knotgrass, redshank *(Persicaria maculosa)*, and common chickweed *(Stellaria media).*

Site 4 – Sussex

Work was carried out on a commercial field crop of wild rocket cv. Torino drilled 11 August and due for harvest 14 September 2015 and the soil is a silty clay loam. There was a wider spectrum of problem weeds at this site including; shepherd's purse, groundsel, redshank, common chickweed, mayweed *(Tripleurospermum inodorum)*, knotgrass, annual meadow grass and sowthistle

Sites 1, 2 and 3

The trials were a fully randomised block design with twelve main treatments including a double untreated control, and included a grower practice control of Devrinol (napropamide). All treatments were applied to the beds and then incorporated using the commercial farm equipment usually used at each site. However, it should be noted that Devrinol is not a standard product used by growers in baby leaf lettuce due to crop safety issues. (Tables 1 and 2). There was four-fold replication, and each plot was 5 m long and 1.5 m wide.

Table 1. Treatments applied to plots in 400 L water per hectare. Wiltshire and Sussex, 2015.

Treatment no.	Product	Rate
1 + 2	Untreated	-
3 (Standard)	Devrinol	0.86 L/ha
4	H23	1/3 N
5	H23	1/6 N
6	H23	1/9 N
7	H41	Normal rate (N)
8	H41	½ N
9	H41	¼ N
10	Wing-P	1.25 L/ha
11	Wing-P	0.63 L/ha
12	Wing-P	0.3 L/ha

Table 2. Active ingredients and approval status of products used in the trials. Wiltshire and Sussex, 2015.

Product	Active ingredient	Approval status	Application timing requirements
Devrinol	napropamide 450 g/L	EAMU	Pre-planting
Wing-P	dimethenamid-P 212.5 g/L + pendimethalin 250 g/L	EAMU	Prior to transplanting or crop emergence
H23	-	Not approved in the UK, approved in the EU	-
H41	-	Not approved in baby leaf crops, approved on a range of brassicas	-

After bedforming, the site was marked out and the treatments were applied on 18 June at Wiltshire and 30 June and 11 August at Sussex. The treatments were applied to the beds using an OPS sprayer and a 1.5 m boom with 02F110 nozzles, to achieve a medium spray quality at 400 L/ha. The markers were then removed and the treatments were incorporated by a second pass with the bedformer. The crop was drilled within 24 hours of application and incorporation of the herbicide treatments at all sites. The trial was re-marked out after drilling.

Site 4

The trial was a fully randomised block design with eight main treatments including a double untreated control, and included a grower practice control of Devrinol (napropamide). A higher rate of H23 was tested in this trial, and the ½ and ¼ rates of Wing-P were repeated to give further information on crop safety and efficacy. All treatments were applied to the beds on 11 August and then incorporated using the commercial farm equipment usually used at each site (Table 3). There was four-fold replication, and each plot was 5 m long and 1.5 m wide.

Table 3. Treatments applied to plots in 400 L water per hectare. Sussex, 2015.

Treatment no.	Product	Rate
1 + 2	Untreated	-
3 (Standard)	Devrinol	0.86 L/ha
4	H23	3/4 N
5	H23	1/2 N
6	H23	1/4 N
7	Wing-P	0.63 L/ha
8	Wing-P	0.3 L/ha

Approval status as in Table 2

Assessments

All trials were assessed on at least three occasions; approximately two, three and four weeks after the application of the treatments and at harvest; on 1 July, 6 July, 14 July and 22 July in the baby leaf lettuce and wild rocket trials in Wiltshire. At the Sussex sites assessments took place on 13 July, 21 July and 27 July at the first site, and 26 August, 4 September and 14 September at the second site. 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 weed incidence by counts per three quadrats per plot. Weed species were also recorded. Data was analysed by ANOVA.

Results

Site 1 – Wild rocket, Wiltshire

H23 applied pre-emergence and incorporated was crop safe to wild rocket at rates used in this trial. These ranged from 1/9 to 1/3 of the full rate. At this site, a few small plants were noted in the plots where H23 was applied at the highest rate of 1/3 'normal' label rate, but overall the plots were scored to be commercially acceptable with no distortion of growth or obvious stunting seen (Figure 1). Whereas, H41 killed the crop at the normal approved rate with barely any crop emerging in these plots, and even at ¼ of the normal rate very little crop emerged and what did emerge was stunted and deformed, with thickened and twisted leaves. Wing-P also caused unacceptable phytotoxicity at all of the rates used at this site. Although levels of emergence were higher than plots treated with H41, this was still not at a commercially acceptable level and at the normal approved rate and ½ approved label rate stunted, distorted and twisted plants of rocket were seen. At ¼ of the approved label rate of Wing-P, emergence and crop appearance improved greatly but not to an acceptable level and an occasional stunted plant was still seen (Figure 2).

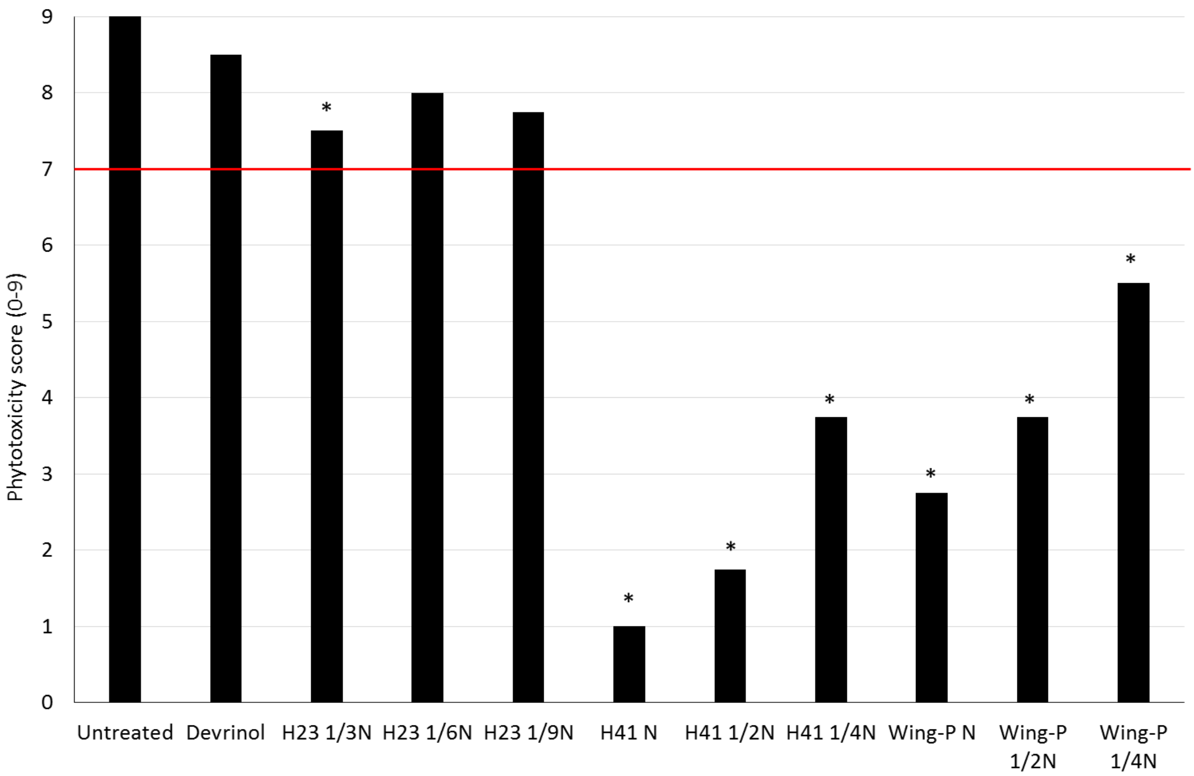

Figure 1. Phytotoxicity scores at harvest for treatments applied to wild rocket, Wilts, 2015 (red line marks the level at which phytotoxicity effects are commercially acceptable, * = significantly different from the grower standard).

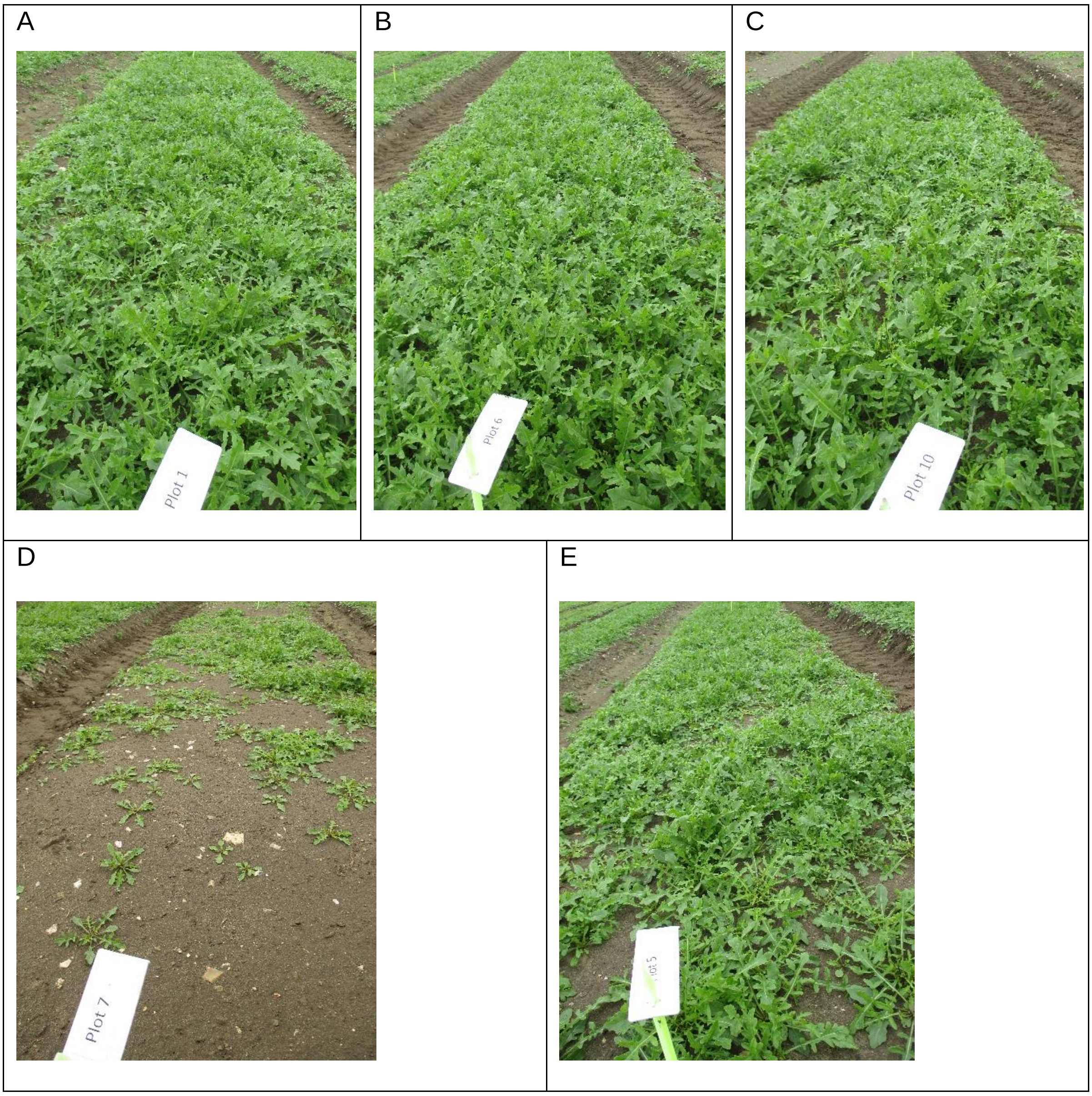

Figure 2. Comparison of crop appearance of A) an untreated plot and B) Devrinol (standard), C) H23 at 1/3 rate, D) H41 at ¼ rate and E) Wing P at ¼ rate, Wilts, 2015.

Crop stand results followed a similar pattern to phytotoxicity, and percentage ground cover in the plots where H23 was applied were very similar to levels in the current grower standard and the untreated plots, further confirming the crop safety of the product in wild rocket. However, in contrast, percentage ground cover was significantly reduced by between 70 to 94% where H41 was used. Barely any wild rocket emerged at all when the full label rate of H41 was used, and even at ¼ of the full rate only 26% crop stand was achieved (Figure 3).

Wing-P also significantly reduced crop stand to below commercially acceptable levels, but not to as great an extent as product H41.

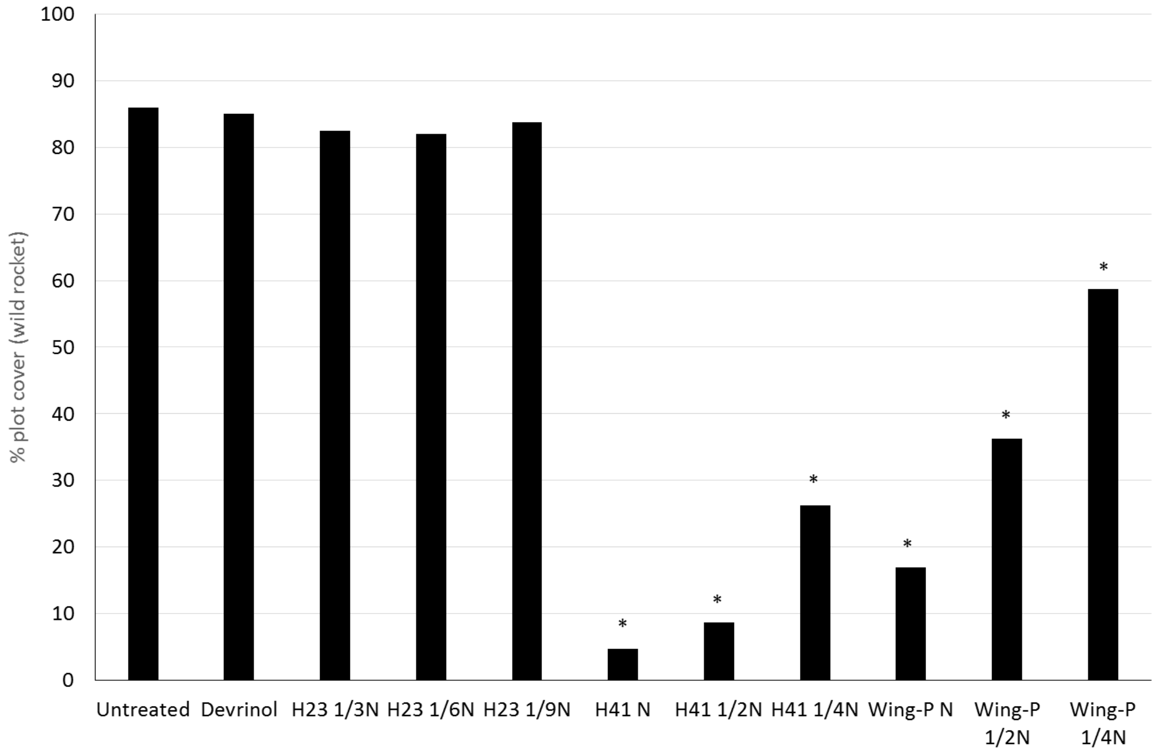

Figure 3. Crop stand of wild rocket at harvest as % plot cover. Wilts, 2015 (* = significantly different from the grower standard).

The weed population was very low at this site and there were no significant differences

Site 2 – Baby leaf lettuce, Wiltshire

H23 applied pre-emergence and incorporated was crop safe to baby leaf lettuce at all rates used in the trial, these ranged from 1/9 to 1/3 of the full rate. Again, at this site, a few small plants were noted in the plots where H23 was applied at the highest rate of 1/3 'normal' label rate, but overall the plots were scored to be commercially acceptable with no distortion of growth or obvious stunting seen (Figure 4). Devrinol caused stunting and reduced crop stand, and is not usually used on baby leaf lettuce for this reason. Kerb Flo (propyzamide) is the typically used commercial grower standard.

As with the wild rocket, H41 killed the crop at the normal approved rate with barely any crop emerging in these plots (0.4% plot cover at harvest). Even at ¼ of the normal rate plot cover only reached 13% and what did emerge was stunted and deformed, with thickened and twisted leaves. Wing-P also caused unacceptable phytotoxicity at all of the rates used at this site. Although levels of emergence were higher than plots treated with H41, this was still not at a commercially acceptable level and at the normal approved rate and ½ approved label rate stunted, distorted and twisted plants of baby leaf lettuce were seen. At ¼ of the approved label rate of Wing-P, emergence and crop appearance improved greatly but an occasional stunted plant was still seen.

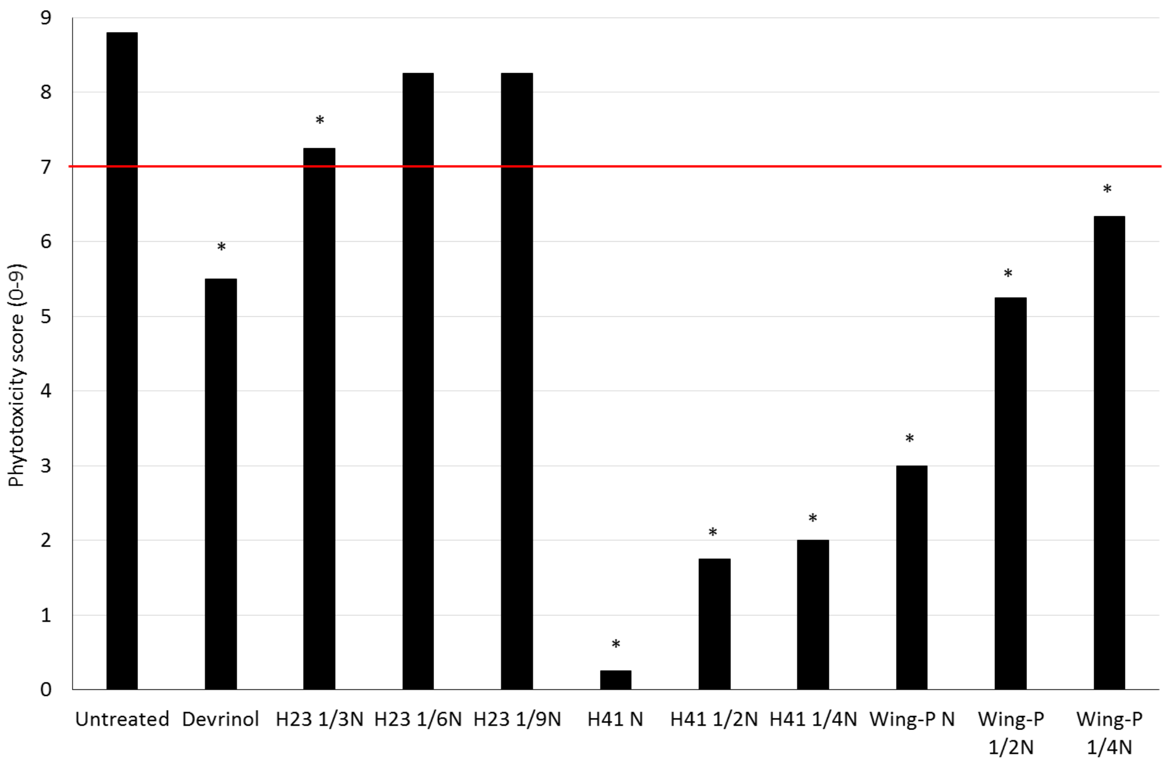

Figure 4. Phytotoxicity scores at harvest for treatments applied to baby leaf lettuce, Wilts, 2015 (red line marks the level at which phytotoxicity effects are commercially acceptable, * = significantly different from the grower standard).

Crop stand results followed a similar pattern to phytotoxicity, and percentage ground cover in the plots where H23 was applied at 1/3 and 1/6 of the full rate were very similar to levels in the untreated plots, showing crop safety of the product at these rates in baby leaf lettuce. At 1/3 of the full rate there was a slight reduction in crop stand but this was not significant and would still be commercially acceptable. In contrast, percentage ground cover was significantly reduced by between 86 to 99.6% where H41 was used with baby leaf lettuce being more sensitive to this product than the wild rocket. Barely any baby leaf lettuce emerged at all when the full label rate of H41 was used, and even at ¼ of the full rate only 13% crop stand was achieved (Figure 5). Wing-P also significantly reduced crop stand to below commercially acceptable levels when applied at full rate or ½ of the full rate, but not to as great an extent as product H41. Wing-P at ¼ of the full rate did not significantly reduce the crop stand of baby leaf lettuce, but there were still phytotoxic effects as aforementioned and therefore it is not crop safe to use on baby leaf lettuce grown on light soils.

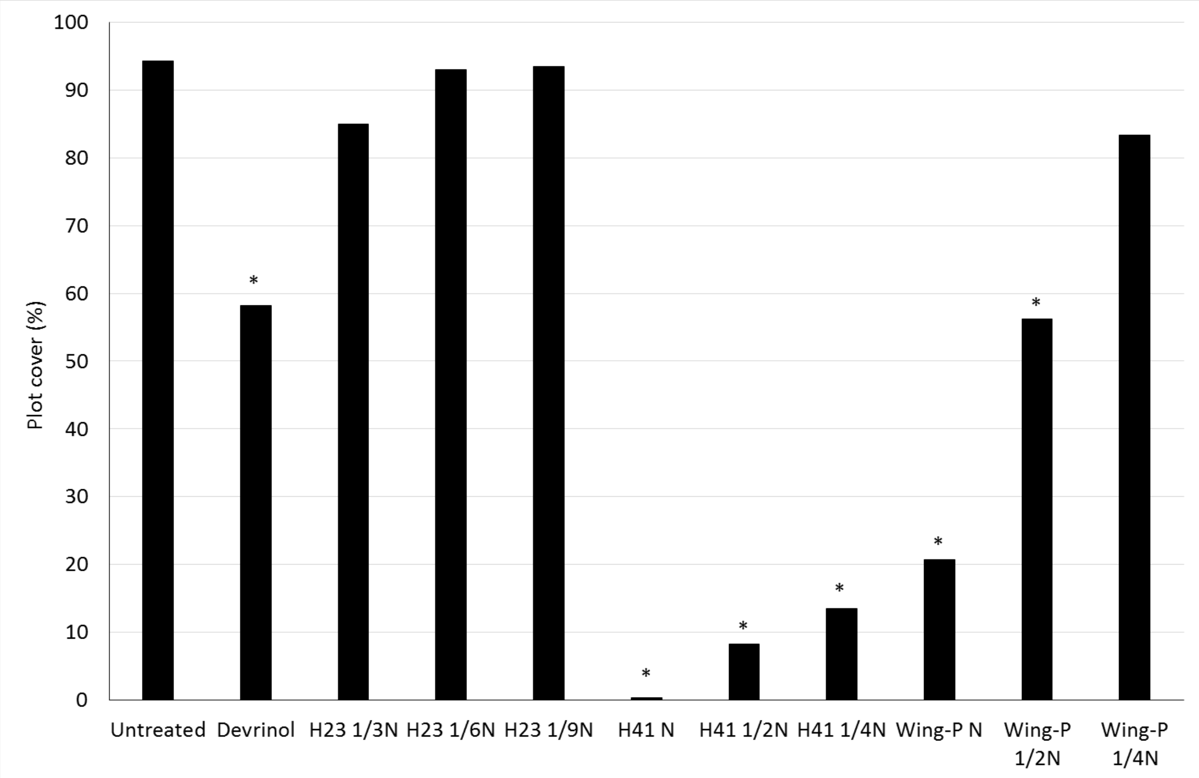

Figure 5. Crop stand of baby leaf lettuce at harvest as % plot cover. Wilts, 2015 (* = significantly different from the grower standard).

All herbicides significantly reduced weed levels but it should be noted that weed levels were low with only six weeds per plot in the untreated. Wing-P and H41 applied at full rate gave the greatest reduction in weed levels, with control increasing as the rate of herbicide used increased (Figure 6).

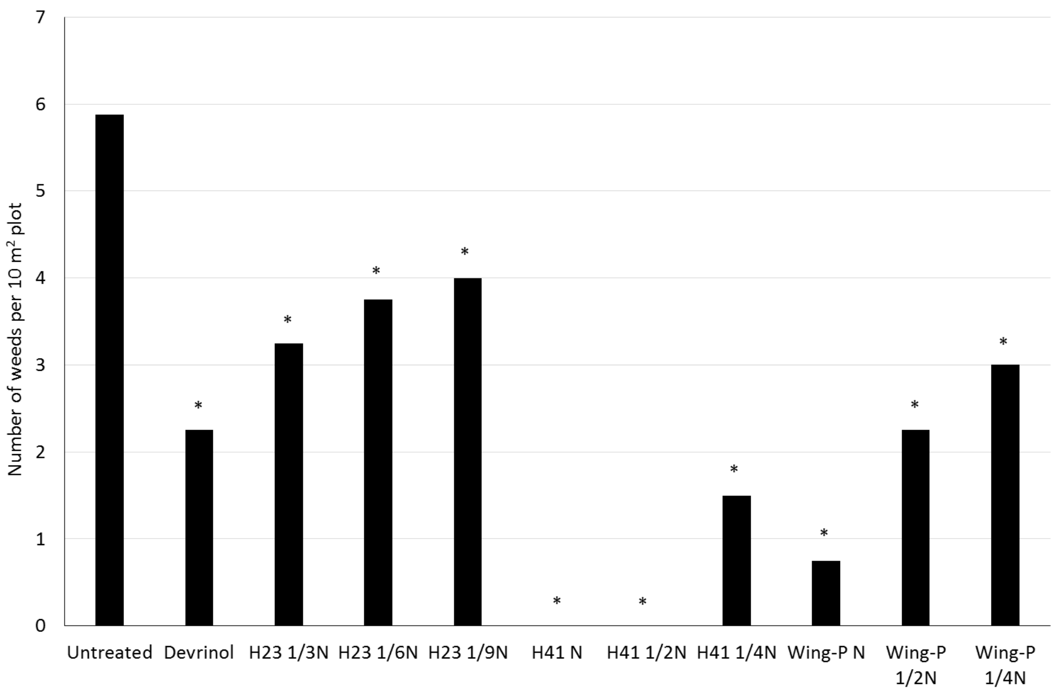

Figure 6. % weed cover at harvest, Wiltshire, 2015 (* = significantly different from the untreated).

Table 3. Mean scores for phytotoxicity, % emergence and weed count in wild rocket and baby leaf lettuce herbicide screens at harvest – Wiltshire, 2015.

Treatment	**Phytotoxicity (0-9)**		**% emergence**		**weed count (per 10m^2)**	
	Wild rocket	Baby leaf lettuce	Wild rocket	Baby leaf lettuce	Wild rocket	Baby leaf lettuce
Untreated	9.0	9.0	86.0	95.2	2.3	15.0
Devrinol	8.5	5.5	85.0	**58.2**	0	9.7
H23 1/3 N	7.5	7.3	82.5	85.0	0.5	**9.5**
H23 1/6 N	8.0	8.3	82.0	93.0	1.5	10.5
H23 1/9 N	7.7	8.3	83.8	93.5	1.7	11.5
H41 N	1.0	0.3	**4.8**	**0.4**	0	**0.0**
H41 ½ N	1.7	1.7	**8.8**	**8.2**	0	**0.0**
H41 ¼ N	3.7	2.0	**26.2**	**13.5**	0	**3.5**
Wing-P N	2.7	3.0	**17.0**	**20.8**	0.7	**1.5**
Wing-P ½ N	3.7	5.3	**36.2**	**56.2**	1.0	**6.7**
Wing-P ¼ N	5.5	6.5	**58.8**	83.8	0.7	11.7
F pr.	<.001	<.001	<.001	<.001	NS	<.001
l.s.d (34 d.f)	1.182	1.207	12.30	13.87	-	5.231

Site 3 – Wild rocket, West Sussex

H23 applied at rates from 1/9 to 1/3 of the full rate, and Wing-P applied at ¼ of the EAMU rate were crop safe to rocket at this site with scores at seven and above at three weeks after the herbicides were applied and incorporated (Figure 7). No commercially unacceptable effects were seen in the plots where these treatments were applied. The phytotoxicity scores for Wing-P and H41 were reduced at this site, possibly due to the soil type, as this trial was carried out on a silty clay soil where risk of crop damage from herbicide movement is known to be lower than on sand soils. Despite this overall reduction in phytotoxicity, H41 and the higher rates of Wing-P were still too phytotoxic to the crop causing stunting, deformation of growth and reduced emergence.

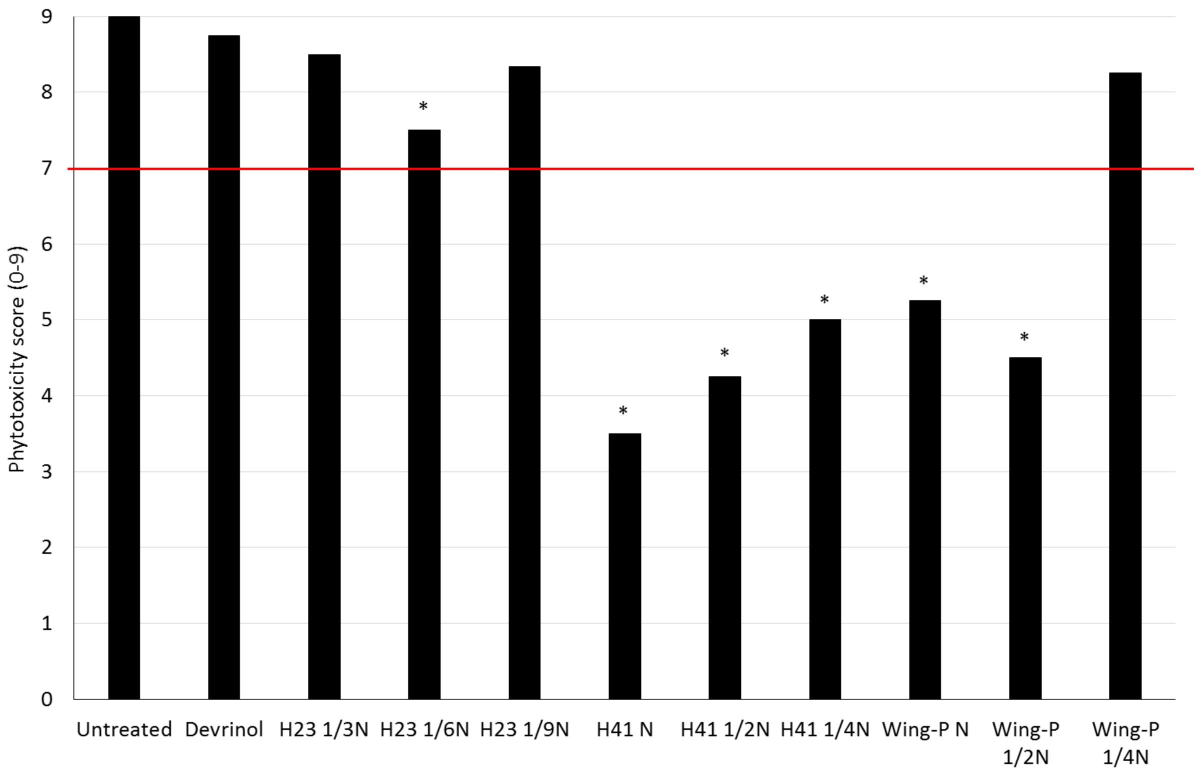

Figure 7. Phytotoxicity scores at three weeks post application for treatments applied to wild rocket, W. Sussex, 2015 (red line marks the level at which phytotoxicity effects are commercially acceptable, * = significantly different from the grower standard).

Emergence reached 100% for all plots at four weeks after application or when the crop would have been ready for harvest, but differences were seen at three weeks after harvest (Figure 8). Despite the crop reaching 100% plot cover at harvest these differences were still exhibited as stunting by H41 and the higher rates of Wing-P. At three weeks after treatment application the plots treated with H23, and Wing-P at ¼ of the approved rate showed similar levels of plot cover to the untreated and grower standard plots with emergence above 90%.

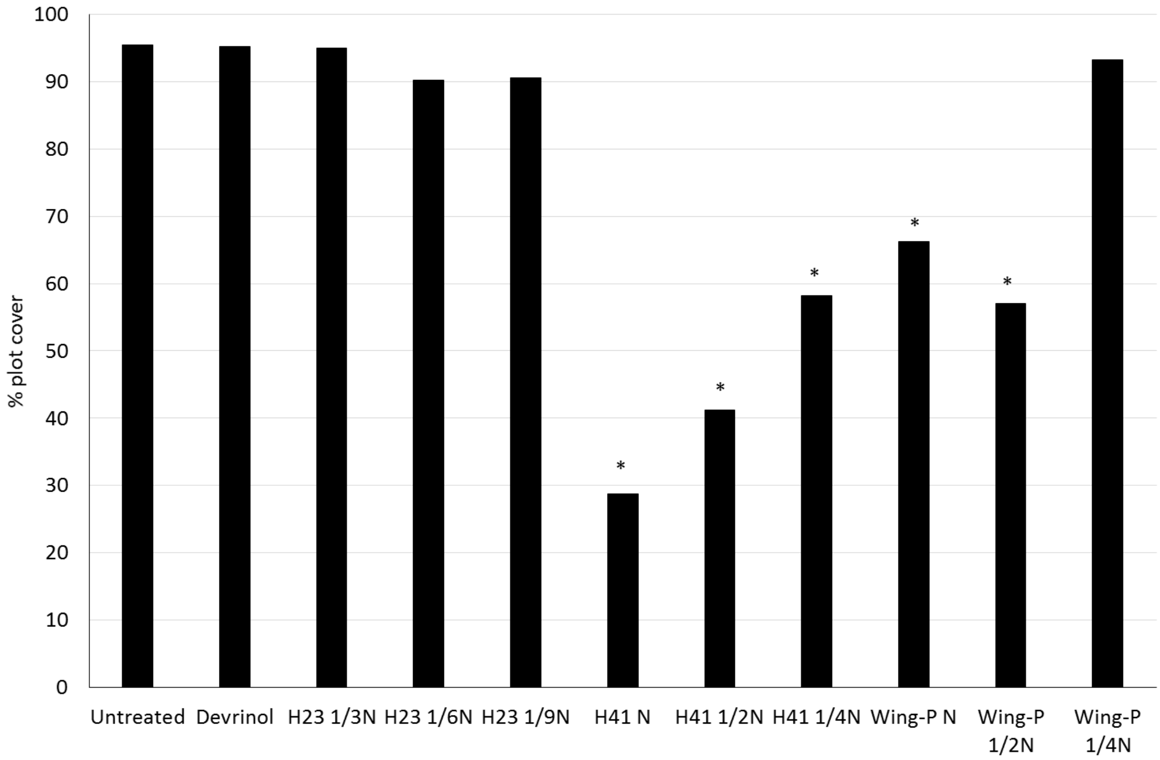

Figure 8. Crop stand of wild rocket as % plot cover, three weeks post treatment application. W. Sussex, 2015 (* = significantly different from the grower standard).

Wing-P and H41 at any of the rates used significantly reduced weed levels at two weeks after application, and even at ¼ of the full rate both herbicides gave better control than the current grower standard, Devrinol (Figure 9). By harvest there were no significant differences as the densely drilled crop had outcompeted the weeds, reducing the number of weeds present at that time. However, the data from two weeks after treatment still gives an indication of herbicide efficacy.

The predominant weed was shepherd's purse and H23 does not control crucifers, hence the poor performance of the product in this trial. At 1/9th of the full rate of H23, significant control of weed numbers is seen, which is unexpected considering the higher rates showed poor weed control.

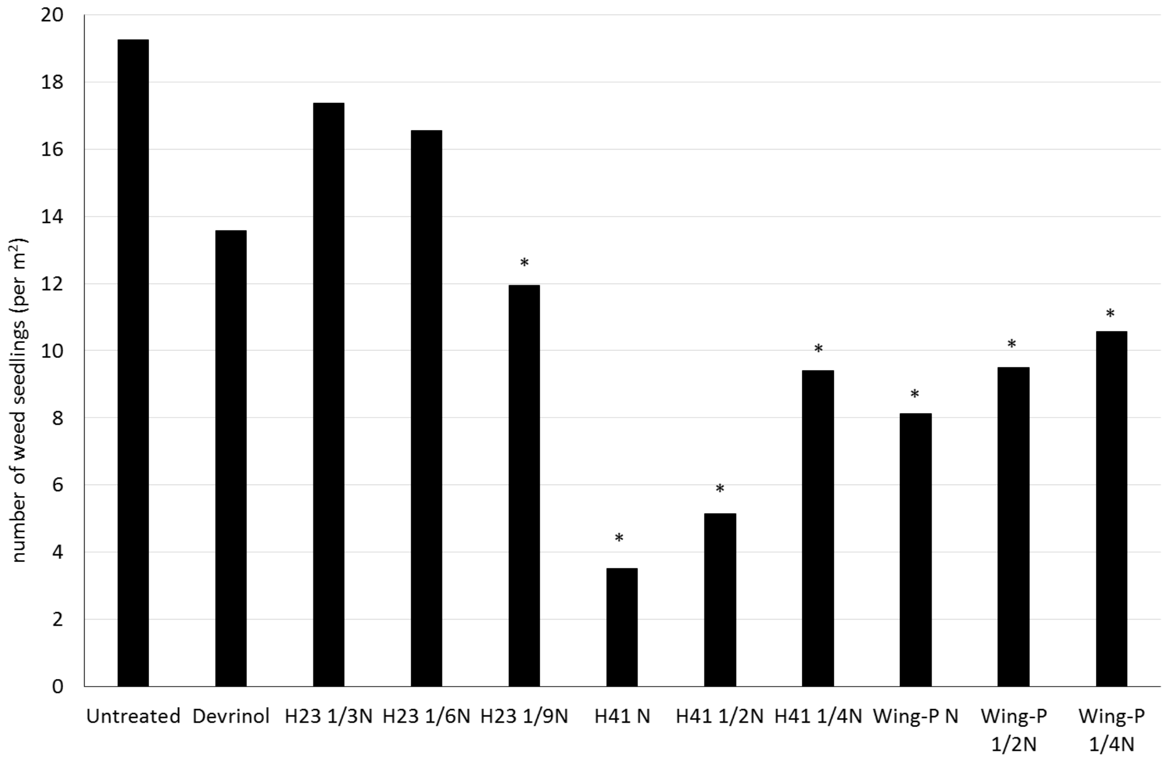

Figure 9. Weed numbers at two weeks after herbicide application, W. Sussex, 2015 (* = significantly different from the untreated).

Site 4 – Wild rocket, West Sussex

H23 applied at rates from ¼ to ¾ of the full rate, and Wing-P applied at ¼ of the EAMU rate were crop safe to rocket at this site. For these treatments scores at seven and above were recorded at harvest, five weeks after the herbicides were applied and incorporated (Figure 10). No commercially unacceptable effects were seen in the plots where these treatments were applied. This trial was also carried out on a silty loam soil, and again the phytotoxicity scores for Wing-P were reduced as herbicide movement is often known to be lower than on sand soils. This was despite two periods of heavy rain recorded at the site with 83 mm of rain falling 24 hours after treatments were applied, and a further 66.6 mm falling two weeks later. No increase in phytotoxicity was seen even with these periods of heavy rain.

Wing-P applied at ½ of the EAMU rate was still too phytotoxic to the crop causing stunting, deformation of growth and reduced emergence.

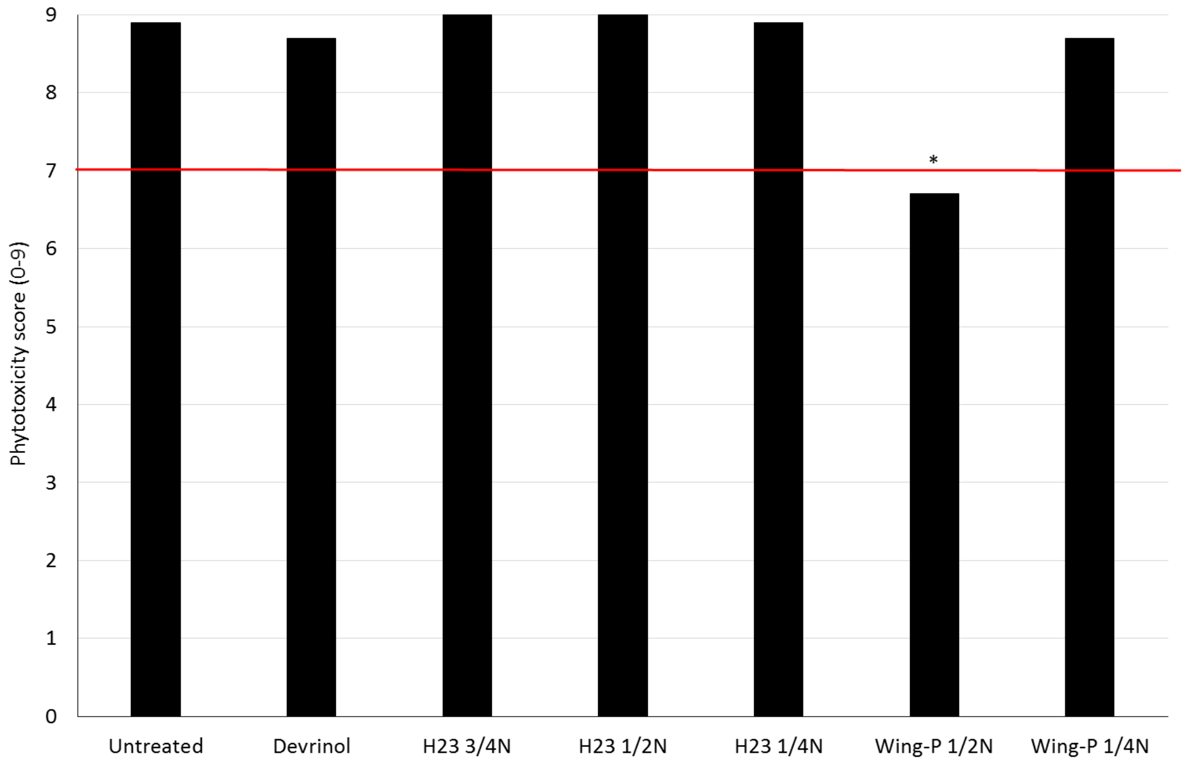

Figure 10. Phytotoxicity scores at harvest for treatments applied to wild rocket, W. Sussex, 2015 (red line marks the level at which phytotoxicity effects are commercially acceptable, * = significantly different from the grower standard).

At three weeks after treatment application the plots treated with H23, and Wing-P at ¼ of the approved rate showed similar levels of plot cover to the untreated and grower standard plots with emergence above 84% (Figure 11). There were no significant reductions in % plot cover between these treatments and Devrinol and the untreated plots. There was a significant reduction in crop stand to 78% plot cover when Wing-P was applied at ½ of the approved rate.

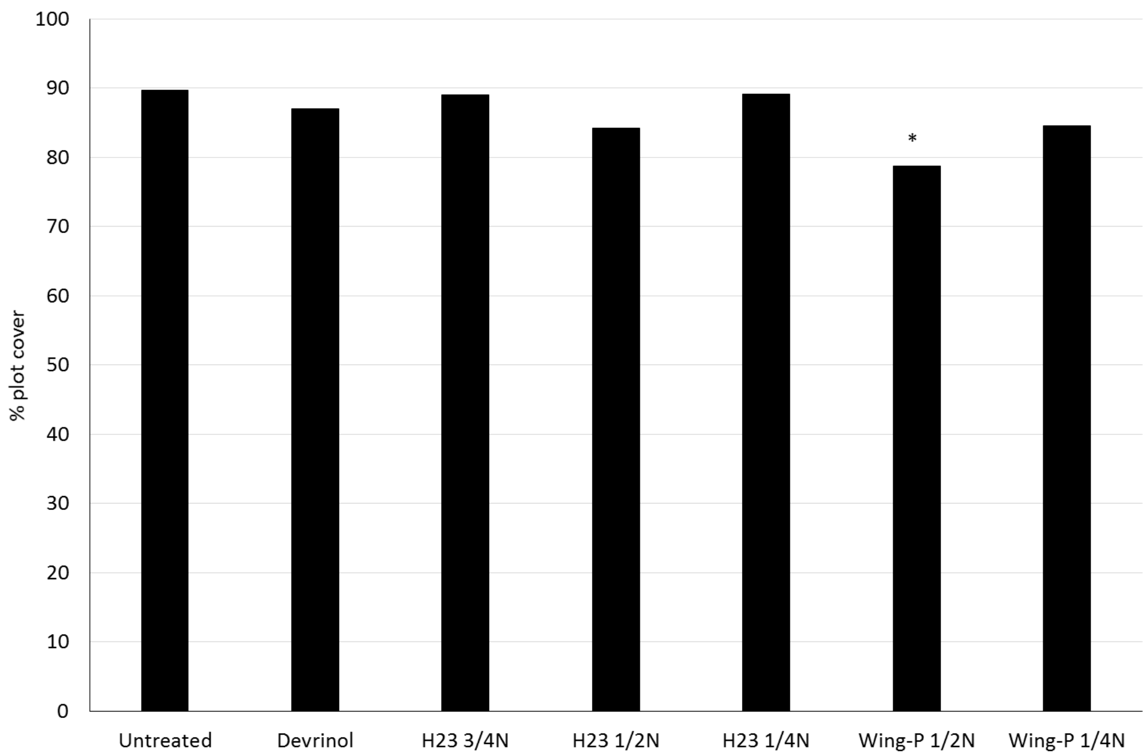

Figure 11. Crop stand of wild rocket at harvest as % plot cover. W. Sussex, 2015 (* = significantly different from the grower standard).

All herbicide treatments significantly reduced weed levels when compared to the untreated. However, the percentage reduction in weed cover was not as great as seen at site 3. This may have been due to the heavy rainfall, which would have moved the herbicide lower in the soil profile and reduced efficacy. Weed levels were reduced by 33% by Wing-P and H23 at ½ of the full rate. All other treatments including the grower standard, reduced weed by 25% compared to the untreated. No treatment was significantly better than another or the grower standard in this trial, and no differences were seen in the range of species controlled

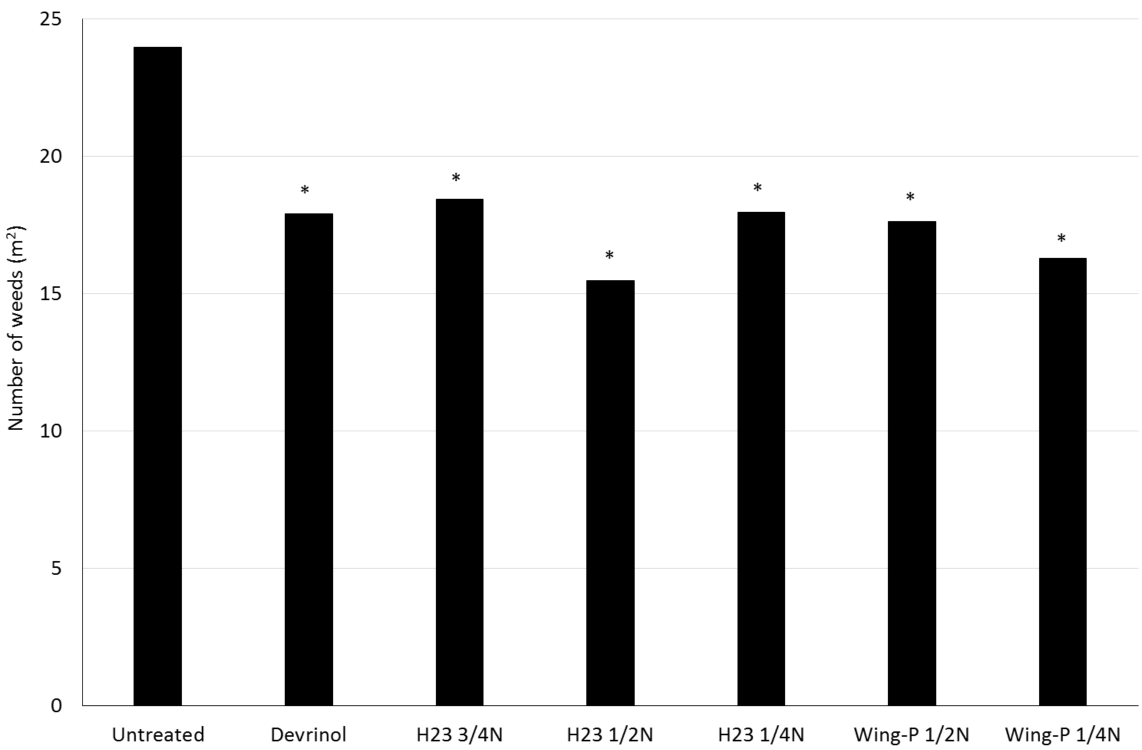

Figure 12. Weed numbers at five weeks after herbicide application, W. Sussex, 2015 (* = significantly different from the untreated).

Discussion

H23 was the most crop safe treatment at both sites and in all trials, but at the sandy loam site in Wiltshire, H23 at 1/3 full rate did cause slight stunting of just a few plants of both baby leaf lettuce and wild rocket. This did not affect all the plots in either of the trials, and an overall score of above seven was recorded which deems H23 crop safe. This slight stunting was not seen on the silty clay loam soil even at the highest rate applied of ¾ of the normal rate of H23. This increased crop sensitivity could be due to herbicides behaviour in the sandy loam soil and consideration of rates may be needed on these soils.

H41 was not crop safe in any of the trials, and caused significant phytotoxicity at both sites and in both crops. Even at the lowest rate of ¼ of the approved rate, and on the silty loam soils, crop emergence was reduced and what did emerge was stunted and deformed, with thickened and twisted leaves.

Crop safety of Wing-P varied with soil type and rates, and was not crop safe at any rates used in the trials on sandy loam soils. However, on the silty clay loam Wing-P applied at ¼ of the EAMU rate to the wild rocket crops was crop safe and gave a commercially acceptable crop.

But, care must be taken with rates even on the silt soils as when used at the higher rates of ½ full rate, and at the full rate the herbicide was not safe. Significant differences were seen in phytotoxicity at these rates and crop losses and deformed plants were recorded.

H23 applied at all the rates tested (1/9 N to ¾ N) exhibited equivalent crop stand to the untreated and the grower standard, Devrinol in the wild rocket crops across the soil types in the trials. In the baby leaf lettuce trial on the sandy loam in Wiltshire, a reduction of 10% plot cover was recorded at 1/3 of the full rate, but this was not a significant reduction and plot cover was on average 85% across the plots. Whereas, there was a significant reduction in crop stand as the rate of Wing-P increased in both soil types in both wild rocket and baby leaf lettuce, when applied at either the full EAMU rate or ½ EAMU rate. At ¼ of the EAMU rate, Wing-P did not significantly reduce crop stand of the wild rocket when applied on the silty clay loams in Sussex or the baby leaf lettuce on the sandy loams in Wiltshire. But, Wing-P at ¼ rate did significantly reduce the crop stand of the wild rocket in Wiltshire by 27% which was commercially unacceptable. Again, this highlights the need for care with the use of Wing-P depending on soil type.

H41 gave significant reductions of 38% crop stand in the silty clay loam at the lowest rate used, to 99% reduction in crop stand in the sandy loam at the highest rate, and was therefore too damaging to any crop at either site.

The overall weed levels at the Sussex sites were higher than seen in Wiltshire, however significant differences were seen at all sites except the wild rocket trial in Wiltshire. At the latter site the weed levels were very low. At those sites where significant differences were seen, Wing-P and H41 significantly reduced the weed levels when compared to the untreated. But, as aforementioned H41 was not crop safe, and Wing-P was only crop safe at ¼ rate on heavier soils.

H23 reduced the weed level at all the sites but the amount of reduction varied and was not always significant. In the baby leaf lettuce trial in Wiltshire H23 gave a significant reduction in weeds, and equivalent control to Devrinol but it should be noted that weed levels were low with only six weeds per plot in the untreated. In the rocket trials in Sussex, results were variable with no consistent significant reduction of weeds in the first trial but the predominant weed was shepherd’s purse and H23 does not control crucifers, hence the possible poor performance of the product in this trial. However, at 1/9th of the full rate of H23, significant control of weed numbers was seen, which was unexpected considering the higher rates showed poor weed control.

In the second trial in Sussex the rates of H23 were increased and all herbicide treatments significantly reduced weed levels when compared to the untreated, and gave equivalent control to the grower standard Devrinol. But, the percentage reduction in weed cover was not as great as seen at the first site in Sussex. This may have been due to the heavy rainfall, which would have moved the herbicide lower in the soil profile and reduced efficacy. Weed levels were reduced by 33% by Wing-P and H23 at ½ of the full rate. All other treatments including the grower standard, reduced weed by 25% compared to the untreated. No treatment was significantly better than another or the grower standard in this trial, and no differences were seen in the range of species controlled.

The most troublesome weeds at each site were not fully controlled, but their percentage ground cover was reduced with by all of the treatments tested in the trials. However, not all of the treatments were crop safe. Further work could determine if combining H23 with the grower standard Devrinol could improve weed control while maintaining crop safety in these sensitive crops. Wing-P at ¼ of the EAMU rate gives an equivalent reduction in weed levels to the grower standard, but is only crop safe on heavier silt soils and even then it would be advisable to test a small area of crop before use on a larger scale as higher rates of Wing-P gave commercially unacceptable stunting and crop loss.

Conclusions

- The grower standard, Devrinol continues to reduce weed cover and is safe to wild rocket crops, but is not safe to use on baby leaf lettuce.
- H23 is crop safe across both baby-leaf lettuce and wild rocket up to ½ rate in all soil types, and gives equivalent reductions in weed cover to Devrinol. An EAMU for this product would be useful to give baby leaf growers an alternative mode of action and guard against the development of resistant weed populations.
- Wing-P at ¼ of the EAMU rate (0.3 L/ha) was crop safe on silty clay loams even after heavy showers, but it is not crop safe on lighter sandy soils and consideration of the soil type must be taken into account when using the product to avoid crop loss.
- H41 is not safe to use on wild rocket or baby leaf lettuce crops.

2.5.1. Top fruit (apple) herbicide screen

Introduction

Weeds compete with trees for light, water, nutrition and space, therefore weed control in soil grown top fruit systems is important. Competition from weeds can result in reduced growth rates of the trees, which is particularly a problem for newly planted orchards. Due to changes in legislation, the top fruit growing industry is currently relying on relatively few herbicides to control weeds. The loss of Ronstar (oxadiazon) has left the industry very much dependent on Stomp Aqua (pendimethalin) tank mixed with Flexidor 125 (isoxaben) as a commercial standard. Although authorised for this use, application to newly planted apple trees is not covered by the label recommendations which refer to use on "established" trees. Relying on only two active ingredients increases the risk of resistance developing amongst the weeds.

Herbicides Nirvana (imazamox + pendimethalin) and Sumimax (flumioxazin) already have EAMUs for use in apples with a 365 day harvest interval but have not been tested for safety, others such as Butisan S (metazachlor) and Wing P (dimethenamid P + pendimethalin) have approval in nursery production. Combinations of these herbicides with standards such as Stomp Aqua may offer better weed control, whilst reducing the risk of resistance developing when used pre-emergence in fruit crops, therefore they are worth investigating.

In order for fruit growers to be able to utilise alternative herbicide products, it is important to establish whether they are safe to use on newly planted apple trees and whether they are as effective at controlling weeds as the standard herbicide tank mix that is used commercially. The objective of this trial was, therefore, to assess a range of novel herbicides for weed control efficacy and crop safety in a newly planted orchard.

Materials and methods

The trial was located in a newly planted commercial apple orchard at Bardsley Farm, Kent. The variety used in the trial was Gala which had been planted in the study area within the orchard in winter 2015 (March). The trial was set up as a fully randomised block design with six treatments: an untreated control, Nirvana, Wing P, Butisan S + Stomp Aqua, Stomp Aqua + Flexidor 125 and Stomp Aqua + Sumimax (Table 1). All treatments were replicated four times. Each plot measured 1.5 m wide and 4.0 m long and consisted of three apple trees per plot.

Prior to the application of the experimental herbicides, on 2 April 2015, all of the plots received an application of Harvest (glufosinate ammonium) at a rate of 5 L/ha to clear any weeds that had germinated. All guard areas and ends of rows were also treated with Harvest, as well as with the commercial standard treatment (Stomp Aqua + Flexidor 125) to avoid excessive growth of weeds around the trial area. All trial treatments were applied on the same day to their appropriate plots whilst the trees were still dormant, 2 April 2015. Treatments were applied using an OPS knapsack sprayer at a water volume of 200 L/ha.

Table 1. Residual herbicide treatments used in the apple herbicide trial, applied on 2 April 2015 - Kent

Treatment number	Product name	Active ingredient	Rate (L/ha)	Timing
1	Untreated	-	-	-
2	Nirvana	imazamox + pendimethalin	4.5	April
3	Wing P	dimethenamid P + pendimethalin	4.0	April
4	Butisan S + Stomp Aqua	metazachlor + pendimethalin	1.5 + 2.0	April
5	Stomp Aqua + Flexidor 125	pendimethalin + isoxaben	2.0 + 2.0	April
6	Stomp Aqua + Sumimax	pendimethalin + flumioxazin	2.0 + 0.1	April

Weed control efficacy was assessed 4, 8, 12, 16 and 24 weeks after the herbicide treatments had been applied. At each assessment, three areas in each plot were randomly selected using a 0.3 m^2 quadrat and the percentage weed cover was recorded, along with the number of individual weed species present. The total percentage cover of weeds was also estimated for each plot.

A phytotoxicity assessment was carried out at 2, 4, 12, 16 and 24 weeks after the treatments had been applied. Phytotoxicity was recorded on a nought to nine scale, with nought representing plant death, nine being healthy and comparable with the untreated control plants, and seven being considered commercially acceptable damage. The phytotoxicity assessment involved recording any spotting, chlorosis, twisting or scorching of foliage and any effects on plant growth that were seen that were attributable to the herbicide treatments. During the final assessment, in October, the extension growth of five representative branches was measured on the central tree in each plot.

Data collected for weed cover, phytotoxicity and stem extension were analysed by analysis of variance.

Results

An initial assessment of weed control on 16 April, two weeks after treatment, showed that there was patchy control of some weed species, such as Parsley-piert (*Aphanes arvensis*), in some of the plots. This was taken into account during the subsequent weed assessments. At the first full weed assessment on 28 April, four weeks after treatment, the highest percentage of weeds was found in the untreated plots (17 %) and the lowest percentage of weeds was seen in the plots treated with Butisan S + Stomp Aqua (1.75 %). However, there were no significant differences in the percentage of weed cover of plots between any of the treatments (p = 0.100, Figure 1).

At the assessment carried out eight weeks after treatment, the untreated plots had a significantly higher percentage cover of weeds (4.25 %) compared to all of the herbicide treatments (p = <0.001, l.s.d. 1.290). At 12 weeks after treatment, the untreated plots had 18.75 % weed cover which differed significantly to all of the treated plots (p = <0.001, l.s.d. 4.145). At the assessment carried out 16 weeks after treatment, the untreated plots had a mean weed coverage of 21.2 % (Figure 2) which was significantly different to the percentage weed coverage for all of the treatments (p = <0.001, l.s.d. 3.374). On this date, the plots treated with Butisan S + Stomp Aqua and Stomp aqua + Sumimax had the lowest percentage weed cover, both 0.25 % (Figure 3).

In the final assessment, carried out 24 weeks after treatment, the untreated plots had 58.75 % weed cover which was significantly higher than all of the herbicide treatments (p = <0.001, l.s.d.11.58). The treatments with the lowest percentage weed cover at this point were Butisan S + Stomp Aqua and Stomp Aqua + Sumimax, 5.5 % and 5.25 % respectively. At the final weed cover assessment on 2 October, 24 weeks after treatment, all of the herbicide treatments were starting to lose their persistence and the percentage weed cover had increased since the previous assessment that had been carried out 16 weeks after treatment.

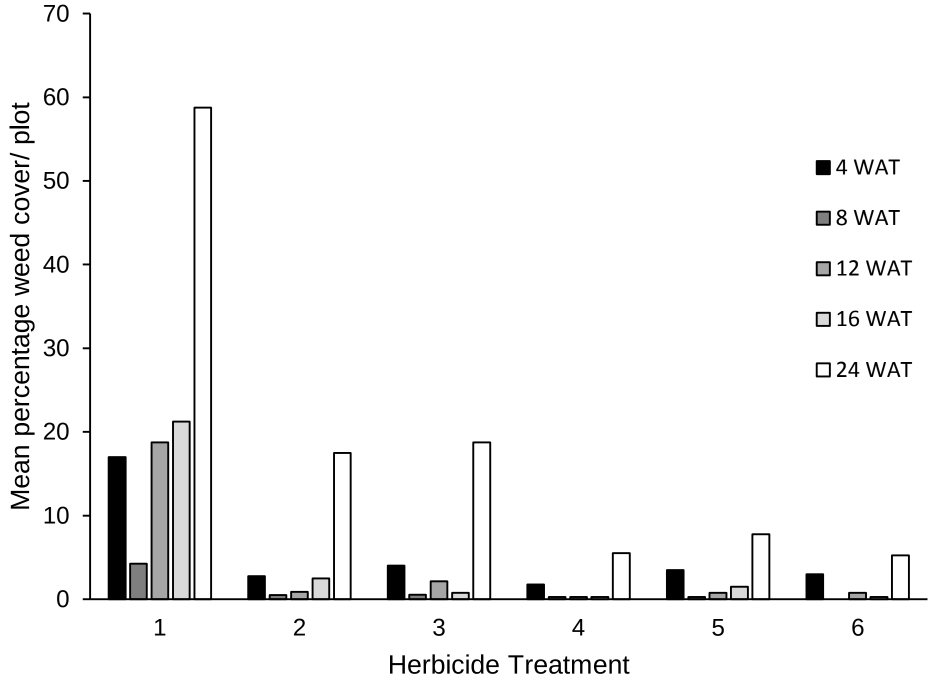

Figure 1. Mean percentage (%) weed cover of plot per treatment, four weeks after treatment (WAT), eight WAT, 12 WAT, 16 WAT and 24 WAT. Treatments: 1 = Untreated, 2 = Nirvana, 3 = Wing P, 4 = Butisan S + Stomp Aqua, 5 = Stomp Aqua + Flexidor 125, 6 = Stomp Aqua + Sumimax

Figure 2. Untreated plot 16 weeks after treatment – 4 August 2015.

Figure 3. Stomp Aqua + Sumimax treated plot 16 weeks after treatment – 4 August 2015.

At the phytotoxicity assessment carried out two weeks after treatment, three trees out of the whole trial were noted as having some slight scorch damage to their lower buds; these trees scored an eight on the phytotoxicity scale (Table 2). This damage was seen in plots that had been treated with Butisan S + Stomp Aqua, Stomp Aqua + Flexidor 125 and Stomp Aqua + Sumimax. In all the remaining phytotoxicity assessments (4, 12, 16 and 24 weeks after treatment) no other damage was noted and all trees were recorded as a nine on the phytotoxicity scale. There were also no significant differences between any of the treatments or the untreated plots with regards to extension growth of the trees (Table 3).

Table 2. Mean phytotoxicity scores of the apple trees at: 2, 4, 12, 16 and 24 weeks after treatment.

Treatment	Phytotoxicity score				
	2 weeks after treatment	**4 weeks after treatment**	**12 weeks after treatment**	**16 weeks after treatment**	**24 weeks after treatment**
1. Untreated	9.0	9.0	9.0	9.0	9.0
2. Nirvana	9.0	9.0	9.0	9.0	9.0
3. Wing P	9.0	9.0	9.0	9.0	9.0
4. Butisan S + Stomp Aqua	8.8	9.0	9.0	9.0	9.0
5. Stomp Aqua + Flexidor 125	8.8	9.0	9.0	9.0	9.0
6. Stomp Aqua + Sumimax	8.8	9.0	9.0	9.0	9.0

Table 3. Mean extension growth (mm) of apple trees in the herbicide trial on 2 October 2015.

Treatment	Extension growth (mm)
1. Untreated	43.3
2. Nirvana	55.5
3. Wing P	52.5
4. Butisan S + Stomp Aqua	62.8
5. Stomp Aqua + Flexidor 125	47.9
6. Stomp Aqua + Sumimax	44.1
P value	**0.635**
LSD (d.f. = 15)	**26.95**

Discussion

The trial has identified some promising residual herbicides for use on commercial orchards. All of the herbicides that were tested performed as well as the commercial standard (Stomp Aqua + Flexidor 125) in terms of weed control efficacy and crop safety. There was no damage to any of the trees, other than some slight transient bud scorching two weeks after treatment caused by: Butisan S, Flexidor 125 and Sumimax (each of which was combined with Stomp Aqua). All trees grew away from the initial damage by the following assessment.

The effects of the herbicides on the weed cover in all treatments were seen most strongly eight weeks after the treatments were applied (4 June 2015). The stand out treatments for weed control were Butisan S, Flexidor 125 and Sumimax, when applied in tank mixes with Stomp Aqua.

The majority of the herbicides tested (Nirvana, Stomp Aqua, Flexidor 125 and Sumimax) currently have approval for use on commercial orchards, whether this be a full label approval or approval by off labels. However, Nirvana and Sumimax can only be used on newly planted trees as the EAMU specifies a 365 day harvest interval. Butisan S and Wing P are not currently approved for use and so EAMUs would need to be applied for so that these herbicides could be used by apple growers.

Conclusions

- The trial has shown that Nirvana, Wing P, Butisan S + Stomp Aqua and Stomp Aqua + Sumimax have potential to be used by apple growers for weed control in newly planted orchards as no treatments caused any long lasting damage to trees.
- All treatments tested proved to be as good at controlling weeds as the commercial standard, (Stomp Aqua + Flexidor 125).
- The use of these herbicides would increase the armoury of actives available to growers and reduce the risk of resistant weeds building up if Stomp Aqua + Flexidor 125 was used exclusively.
- EAMUs will need to be applied for so that Butisan S and Wing P could be used by growers for weed control.

2.6 Living mulches in apple orchards

Introduction

Recent changes that have come about due to changes in legislation, i.e. the introduction of Regulation 1107/2009, have meant that many herbicides have been lost throughout the horticultural industry, including many herbicides that were relied on for use in top fruit. It is, therefore, important to investigate alternative methods of weed control that will reduce reliance on traditional herbicides and help growers to achieve sustainable management of their crops.

Living mulches are crops established either prior to or at the same time as the main crop, with the main objective of improving soil conditions. For instance, living mulches enhance soil structure, increase organic matter and prevent soil erosion by covering the bare soil, whilst also providing an appropriate habitat for beneficial insects and increasing local biodiversity. Furthermore, they effectively suppress weed populations which could be particularly helpful when herbicide choice is limited. However, it is essential that the appropriate living mulch is chosen in order to avoid competition for water and nutrients, which can be damaging to the crop.

This field trial follows initial container trials that were carried out in 2012-13 to study the characteristics of species that could potentially be used as living mulches (Atwood et al., 2014). The field trial was set up in autumn 2013 and investigates the effect of living mulches when sown in an apple orchard for weed control; on soil moisture and nutrient content and nutrient status and yield of the trees. The species of plants that were investigated for suitability as living mulches during the two growing seasons of this study (2014-2015) included; *Trifolium repens* (white clover), *Medicago lupulina* (black medic), *Festuca rubra* (creeping red fescue) and *Lotus corniculatus* (birdsfoot trefoil). This report presents the results of the final year of the study 2015.

The main objective of the study was to assess different species of living mulches for weed control efficacy, and their effects on the soil moisture and nutrient content and nutrient status of the trees, when sown in an apple orchard.

Material and Methods

The trial was carried out in a commercial apple orchard at Lavender Farm in Faversham, Kent. An undisclosed (confidential) variety from Worldwide Fruit Ltd. was used for the trial. There were seven treatments tested in this trial (Table 1): white clover, black medic, creeping red fescue, birdsfoot trefoil, creeping red fescue/birdsfoot trefoil, untreated and an herbicide treatment (Table 2). The trial was set up as a fully randomised block design with four replicated blocks. Each plot measured 1.70 m wide and 2.50 m long and consisted of three apple trees per plot, with a 1.25 m gap between plots.

Table 1. Treatment list for living mulches trial – Kent.

Treatment no.	Common name	Scientific name
1	White clover	*Trifolium repens*
2	Black medic	*Medicago lupulina*
3	Creeping red fescue	*Festuca rubra*
4	Birdsfoot trefoil	*Lotus corniculatus*
5	Creeping red fescue + birdsfoot trefoil	*Festuca rubra + Lotus corniculatus*
6	Untreated	-
7	Herbicide treatment*	-

* *Details for the herbicide treatment are shown in Table 2*.

Table 2. Herbicide programme (treatment 7) for living mulches trial – Kent.

Herbicide	Active ingredient	Timing	Rate (L/ha)	Water volume (L/ha)
Ronstar liquid	oxadiazon	March 2014 and February 2015	4.0	300.0
Harvest	glufosinate-ammonium	March 2014 and February 2015	3.0	300.0

The trial was set up and the living mulch seeds were sown autumn 2013. A tank mixture of Ronstar liquid and Harvest was sprayed using a Knapsack OPS sprayer at a water volume of 300 L/ha to the respective plots on 27 February 2015. No other herbicides were applied to any of the living mulches plots.

In the final year of the trial, 2015, the growth of the living mulches was assessed on three occasions: 15 April 2015, 4 June 2015 and finally on 2 October 2015 at harvest. Growth of the living mulches was assessed by monitoring the plant density, estimating the percentage of ground covered and measuring the average height of the living mulches. Assessments were also carried out on the same dates to estimate the percent weed cover of the plots.

Soil moisture was measured on 4 June 2015 using a soil sensing device (Delta T). The soil nitrogen content was also measured on this date and was done by taking bulk samples across the four replicate plots for each treatment and sending the samples away to Natural Resource Management (NRM) Laboratories for analysis. Also on 4 June 2015, 10 of the youngest fully expanded leaves were sampled from each treatment and sent away to NRM Laboratories for nutrient analysis.

At harvest, on 2 October 2015, the following measurements were recorded: the diameter of 10 apples per plot, the extension growth of five branches per plot and the yield of three trees per plot. Means were then calculated for each treatment. Maturation testing, which included Brix^{o}, firmness and starch measurements for one block of the trial was conducted by Worldwide Fruit Ltd. Firmness is measured using a pressure meter (Psi). Data collected were analysed using one-way analysis of variance.

Results

The percentage of living mulch cover for each plot was assessed (Table 3). The results showed that by harvest, 2 October 2015, most of the living mulches had achieved high coverage. The differences between the percentage cover of the different living mulch treatments were significant at all of the assessment dates. The creeping red fescue and the creeping red fescue/birdsfoot trefoil plots had the highest living mulch cover by harvest. The plots treated with the creeping red fescue/birdsfoot trefoil mix were dominated by the creeping red fescue (90-95 % cover) with the birdsfoot trefoil contributing only a small percentage of the total cover. Throughout 2015, the birdsfoot trefoil treatment percentage cover was significantly lower than the treatments containing creeping red fescue, however the birdsfoot trefoil still achieved a final coverage of 73.8 %.

Table 3. Mean percentage cover of the living mulch treatments at three assessment dates in 2015.

Treatment	Mean percent living mulches cover (%)		
	15 April 2015	04 June 2015	02 October 2015
White clover	96.0	86.3	92.3
Black medic	56.3	82.0	92.5
Creeping red fescue	100.0	99.0	96.0
Birdsfoot trefoil	51.3	73.8	73.8
Creeping red fescue + birdsfoot trefoil	100.0	100.0	96.0
Untreated*	0.0	0.0	0.0
Herbicide treatment*	0.0	0.0	0.0
P value	<0.001	0.004	<0.001
LSD (19d.f)	10.86	13.07	9.49

** Untreated and herbicide treatment plots were not included in the statistical analysis*

The mean percentage weed cover was significantly different between the living mulch treatments throughout the assessments (Table 4). The creeping red fescue and the creeping red fescue/birdsfoot trefoil were the best living mulches in terms of weed suppression, with weed cover of 0 % and 2.5 % respectively at harvest (Figure 1). All of the living mulches, except for the birdsfoot trefoil, outperformed the standard herbicide treatment at controlling weeds. The weed cover for the birdsfoot trefoil treatment at harvest was significantly higher than the other living mulch treatments. However, it was still significantly lower than the untreated and the herbicide treatments.

Table 4. Mean percentage weed cover for the living mulch trial at three assessment dates in 2015.

Treatment	Percentage weed cover (%)		
	15 April 2015	**04 June 2015**	**02 October 2015**
White clover	9.5	10.5	32.5
Black medic	32.5	20.0	41.3
Creeping red fescue	0.0	0.5	0.0
Birdsfoot trefoil	23.0	26.3	65.0
Creeping red fescue + birdsfoot trefoil	0.8	3.0	2.5
Untreated	77.5	72.5	97.0
Herbicide treatment	8.5	31.8	83.8
P value	<0.001	<0.001	<0.001
LSD (27d.f)	15.33	21.56	18.09

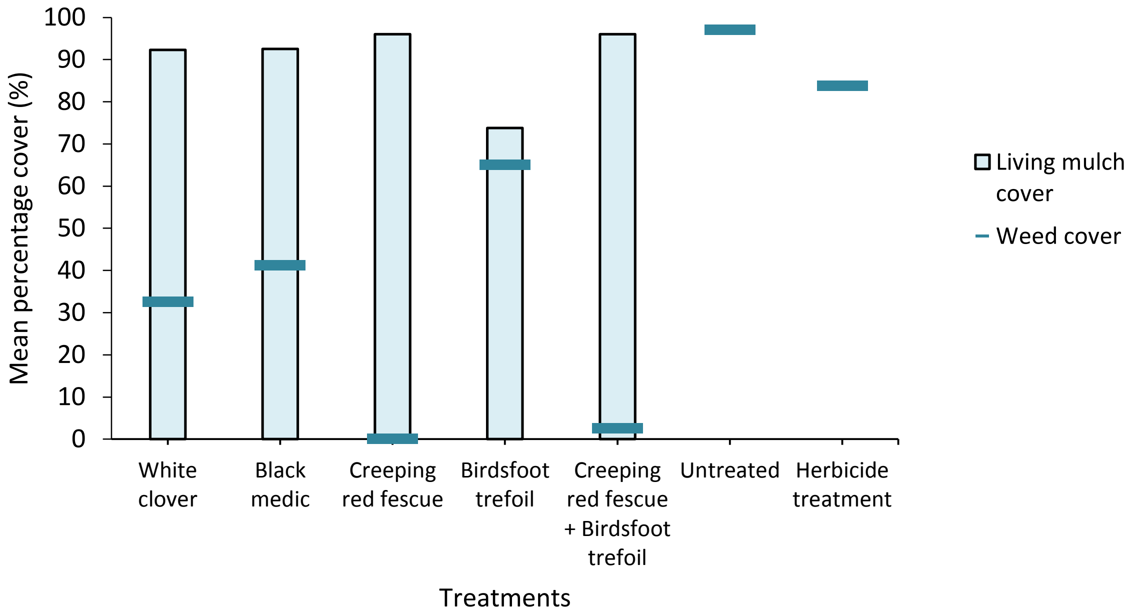

Figure 1. Living mulches percentage cover compared with the overall weed population, during the final assessment on 2 October 2015.

Extension growth

The average extension growth was calculated by measuring five branches from the middle tree of each plot at harvest on 2 October 2015 (Table 5). The mean extension growth for the creeping red fescue and the creeping red fescue/birdsfoot trefoil mix were lower than in the other plots (92.9 mm and 102.1 mm respectively). However, due to large variability within the dataset, there were no significant differences between any of the treatments. The greatest extension growth was seen in the plots that had the white clover treatment, with a mean extension of 161.5 mm.

Table 5. Average extension growth per treatment in the living mulch trial.

Treatment	**Mean extension of growth (mm)**
White clover	161.5
Black medic	158.6
Creeping red fescue	92.9
Birdsfoot trefoil	137.9
Creeping red fescue + birdsfoot trefoil	102.1
Untreated	155.5
Herbicide treatment	158.25
P value	0.477
LSD (27d.f)	87.5

Apple diameter and post-harvest grades and yield

The mean diameter of 10 apples from the middle tree of each plot was calculated (Table 6**Table**). Apple diameter ranged from 64.9 mm for the creeping red fescue/birdsfoot trefoil treatment to 70.3 mm for the black medic treatment. However, there were no statistically significant differences between treatments.

Table 6. Mean apple diameter from the different living mulch treatments on 2 October 2015.

Treatment	**Mean apple diameter (mm)**
White clover	69.7
Black medic	70.3
Creeping red fescue	66.3
Birdsfoot trefoil	68.5
Creeping red fescue + birdsfoot trefoil	64.9
Untreated	67.7
Herbicide treatment	68.8
P value	0.287
LSD (27d.f)	4.84

There were significant differences in the total yield of apples for two of the treatments (Table 7). The creeping red fescue treatment had the lowest total yield out of the treatments and the herbicide treatment had the highest total yield. There was no significant difference in total yield between the herbicide, white clover, black medic and birdsfoot trefoil treatments.

There was no significant difference between the different treatments in the category for underweight and waste fruit. The black medic living mulch and the herbicide treatment had the highest weights of underweight and waste fruit in October 2015.

Table 7. Mean total yields of apples per plot (3 trees) for each living mulch treatment. The total yields have been split into three grading categories: <60 mm and waste, 60-80 mm and >80 mm and the percentage of marketable apples calculated.

Treatment	Total apple yield	<60 mm and waste	60 – 80 mm (marketable)	>80 mm (oversize)	Percentage marketable
	(kg)	(kg)	(kg)	(kg)	(%)
White clover	31.23	6.12	23.19	1.93	73.9
Black medic	35.69	8.12	24.01	3.56	66.8
Creeping red fescue	11.67	3.03	8.45	0.20	72.9
Birdsfoot trefoil	32.48	7.33	22.85	2.31	70.4
Creeping red fescue + birdsfoot trefoil	18.80	5.68	12.68	0.45	68.8
Untreated	23.83	4.79	18.14	0.90	74.7
Herbicide treatment	43.47	7.88	32.01	1.63	73.3
P value	0.001	0.052	0.003	0.038	0.477
LSD (27d.f)	12.89	3.352	10.22	2.05	8.90

The black medic living mulch plots had the highest weight of oversized fruit, whilst the creeping red fescue plots had the lowest weight of oversized fruit (Figure 2). There was a significant difference in the marketable yield across the plots (Table 7). The lowest marketable yield was from the plots with the creeping red fescue, which was significantly lower than the highest marketable yield in the herbicide treatment. However, the percentage of the marketable yield was not significantly different between any of the living mulch treatments. This means that although there was a lower marketable yield overall in the creeping red fescue plots, the proportion that was marketable was still the same as for the other treatments.

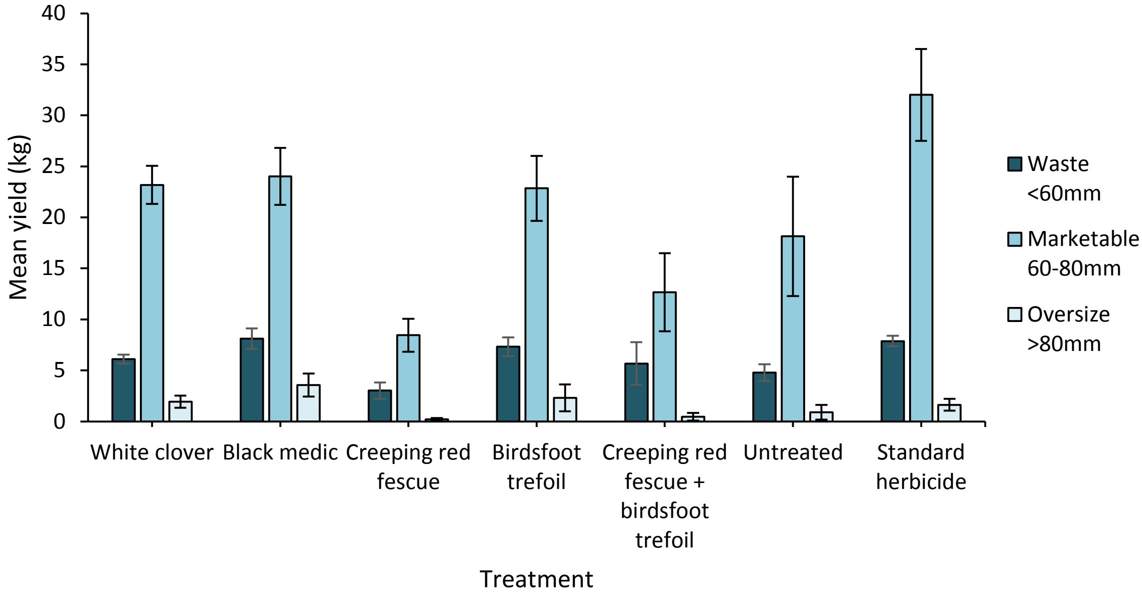

Figure 2. Mean yields for apples, from three trees, graded into the categories: <60 mm (waste), 60-80 mm (marketable) and >80 mm (oversized) on 2 October 2015.

Maturation test

After harvesting, ten apples from each treatment were tested for firmness (Psi), sugar content (Brix°) and starch content (Table 8). This variety was going for storage under appropriate conditions, for a minimum of 10 weeks. Psi and Brix results, therefore, recorded immediately after harvest provide an indication of relative firmness and sugar content at that time; they do not necessarily represent normal market values. However, starch levels at harvest are relevant, as they are used to determine the optimum harvesting date.

Psi ranged from 9.86 kg in the white clover treated plots to 13.75 kg in the birdsfoot trefoil treated plots. The lowest Brix content was 11.0 % in the birdsfoot trefoil treated plots and the highest mean was 11. 6 % in the creeping red fescue plots. Starch content ranged from 79.8 % in the untreated plots to 90.3 % in the creeping red fescue/birdsfoot trefoil treated plots. No statistics were carried out on these data.

Table 8. Maturity test results from apples picked on 2 October 2015.

Treatment	Maturities test		
	Mean Psi (kg)	Mean Brix (%)	Mean Starch (%)
White clover	9.86	11.4	81.3
Black medic	10.08	11.3	82.0
Creeping red fescue	12.15	11.6	88.8
Birdsfoot trefoil	13.75	11.0	80.0
Creeping red fescue + birdsfoot trefoil	12.75	11.2	90.3
Untreated	11.75	11.1	79.8
Herbicide treatment	10.40	11.5	85.0

Leaf nutrient analysis

For each plot, 10 of the youngest fully expanded leaves were sampled and as the samples were bulked for each treatment statistical analysis was not appropriate. The leaf nutrient analysis results in 2015 showed more variation compared with those for 2014. Leaf nitrogen content noticeably decreased in 2015 compared with 2014 in all treatments (ranges: 1.26-1.69 % w/w and 1.60-2.17 % w/w respectively). The nitrogen content in 2015 for all of the treatments was lower than the optimum range for apple trees (2.0-2.4 % w/w) (Table 9). Only the plots treated with birdsfoot trefoil had a similar nitrogen leaf content level to 2014, although it was still below the optimal range. The plots containing creeping red fescue had the lowest leaf nitrogen content and had yellowing foliage when the trees were assessed in August 2015 (Figure 3).

Figure 3. (Left) Apple tree in creeping red fescue plot showing yellowing foliage. (Right) Comparison of apple foliage from creeping red fescue treated plots to herbicide plot, August 2015.

Available phosphorous, potassium and calcium were in the optimum range for all treatments, although all were with slightly reduced concentrations when compared with 2014 content levels. All plots, except those treated with white clover, birdsfoot trefoil or the standard herbicide treatment, had a slight magnesium deficiency. All plots had manganese, iron and zinc concentrations within the acceptable ranges. The boron content for 2015 is higher than that of 2014 and is within optimal ranges for all treatments.

Table 9. Leaf nutrient analysis results, 4 June 2015.

Treatment	N	P	K	Ca	Mg	Mn	Fe	Zn	B
	(% w/w)	(mg/kg)							
White clover	1.47	2356	14825	10496	2037	23.2	87.6	17.0	21.4
Black medic	1.39	2442	16026	9682	1995	22.6	90.8	16.1	22.4
Creeping red fescue	1.26	2243	14964	8399	1853	29.3	150.0	18.4	26.7
Birdsfoot trefoil	1.63	2577	15718	10510	2062	27.7	83.0	17.6	22.1
Creeping red fescue + birdsfoot trefoil	1.31	2324	15430	9382	1894	23.3	68.2	16.4	26.1
Untreated	1.35	2175	14523	9669	1902	21.6	71.4	16.0	21.9
Herbicide treatment	1.69	2519	16597	10825	2034	19.6	86.6	16.6	21.1

Soil analysis and pH

A soil sample was taken prior to sowing the mulches in November 2013 (Table 10). Additional representative soil samples from each treatment were taken for the next two consecutive summers (Table 11). Results showed that the pH across all of the plots stayed within a range similar to the starting pH of 7.6, in 2013, and the treatments were not significantly different to one another. The living mulch treatments did not have a significant effect on any of the soil nutrients measured. Due to high variability in the available nitrogen data, the median rather than the mean was calculated for the available nitrogen content across the different treatments. The high variability meant that no significant differences could be detected in the available nitrogen, despite apparent differences between treatments.

Table 10. Soil profile before setting up the trial, November 2013.

Sample	pH	Available N (kg N/ha)	P (mg/l)	K (mg/l)	Mg (mg/l)
Lavender farm	7.6	15.4	64.0	258	100

Table 11. Soil available N, P, K, Mg content and pH results for each of the treatments in June 2015.

Treatment	Mean pH	Median Available N (kg/ha)	Mean P (mg/l)	Mean K (mg/l)	Mean Mg (mg/l)
White clover	7.6	216.65	80.6	319.3	118.0
Black medic	7.5	119.35	87.9	281.3	119.3
Creeping red fescue	7.3	18.7	83.9	245.3	122.5
Birdsfoot trefoil	7.5	60.75	79.9	250.3	121.0
Creeping red fescue + birdsfoot trefoil	7.5	27.75	83.2	255.0	125.8
Untreated	7.3	178.15	84.2	347.5	118.3
Herbicide treatment	7.1	203.45	87.8	313.5	121.3
P value	0.100	0.666	0.280	0.126	0.999
LSD (27 d.f)	0.36	250.1	7.9	84.8	33.4

Soil water content

On 4 June 2015, soil samples were collected from each plot and were assessed for soil water content by recording the soil weight before and after drying the soil in an oven (Table 12). Birdsfoot trefoil treated plots had the highest soil moisture content, 9.3 %, and the untreated plots had the lowest soil water content, 7.1 %. However, there were no statistically significant differences in the soil water content between any of the treatments.

Table 12. Mean soil moisture content for the living mulch treatments, 4 June 2015.

Treatment	Soil moisture (%)
White clover	8.5
Black medic	7.6
Creeping red fescue	7.9
Birdsfoot trefoil	9.3
Creeping red fescue + birdsfoot trefoil	7.6
Untreated	6.8
Herbicide treatment	7.1
P value	0.237
LSD (27 d.f)	2.074

Discussion

All of the living mulch treatments had formed a dense coverage by harvest in October 2015, ranging from 73.8 % (birdsfoot trefoil) to 96 % cover (creeping red fescue and creeping red fescue/birdsfoot trefoil). They also had significantly greater weed suppression compared with the untreated control and were as good, if not better than the herbicide treatment by harvest 2015. This suggests that they were able to out compete the weeds in the treatment plots. All of the creeping red fescue/birdsfoot trefoil mix plots were dominated by creeping red fescue, with it having 90 % to 95 % coverage. This resulted in the two treatments having similar effects on weed cover, apple yields and nutrient content.

There was no difference in the proportion of marketable apples between any of the treatments, however there was a difference between the total yields between the treatments. The lowest yields were in the plots that contained creeping red fescue either on its own or with the birdsfoot trefoil. The nitrogen demanding creeping red fescue may reduce the amount of nitrogen available to the trees for fruit growth, whilst the black medic may provide extra nitrogen from nitrogen fixation; the same may be true for birdsfoot trefoil. The herbicide treatment plots produced the highest total yield and one of the highest proportions of marketable apples. Although this was not significantly higher than any of the living mulch treatments that did not contain any creeping red fescue, the numerical yield reductions for all of the mulch treatments would be of concern because of the value of the crop lost. The more severe yield reductions due to the creeping red fescue swards would be due to the high nutrient use compared with the other mulch species.

The black medic living mulch treatment had the highest total apple yield of the living mulch treated plots, but the difference was not significant. The proportion of undersized or waste apples was also highest in the black medic treated plots, which was most likely due to a large amount of rosy apple aphid damage on a number of trees. The creeping red fescue produced the lowest yield of oversized apples, suggesting that some suppression of vigour or available nitrogen by the living mulch may have reduced the number of fruit exceeding the upper size grades. This may be of benefit in a year of good apple size and on a vigorous variety but may be detrimental if this is not the case.

None of the treatments had starch levels within the acceptable range needed at harvest time for storage of 10 months. The Psi and the mean starch percentage were both higher in 2015 than they were in 2014, suggesting that the fruit was less ripe at harvest. This may have been as a result of poorer growing conditions in 2015, in particular lower sunshine duration during August. However, the mean Brix percentage for all of the treatments remained about the same as 2014.

Leaf nitrogen content was lowest in the creeping red fescue plots (1.26 % w/w), which was much lower than the optimal range (2.0-2.6 % w/w) of nitrogen required for good apple tree growth. Significant yellowing was seen in the plots containing creeping red fescue whether this was with or without birdsfoot trefoil, suggesting nitrogen deficiency. The extension of growth seen in the plots containing creeping red fescue was slightly lower than the other treatments. Although this result was not significant it could due to nitrogen deficiency. There were no differences in any of the soil nutrient parameters between the treatments in this study. Although there appear to be differences in the available nitrogen within the soil, large variations within the data meant that there was no statistical difference between the treatments.

Conclusions

The main objective of the trial was to investigate the potential of sowing living mulches in apple orchards in place of maintaining an herbicide strip; with particular regard to weed control, soil moisture and nutrients and tree growth. The final year's results showed that:

- Overall, the living mulch treatments that did not contain creeping red fescue performed as well as the herbicide treatment in terms of weed suppression.
- All of the living mulch treatments had significantly greater weed suppression compared with the untreated control as well as the herbicide treatment.
- The creeping red fescue treatments, both with and without birdsfoot trefoil, were best at supressing weeds. However, they also had a negative impact on the total yield, with the creeping red fescue plot only yielding an average of 11.7 kg per plot (three trees). This was compared to 43.5 kg per plot for the herbicide treatment.
- The living mulch treatments that did not contain creeping red fescue had similar total yields to the herbicide treatment and were higher than the untreated control.
- Leaf nutrient analysis of fruit was not replicated so statistical analysis was not appropriate, however, there was an overall reduction in leaf nitrogen content in all of the treatments to below the optimal range.
- Whilst there were some differences in the soil nutrient analysis, they were not significantly different. However, the plots with creeping red fescue did tend to have a lower nitrogen content.
- There was no significant difference in the soil moisture between any of the treatments, however it should be noted that this was only measured on one occasion, so may not necessarily have been representative.
- Living mulch treatments that do not contain creeping red fescue may be a suitable alternative to herbicides for supressing weeds in orchards although potential yield reductions are still of concern. Living mulches may become more widely adopted in the future if current herbicides are withdrawn.
- Future work could investigate management techniques such as mowing, to reduce competition with the apple trees.

References

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2.7 Cover crops for weed suppression prior to planting blackcurrant

Introduction

Perennial weeds cause serious losses in fruit crops each year by reducing yield and fruit quality. Perennial weeds are often harder to control than annual weeds due to their persistent nature and because they spread by vegetative means as well as by seed. Whilst tillage can provide effective control for annual weeds, it often hinders efforts to control perennial weeds as it will break roots, rhizomes and stolons and will spread these parts to other areas of the field or to other fields. Therefore, in a perennial crop such as blackcurrant, control of perennial weeds within the row presents a real challenge for growers.

Blackcurrants grow best in moist soils as the fruits require moisture in order to develop. Thus, any weeds present will compete with the blackcurrants for this moisture which will compromise blackcurrant establishment in young plantations and harvested yields in mature plantations. Perennial weeds such as thistles can also present contamination at harvest and damage harvesting machinery by getting caught in the mechanisms. Currently perennial weeds are controlled in blackcurrants by hand weeding or by using band treatments with glyphosate alongside the crop row. Band spraying, however, does not control weeds directly in the crop row, and some broad leaved perennials are moderately resistant. With this and the loss of certain active ingredients (e.g. dichlobenil) in the past five years, and the future threats to actives due to the Sustainable Use Directive, Water Framework Directive and the endocrine disrupter review, there is a real need for the development of alternative mechanisms for the control of perennial weeds in fruit crops.

Cover crops are growing in popularity, particularly in arable systems, as they provide many advantages to soil quality and management through: reduced risk of soil erosion and diffuse water pollution, improving soil structure, organic matter content, water holding capacity and overall soil health. Moreover, cover crops have the ability to suppress certain pest populations and, more importantly for this investigation, to control the weed population. This can either be through physical competition or by chemical action. For example, buckwheat has allelopathic properties where root and shoot exudates can inhibit growth of other living organisms; whilst mustard species can produce bio-fumigant gases when they are cut and incorporated in to soil. All of these properties will also benefit a perennial crop such as blackcurrant, particularly at establishment where cuttings need moist, well structured, fertile soils and little competition from weeds.

The objective of this project was to compare three cover crop sowing mixes for their perennial weed suppressant potential when sown prior to blackcurrant planting.

Materials and methods

This trial was located on an area of fallow land within a commercial blackcurrant plantation site in Essex. The site chosen was grubbed of blackcurrants in 2013 and was due to be re-planted with blackcurrants in winter 2015. The part of the field selected was chosen to give an even a stand of perennial weeds as possible. There were five treatments in total, these included: an untreated control, buckwheat cv. Kora, rye-grass/red clover mix, creeping red fescue/black medic mix and the grower's standard control, maize game cover (Table 1). The plot containing buckwheat was split into two subplots, A and B. The buckwheat in subplot A was allowed to die back naturally and re-seed through the year. In subplot B the buckwheat was cut down after flowering and incorporated shallowly into the soil using a tractor trailed rotavator. Trial plots were large, 12 m wide and 48 m long, with no replication and were situated alongside each other in the centre of the chosen site.

Table 1. Treatment list for blackcurrant cover crop trial - Essex

Treatment	**Species**	**Sowing density (kg/ha)**
1. Untreated control	-	-
2. Buckwheat cv. KORA	*Fagopyrum esculentum*	100
3. Rye-grass/red clover mix	*Lolium multiflorum* + *Trifolium pratens*	35 + 15
4. Creeping red fescue/ black medic mix	*Festuca rubra* + *Medicago lupulina*	75 + 8
5. Maize game cover – grower control	Grower standard	Grower's rate

The site was cultivated shallowly by the grower using disks prior to sowing. The cover crop seed was then sown on 24 April 2014 using an Allen-Spread Master, adjusting the aperture of the spreader to accommodate the various seed sizes and rates detailed in Table 1. The plots were then rolled by the host grower.

A pre-treatment assessment was carried out prior to sowing in order to determine the weed population across the plots. Weed and cover crop ground cover were then also assessed in June and November 2014. At each assessment a 0.25 m^2 quadrat was thrown into the plot at 15 approximately equidistant points, spanning the whole length and width of the plot. For each quadrat, the percentage area covered by each weed species was recorded along with the percentage area occupied by the cover crop species at the latter experiments in the relevant plots.

All plots, except subplot A of the buckwheat plot and the maize game cover plot, were mown in September 2014 by the host grower and subplot B of the buckwheat plot was rotavated shallowly to incorporate the plant material.

The GPS coordinates of the plot corners were logged and over winter 2014/15 the trial area was shallowly cultivated and the land was prepared for blackcurrants. This involved bed forming and covering these raised beds with woven polythene membrane before inserting blackcurrant cuttings in April 2015. Using GPS coordinates, plot corners were re-placed and two further assessments were carried out in June and August 2015, assessing levels of weeds in the un-mulched alleyways using the same methods as in 2014. Blackcurrant growth was assessed at the August visit by measuring the height of 15 blackcurrant plants per plot.

The host grower also sowed a pollinator seed mix of 25 + species down the alleyways after planting, this is currently their standard practice on site to improve soil structure, moisture retention and pollination in plantations, however it did make the weed cover assessments in 2015 more difficult.

Results

The results at the June assessment in 2015 the year following the cover crop treatments, showed that the total weed cover of the plots was significantly different between the treatments and the untreated control, except for plots containing buckwheat (Table2). The creeping red fescue/black medic mix had the lowest percentage cover of weeds (12.1 %) and the untreated plots had the highest weed cover percentage (29 %). The number of fat hen per m^2 was significantly different between the different treatments. The lowest number of fat hen was seen in the rye-grass/red clover mix and in the maize game cover plots, whereas the highest number of fat hen was found in the unincorporated buckwheat plots. The rye-grass/red clover mix and buckwheat incorporated had no creeping thistles in the sampled quadrats, whereas an average of two creeping thistles were found in the maize game cover plots and in the creeping red fescue/black medic mix however these differences were not significant due to variability. The number of creeping mayweed differed significantly between treatments, with the lowest number per m² found in the creeping red fescue/black medic mix and the highest number found in the plots that had buckwheat unincorporated in. The number of dock per m² was also significant, with the highest number of docks in the plot with the rye-grass/red clover mix (2) and the lowest number found in the buckwheat unincorporated (0). Photos of the different plots can be seen in Figure 1.

Table 2. Average percentage weed cover and average number of weed species - June 2015.

	Total weed cover %	**No. fat-hen/m²**	**No. creeping thistle/ m²**	**No. creeping mayweed /m²**	**No. dock/m²**
Untreated control	29.0	31.3	0.6	2.53	0.27
Buckwheat incorporated	14.0	22.6	0.0	1.40	1.00
Buckwheat unincorporated	24.0	34.5	0.4	2.70	*
Rye-grass/red clover mix	24.1	13.3	0.0	1.40	2.00
Creeping red fescue/black medic mix	12.1	26.3	2.0	0.46	1.00
Maize game cover – grower control	17.5	13.4	2.0	1.00	0.20
P. value	**<0.001**	**<0.001**	**0.157**	**<0.001**	**<0.001**
LSD (69 d.f)	**7.900**	**0.650**	**1.765**	**0.184**	**7.900**

*No docks in quadrat

The height of blackcurrant was recorded in August 2015 and no significant differences were seen between the treatments (Table 3). Weed cover percentage had increased since June and was significantly different on this date between the untreated plots (65.33 %) and the maize game cover plot (48 %).

Table 3. Average blackcurrant shoot height and percentage weed cover - August 2015.

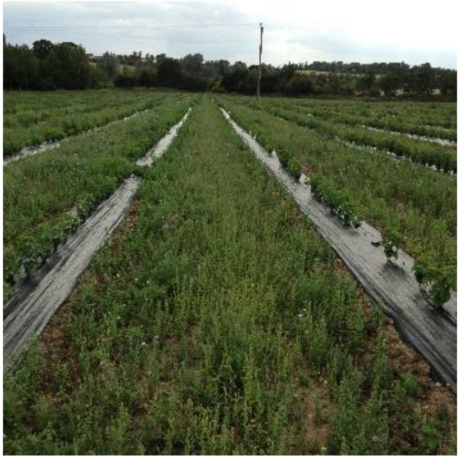
Treatment	Shoot height cm	% Quadrat cover of weeds
Untreated control	28.93	65.33
Buckwheat incorporated	30.20	65.00
Buckwheat unincorporated	32.30	48.50
Rye-grass/red clover mix	28.07	59.67
Creeping red fescue/black medic mix	35.00	51.67
Maize game cover – grower control	35.27	48.00
P. value	**0.230**	**0.057**
LSD (69df)	**7.120**	**13.16**

Untreated control plot

Buckwheat plot

Creeping red fescue/clover mix

Rye-grass/black medic mix plot



Maize plot

Blackcurrants at the June 2015 assessment

Figure 1. Images of the trial plots – August 2015

Discussion

Results in 2014 showed that all of the crop cover species tested do have a suppressive effect on many of the annual weed species present, along with some perennial weeds. Success of weed suppression seems to be determined by the rate of establishment and density of cover achieved by the cover crop. Both the grass mixes achieved nearly 100 % ground cover within three to four months. Buckwheat grew quickly but never achieved more than 40 % ground cover. It is thought that a higher sowing density may help this species but cost will also come into play as this is already one of the more expensive cover crops. The maize also grew rapidly but did not achieve more than 40 % cover, however as it grows to nearly 2 m, the shading effect appears to work well at supressing weeds.

At both 2014 assessments, the buckwheat plot was the least suppressive of the four cover crops and the two grass legume mixes were the most suppressive of weeds. In terms of the perennial weed species controlled, again, the grass mixes tended to show greater suppression with both the rye-grass/red clover mix and the creeping red fescue/black medic mix showing little or no nettle or thistle in the quadrat survey. Buckwheat and the maize game cover also showed a reduction in thistle and the buckwheat plot was also the only cover crop which did not show an increase in the level of docks during 2014.

In 2015, the year following the cover crop treatments, the creeping red fescue/black medic mix remained the best cover crop in terms of weed suppression. In 2014 this species mix formed a dense coverage and so it was most likely able to control weeds by smothering them and outcompeting them for water and nutrients. However, the rye-grass/red clover mix also formed a dense cover in 2014, and whilst it controlled weeds well in 2014, the weed suppression effect was less persistent in the following year than for the creeping red fescue/black medic mix. None of the crop covers re-established into 2015 to much extent (2.1 % rye-grass/red clover and 3.2 % creeping red fescue/black medic in June 2015) which suggests that the creeping red fescue/black medic mix was also controlling weeds by another mechanism i.e. allelopathy.

The creeping red fescue/black medic mix was closely followed by the incorporated buckwheat crop cover in terms of being the best treatment for suppressing weeds when recorded in June 2015, although the effect was less marked by August. Buckwheat is also known to have allelopathic properties. However, these appear to be more pronounced when the buckwheat is incorporated, rather than when it is left to re-seed natural, suggesting that these compounds are possibly found in the aerial parts of the plant. The lowest numbers of fat-hen and creeping mayweed were found in the creeping red fescue/black medic plots suggesting that this cover crop species combination is best for controlling these species of weeds. The lowest number of docks were seen in the buckwheat incorporated plots which is surprising as docks are in the same family as buckwheat, *Polygonaceae*.

Whilst cover crops with allelopathic activity may offer benefits for weed control, there is the concern that using cover crops with allelopathic properties may be detrimental to the growth of future crops. In this trial no negative effect was seen to the growth of blackcurrants from any of the cover crops that were used in the trial.

Conclusions

- All cover crops tested showed some suppression of both perennial and annual weeds whilst they were growing in 2014. The grass legume mixes were more suppressive than buckwheat and performed similarly to the maize game cover treatment in 2014.
- The following year, once the crop cover had been removed, the residual effect on weeds was harder to assess due to the presence of the pollinator mix that was sown by the grower over all plots after planting.
- Of the weed species present across all plots, there did appear to be differences in number/m^2 with the plots previously sown with buckwheat, creeping red fescue and maize game cover showing fewer weed species in the alley ways than the untreated control and the rye-grass/ clover mix.
- There was clear evidence of volunteer cover crops re-seeding in the alley ways and planting holes, so management strategies after establishment of cover crops, prior to crop establishment, need to be developed.
- No significant differences in plant height of blackcurrants were observed between the plots in August 2015.
- The creeping red fescue/black medic mix and the incorporated buckwheat crop covers were the treatments with the best residual effect in 2015 for controlling weeds.

2.8 Alternatives to Basamid in baby leaf salad production

Introduction

Weeds are expensive to control in organic salad production systems with few available options to the grower, and all weeds need to be completely removed before harvest to avoid contamination and rejection from retailers. Typical options used are strategically timed cultivations such as stale seed bed technique, hoeing, and weeding just before harvest and appropriate cover crops in the fallow season. In addition in conventional production, the future use of soil sterilants such as Basamid (dazomet) is uncertain and there is increasing interest in the use of alternative methods for weed suppression such as using cover crops.

Cover crops are growing in popularity particularly in arable systems as in addition to their potential for weed suppression, they provide many advantages to soil quality and management through; reduced risk of soil erosion and diffuse water pollution, improving soil structure, organic matter content, water holding capacity and overall soil health. Cover crops are already used in rotation by some salad growers for these latter purposes, including by the grower which hosted the trial. Cover crops can help with weed suppression either directly through physical competition or by chemical action, for example buckwheat (*Fagopyrum esculentum*) has allelopathic properties where root and shoot exudates can inhibit growth of other living organisms, while mustard species can produce bio-fumigant gases when they are cut and incorporated in to soil. However, mustards are not favoured in baby leaf salad rotations due to fears that they may be a host for brassica pests and disease such as club root that can trouble wild rocket. Therefore red clover (*Trifolium pratense*) and buckwheat were chosen to be used in the trials as alternatives to the current grass/white clover (*Trifolium repens*) mix that is currently sown.

The objective of this project was to compare the advantages of sowing five different cover crop mixes in an organic salad crop rotation, and assessing their influence on weed suppression and effects on nutrient and organic matter status.

Materials and methods

The work was carried out on a site at a commercial salad grower in Wiltshire on an area of organic land that was being fallowed and sown with cover crops during the summer with the aim to increase soil fertility and also reduce weed burden in the following season. The area was due to be sown with baby leaf spinach in April 2015.

There were five different cover crop species and mixes in total (Table 1), with the area representing current grower practice being sown with a grass/clover ley. Experimental treatments included buckwheat (cv. Kora) and red clover (cv. Formica), and also combinations of these cover crops sown together by intentionally overlapping the application with the spreader (Figure 1). There were no untreated plots. The grass/clover mix and buckwheat was sown by the grower on 17 April using a 24 m fertiliser spreader with spinning discs in areas of one hectare and nearly half a hectare respectively. ADAS staff sowed the red clover on 16 April by hand in an area of 12 m x 50 m. To achieve an area with just red clover in addition to an area with a mix of buckwheat and red clover, ADAS sowed the red clover the day before the buckwheat was sown by the grower and then covered half of the plot with plastic to prevent the buckwheat being oversown in the red clover only plot (Figure 2). Once sown all the plots were rolled by the grower.

The cover crops were allowed to establish, and then mowed as per current practice in mid-July and again in late August. This is to encourage a mat of material in the grass/clover ley to build organic matter and suppress weeds. It is also done before the cover crop sets seed to prevent problems with volunteers in the commercial spinach crop in the following season.

Table 1. Cover crop treatments and sowing rates – Wiltshire 2014

Treatment no.	Common name	Scientific name	Sowing density (kg/ha)
1	Grass and clover ley Italian Ryegrass cvs. Danergo, Dracar, Fox, Red clover cv. Milvus (grower standard)	Lolium multiflorum +Trifolium pratense	22.5
2	Buckwheat cv. Kora	Fagopyrum esculentum	100
3	Red clover cv. Formica	Trifolium pratense	25
4	Clover and grass/Buckwheat cvs as above	Lolium multiflorum + Trifolium repens / Fagopyrum esculentum	22.5 + 100
5	Red clover/Buckwheat cvs as above	Fagopyrum esculentum/ Trifolium pratense	25 + 100

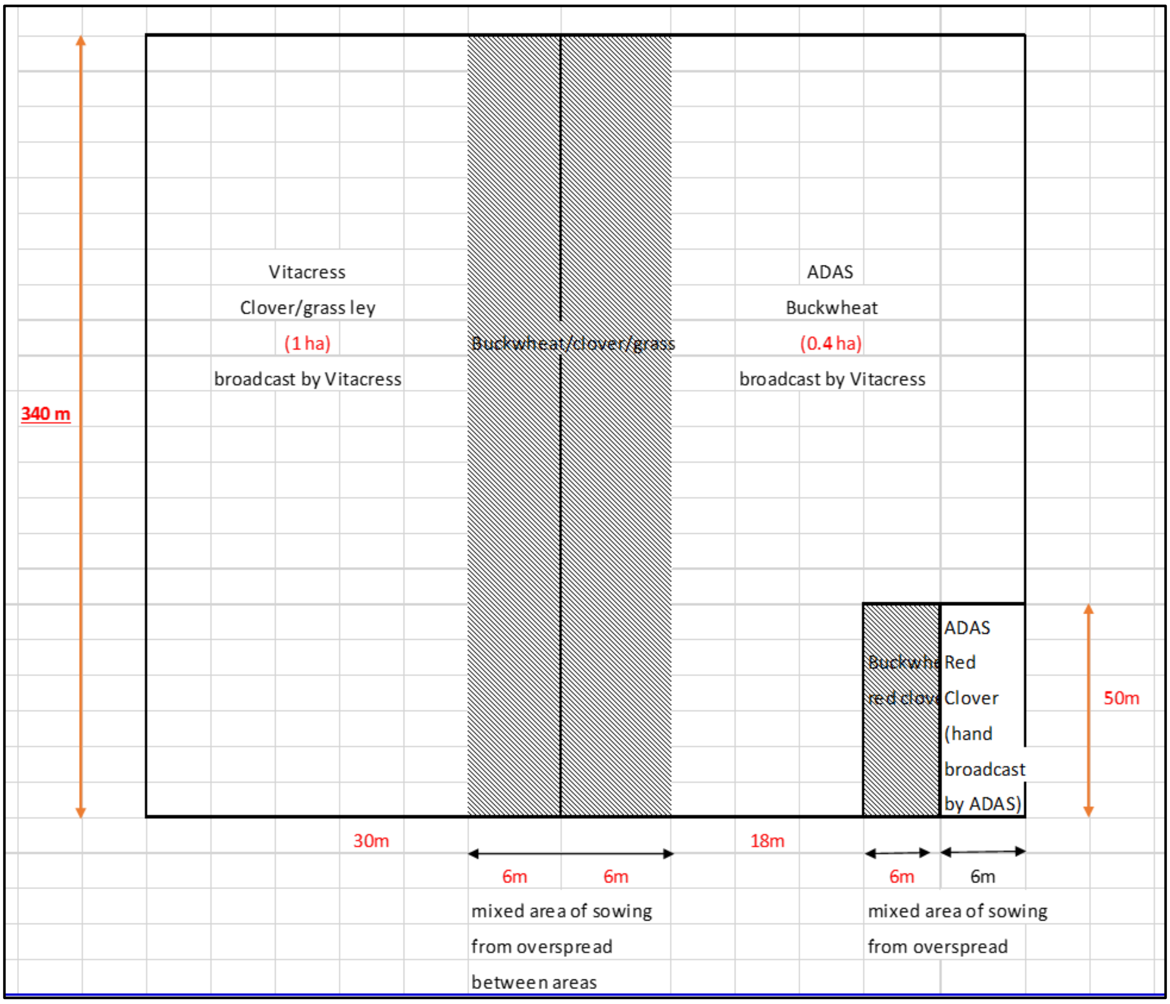


Figure 1. Detail of cover crop area sizes and treatments – Wiltshire, 2014

Figure 2. (Left) Area sown with red clover by hand by ADAS showing half of the plot covered with plastic to prevent overspread **(Right)** Successful establishment of both the buckwheat/red clover mix and the red clover only area (4 July) – Wiltshire, 2014.

Assessments

During the period of cover crop establishment five randomly selected areas were marked so that progress of establishment could be recorded in the same areas on 6, 19, and 30 May. Percentage of weed species and percentage weed cover were also recorded at these assessments. The final assessment in 2014 to record cover crop establishment, percentage of weed cover and weed species present was then made on 4 July in five randomly selected areas using a 0.25 m^2 quadrat. A subsequent visit was also made to the trial in September.

In 2015 the weed levels were then assessed in the spinach crops subsequently established in each of the areas where the cover crop treatments had been grown in 2014. Within each treatment area weed species and number were recorded within 20 randomly selected areas using a 0.25 m^2 quadrat.

A soil sample was taken from the whole trial area before the cover crops were sown to measure soil mineral nitrogen (SMN) to 90 cm in 30 cm increments and pH, P, K, Mg and organic matter (OM) were also measured. Once the cover crops had been mown and incorporated in October, these soil analysis were then repeated from each cover crop area in November to assess the effects of the cover crops on these parameters. The soil sampling was repeated in early April 2015 to assess the effects of the cover crops on spring levels of SMN, pH, P,K, Mg and OM.

Biomass of the cover crops was assessed on 30 October before the cover crops were mown. Results were analysed by ANOVA.

Results

Establishment

The cover crops germinated well and established with varying degrees of percentage ground cover depending on canopy size and morphology. For example, the larger leaf canopy of buckwheat and clover gave a significantly greater percentage cover than the thin grass leaves, especially earlier on. There were significant differences between percentage ground cover of each crop type at every assessment. At the assessment made on 30 May during establishment, the buckwheat and red-clover mix, as well as the buckwheat and red clover alone gave significantly greater ground cover (Figure 3). However, by 4 July the grass/clover mix had established the greatest percentage of ground cover at nearly 100% with the red clover and buckwheat mix also giving greater than 90% ground cover as seen in the photos in Figure 4. Where the clover/grass mix and the buckwheat were sown by overlapping the seed spreading, establishment and ground cover was patchy. This could have been due to less even seed spread at the outer edges of the spreading area.

After the cover crops were mown in mid-July, as it was not allowed to seed, the buckwheat failed to re-establish and white clover grew extensively in its place.

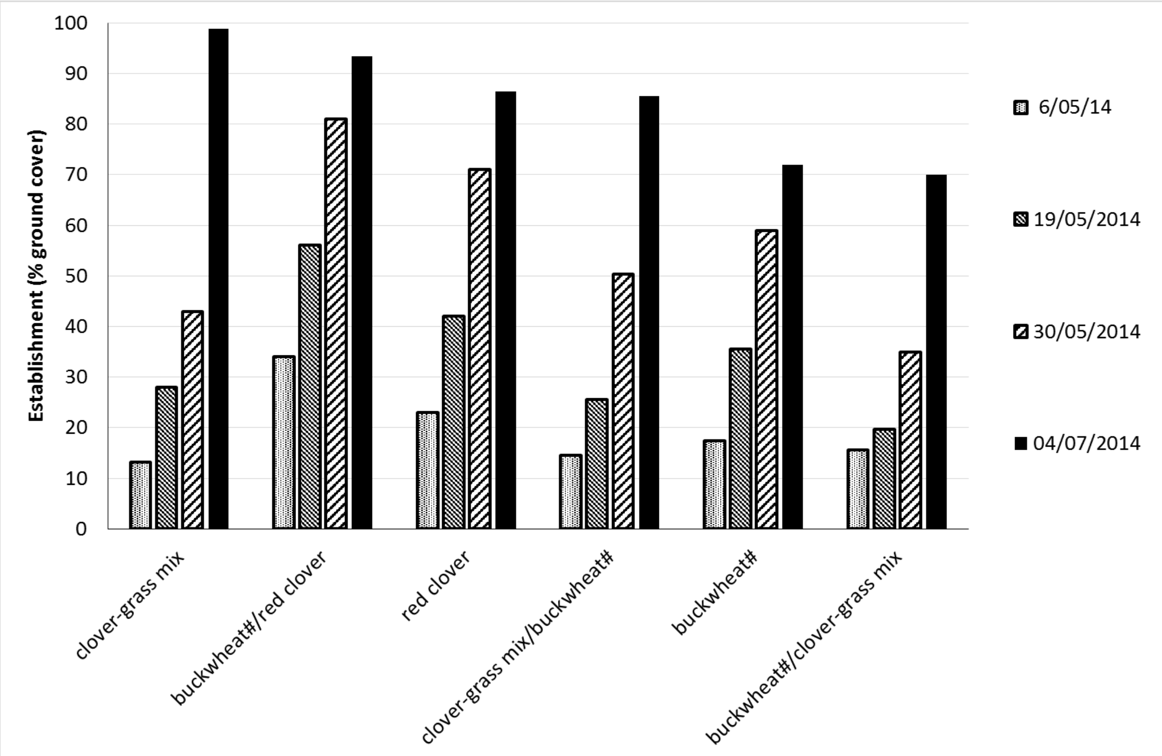


Figure 3. Establishment of the six cover crop treatments shown as percentage of ground cover from May through to flowering in July. Wiltshire, 2014.

Grass clover mix (grower standard)

Grass clover mix/buckwheat

Buckwheat/grass clover mix

Buckwheat

Buckwheat/red clover

Red clover

Figure 4. Appearance of cover crop treatments on 4 July at flowering and just before mowing, Wiltshire, 2014.

Weed cover- 2014

Weed levels and species present before the area was cultivated and the cover crops were sown was recorded in early April 2014 (Table 2 and Figure 5). Common chickweed (*Stellaria media*) was the most common species present.

Table 2. Weed species present over the trial area before cultivation and trial sowing in April, Wiltshire, 2014.

Weed species	Common name
Amsinckia intermedia	Amsinckia
Capsella bursa-pastoris	Shepherds purse
Chenopodium album	Fat hen
Diplotaxis tenufolia	Volunteer wild rocket
Epilobium sp.	Willowherbs
Geranium molle	Crane’s bill
Matricaria disciodes	Pineappleweed
Poa annua	Annual meadow grass
Polygonum aviculare	Knot-grass
Senecio vulgaris	Groundsel
Spinacia oleracea	Volunteer spinach
Sonchus sp.	Sow thistle
Stellaria media	Common chickweed
Tripleurospermum inodorum	Scentless mayweed
Urtica urens	Small nettle
Veronica persica	Common field-speedwell

Figure 5. Appearance of trial area on 11 April just before cultivation, Wiltshire, 2014.

The percentage of weed cover was assessed during establishment of the cover crops and red clover gave the best weed suppression, slightly better than the current clover grass mix used by the grower, but not significantly so. Buckwheat did not significantly suppress weeds compared to the other cover crop treatments during the first month of establishment, but once it had established a good canopy through June, competition for light and possible allelopathic effects meant that weed cover was reduced from 75% at the 30 May assessment to 15% at the 4 July assessment (Figure 6). The red clover and buckwheat mix also gave very slightly better weed suppression than the clover-grass mix.

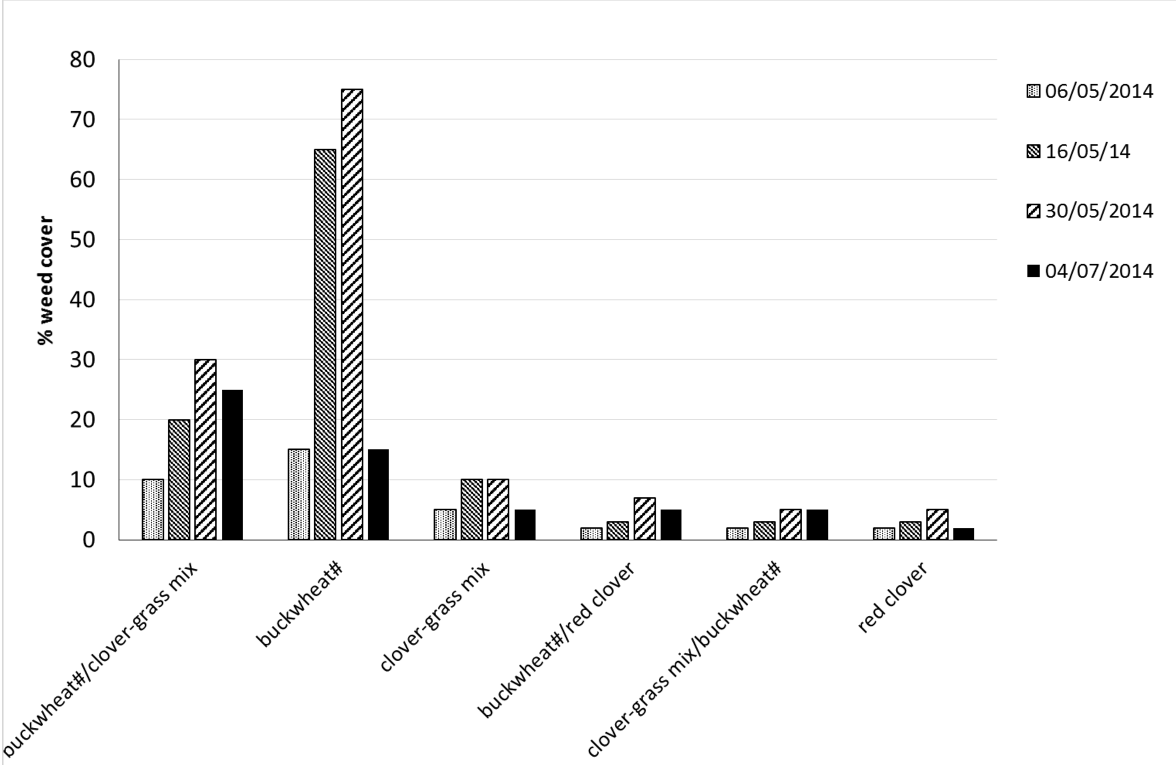


Figure 6. Percentage weed cover between the six cover crop treatments from May to July, Wiltshire, 2014. (# buckwheat was replaced by white clover after 4 July as it failed to re-establish).

When the trial was viewed in September and at the biomass sampling in October no weeds were recorded. This was because, at these times the clover in the cover crop mixes, or the clover that had re-established instead of the buckwheat had formed a dense canopy covering at least 80% of the quadrats. In addition, those treatments which included grass in the mixture had a weed suppressive mat of decayed organic matter at the soil surface which built up after each mowing and smothered any weeds (Figure 7).

Figure 7. Grass clover mix showing the mat of organic matter at the soil surface, Wilts, 2014.

Treatments with a high proportion of clover gave the highest biomass when assessed just before the cover crops were incorporated at the end of October (Figure 8).

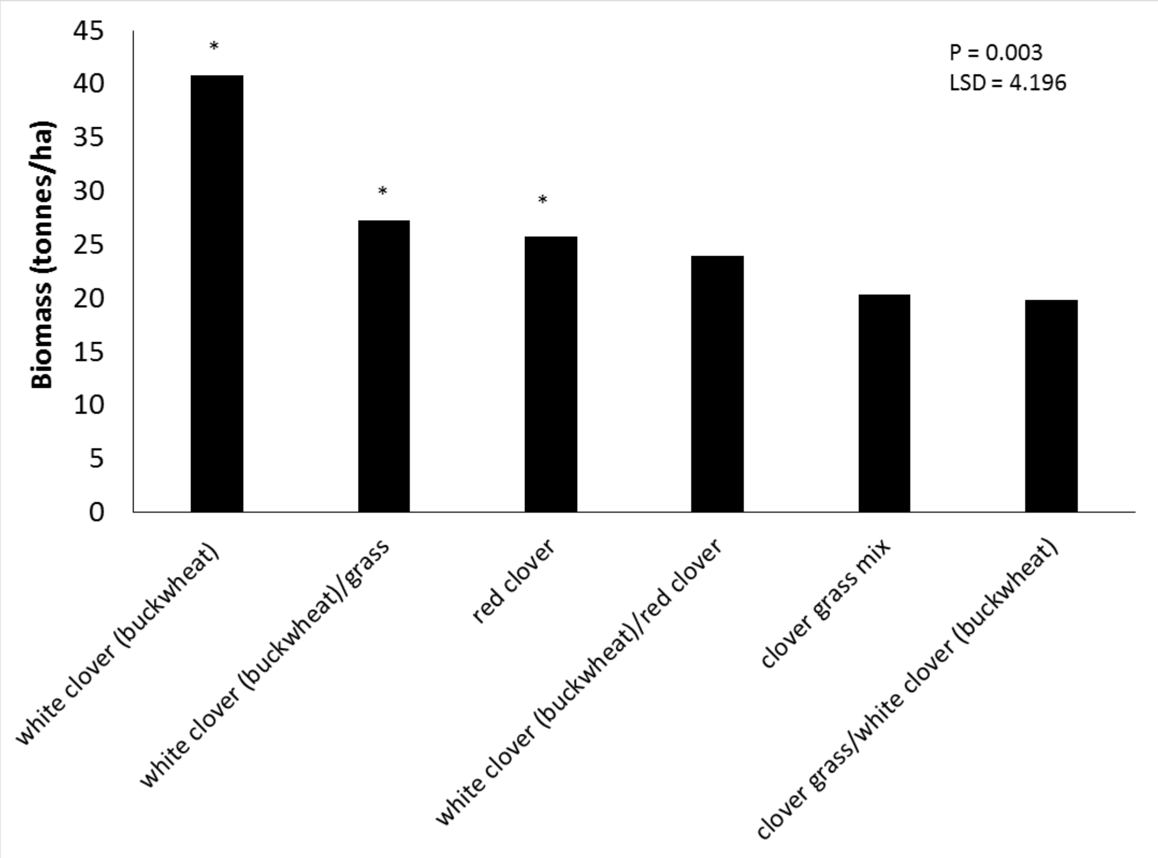


Figure 8. Biomass compared between the six cover crop treatments in October, Wiltshire, 2014. (# buckwheat was replaced by natural regrowth of white clover after 4 July as it failed to re-establish) Note: LSD and P value shown is for analysis minus the white clover which replaced the buckwheat.

Weed cover in subsequent spinach crops – 2015

Weed levels and species present within the spinach crops was recorded at each assessment (Table 3 and Figure 9). Common chickweed was the most common species present, with small nettle, annual meadow grass and volunteer clover also prevalent. Buckwheat (white clover) alone and red clover with buckwheat (white clover) gave best overall weed suppression in the spinach crops drilled in spring/summer 2015. This was due to improved suppression of small nettle and volunteer clover, as the suppression of chickweed remained equivalent to the current grower standard.

Table 3. Weed species present over the trial area before cultivation and trial sowing in April, Wiltshire, 2014.

Weed species	Common name
Capsella bursa-pastoris	Shepherds purse
Fallopia convolvulus	Black bindweed
Geranium molle	Crane's bill
Matricaria disciodes	Pineappleweed
Persicaria maculosa	Redshank
Poa annua	Annual meadow grass
Polygonum aviculare	Knot-grass
Senecio vulgaris	Groundsel
Sonchus sp.	Sow thistle
Stellaria media	Common chickweed
Trifolium pratense	Volunteer rocket
Tripleurospermum inodorum	Scentless mayweed
Urtica urens	Small nettle
Veronica persica	Common field-speedwell

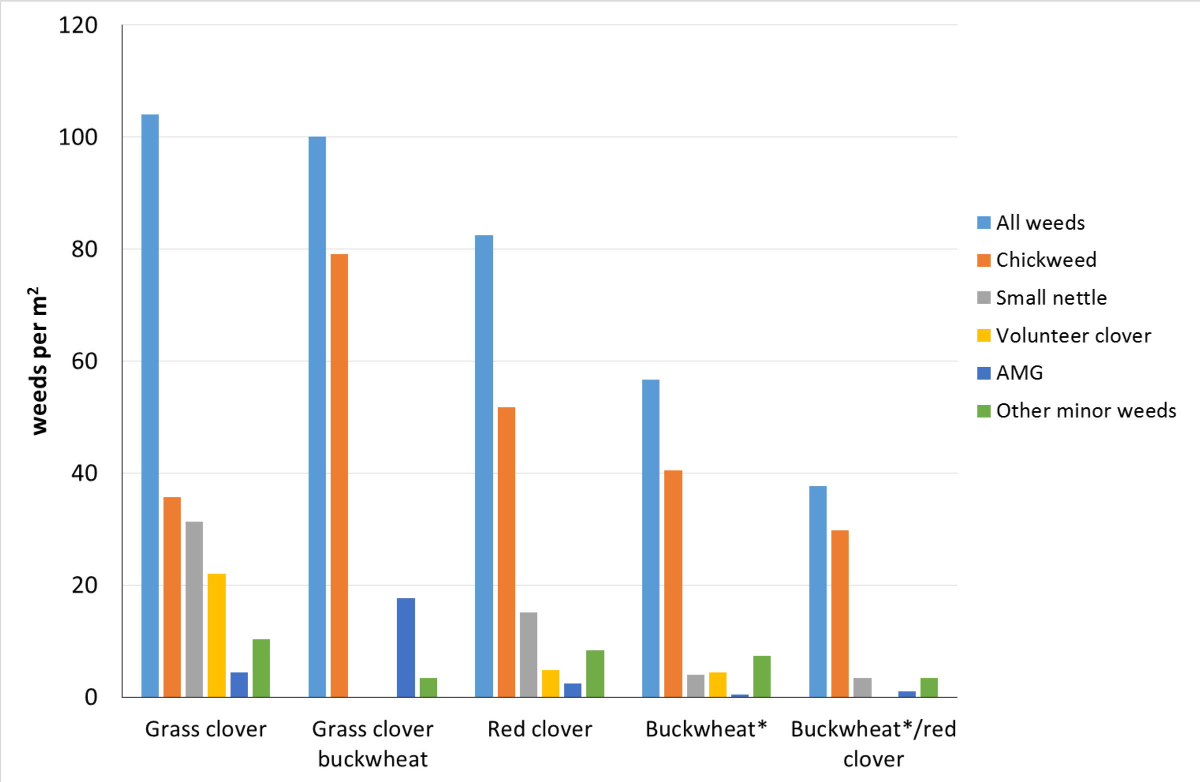


Figure 9. Comparison of weeds per m^2 weed cover in the subsequent spinach crops drilled in the areas after the cover crop treatments. June, Wiltshire, 2015. (* buckwheat was replaced by white clover after 4 July 2014 as it failed to re-establish).

Soil and cover crop N uptake analysis

Treatments with the highest N uptake were those with a higher proportion of clover in them when the biomass samples were taken. This includes the plots that originally contained buckwheat but in which white clover re-established later (Figure 10). There were no significant differences in N uptake.

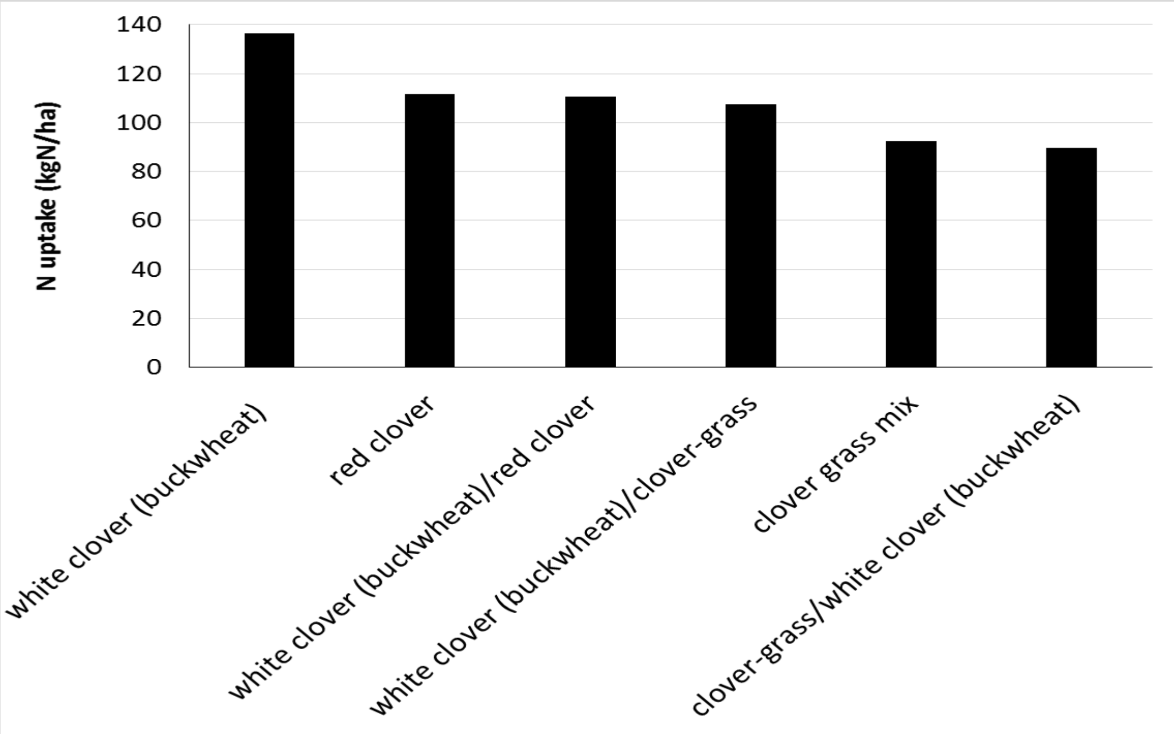


Figure 10. Crop N uptake compared between the six cover crop treatments in October, Wiltshire, 2014. (Buckwheat was replaced by natural regrowth of white clover after 4 July as it failed to re-establish) Note: There were no significant differences if the data is analysed without including the buckwheat only treatment

With the exception of the clover grass mix, all other treatments increased organic matter by at least 0.2% compared with the measurement taken in April (Table 3 and 4). Also, all treatments that originally contained buckwheat in any proportion had the lowest SMN through the 0-90 cm profile when the sample was taken in November. The red clover and the grass clover ley had the highest remaining SMN. Potassium (K) was reduced by one index by the cover crops that were mainly grass, but all other indices were largely unaffected. A soil sample was taken in Spring 2015 to test for any effects that remain prior to drilling of the commercial spinach crops.

Table 3. Soil profile before setting up the trial, April 2014. (Soil index in brackets)

Sample	pH	Organic Matter (%)	Available N (kgN/ha)	P (mg/L)	K (mg/L)	Mg (mg/L)
Whole trial area	7.1	4.2	70.9 (1)	103 (6)	522 (4)	111 (3)

Table 4. Soil available N, P, K or Mg content (Index in brackets) and pH results in November after incorporation, 2014. (Soil Index in brackets)

Treatment	pH	Organic Matter (%)	Available SMN Autumn 2014 (kgN/ha)	Available SMN Spring 2015 (kgN/ha)	P (mg/L)	K (mg/L)	Mg (mg/L)
Grass and clover ley (grower standard)	7.4	3.8	131.8 (4)	75.1 (1)	103 (6)	490 (4)	91 (2)
Buckwheat cv. KORA	7.1	4.4	47.1 (0)	138.5 (4)	104 (6)	468 (4)	102 (3)
Red clover cv. FORMICA	7.3	4.7	112.4 (3)	132.3 (4)	108 (6)	602 (5)	106 (3)
Clover and grass/Buckwheat	7.3	5.0	46.1 (0)	105.5 (3)	104 (6)	577 (4)	98.5 (2)
Buckwheat/clover and grass	7.0	4.8	56.6 (0)	124.9 (4)	106 (6)	589 (4)	105 (3)
Red clover/Buckwheat	7.2	4.4	69.4 (1)	120.7 (3)	115 (6)	575 (4)	110 (3)

In spring, all treatments which had been sown with clover or where volunteer clover had re-grown to form the predominant species had a high available SMN content through the soil profile and soil nitrogen supply (SNS) indices of 3-4. Although there was clover in the grass/clover ley, this was predominantly a grass ley and as grass has a higher carbon:nitrogen ratio it would breakdown slower with less readily available N in spring in comparison to the clover cover crops which release N at a quicker rate. This would be useful nutrient for the following spinach crops, and would allow the grower to reduce rates of manufactured fertiliser.

Discussion

In the first year of the trial, cover crop establishment was one of the key aspects that was measured and all of the cover crop treatments germinated and established well reaching at least 70% ground cover by 4 July at 11 weeks after sowing. Red clover sown with buckwheat was the quickest to establish by the end of May (six weeks after sowing) reaching 81% cover, and red clover alone was second quickest reaching 71% cover at the same date. The clover and grass mix was initially slower to establish in the first six weeks but, by 4 July the grass/clover mix had established the greatest percentage of ground cover at nearly 100%, with the red clover and buckwheat mix also giving greater than 90% ground cover.

The cover crops were all mown in mid-July and again at the end of August to prevent the cover crops reaching seed, which is done to avoid volunteers germinating in the following commercial organic spinach crop. Due to this mowing, the buckwheat failed to re-establish and white clover grew extensively in its place. In hindsight a different mix could have been used as it does not respond well to being mown before it seeds. Nevertheless, there were still treatment differences in weed emergence noted when areas were assessed in 2015 after the commercial spinach crops were drilled.

Biomass was measured in October and the treatments containing the greatest proportion of clover gave the highest fresh weight per quadrat equating to 23.9 to 40.8 tonnes/ha of material.

The percentage of weed cover was assessed during establishment of the cover crops and red clover gave the best weed suppression, slightly better than the current clover grass mix used by the grower, but not significantly so. Buckwheat did not significantly suppress weeds compared to the other cover crop treatments during the first month of establishment, but once it had established a good canopy through June, competition for light and possible allelopathic effects meant that weed cover was reduced from 75% at the 30 May assessment to 15% at the 4 July assessment. The red clover and buckwheat mix also gave very slightly better weed suppression than the clover-grass mix. By the time the cover crops were ready for incorporation the successive periods of mowing had encouraged a mat of organic matter to form at the soil surface, which suppressed all weed growth in October in all treatments. This appeared to be greatest in the treatments with a higher proportion of grass. This would be due to the higher carbon: nitrogen ratio that grass has compared to clover, meaning that breakdown of the remaining debris is slower.

Measurements taken to consider the nutrient uptake and influence of the cover crops on soil fertility showed no significant differences in N uptake between the original treatments that were sown, but the buckwheat plots had the lowest SMN in November. This could be an advantage as the highest risk to leaching in winter is nitrogen left in soil rather than crop residues.

In the second year of the trial (2015) the effects on weeds in the following crop was recorded. Buckwheat (white clover) alone and red clover with buckwheat (white clover) gave best overall weed suppression in the spinach crops drilled in spring/summer 2015. This was due to improved suppression of small nettle and volunteer clover, but the suppression of chickweed was no better than the current grower standard. This indicates that even though the buckwheat failed to re-establish after topping, the possible allelopathic qualities of the species may have still suppressed the growth of some susceptible weeds.

There was also an increase in the amount of available SMN in spring 2015 in the areas which were sown with the cover crops which contained a larger proportion of clover, with increased nitrogen remaining when compared with the grower standard grass/clover ley. Although there was clover in the grass/clover ley, this was predominantly a grass ley and as grass has a higher carbon:nitrogen ratio it would breakdown slower with less readily available N in spring in comparison to the clover cover crops which release N at a quicker rate. This increased SMN would be useful for the following spinach crops, and would allow the grower to reduce rates of manufactured fertiliser. However, the amount of SMN may vary year on year with overwinter rainfall, and in the 2014/15 winter the rainfall was lower than average in the area where the trial was carried out. This indicates that it would be prudent to test for SMN to rooting depth before drilling a following crop to take account of the correct levels of SNS where cover crops have been used.

Conclusions

- All cover crops established at, at least 70% ground cover with the clover grass ley and buckwheat/red clover mix initially showing the best establishment before mowing.
- During the cover crop establishment, the red clover, and red clover and buckwheat mix gave slightly better weed suppression than the currently used grass clover ley.
- Buckwheat failed to re-establish after mowing, but at soil sampling in November the lowest SMN remained in these areas reducing risk of nitrogen leaching.
- The areas that were sown with buckwheat (subsequently colonised by white clover) alone and red clover with buckwheat (subsequently colonised by white clover) gave best overall weed suppression, reducing levels of small nettle.
- Useful levels of soil mineral nitrogen remained after all cover crops, with the greatest levels in spring seen after those mixes which predominantly contained clover.

2.10 Leek contact herbicide screen – alternatives to Totril in programmes

Introduction

The control of weeds in leek crops in the early part of the season soon after crop emergence is challenging. This is because the crop is sensitive to a number of herbicides before the leeks reach two true leaves. At this stage weeds are suppressed as long as possible by pre-emergence residual herbicides and low doses of contact herbicides. It's not until after this growth stage that combinations of stronger contact herbicides can be used to gain control of troublesome weeds such as groundsel (*Senecio vulgaris)*, mayweed *(Tripleurospermum inodorum)*, field pansy *(Viola arvensis)* and chickweed *(Stellaria media).* Previously Totril (ioxynil) was used in combination with other contact herbicides such as Starane 2 (fluroxypyr), Afalon (linuron) or Basagran SG (bentazone) at this later stage to gain effective control of more troublesome weeds that escape control from the earlier herbicide applications. However, ioxynil will be withdrawn at the end of August 2016 leaving a gap in programmes. Bromoxynil (Buctril) has gained approval in alliums and is aimed at a similar place in grower programmes but it's crop safety and weed spectrum is different to ioxynil, and therefore growers require information on the efficacy and crop safety of bromoxynil to allow them to use the product safely and effectively.

The main objective of the trial was to assess the crop safety and efficacy of Buctril alone and in typical grower programmes with commonly used tank-mix partners such as Starane 2, Afalon and Basagran SG.

Materials and methods

Trial site

Work was carried out on a commercial field crop of leeks cv. Pancho. The crop was drilled on 30 April and the crop would have been due for harvest in November 2015. The soil is a sandy loam and the major weeds were groundsel, volunteer oilseed rape *(Brassica napus ssp. oleifera),* mayweed and red dead-nettle *(Lamium purpureum).* Fat hen *(Chenopodium album)*, sow thistle *(Sonchus* spp*.)*, black bindweed *(Fallopia convolvulus)*, common chickweed, willowherb *(Epilobium* spp), annual meadow grass (*Poa annua)*, charlock *(Sinapsis avensis)*, Canadian fleabane *(Conyza canadensis)*, and crane's-bill *(Geranium molle)* also appeared in many plots in the trial but not as frequently.

Trial design

The trials were a fully randomised block design with nine main treatments including an untreated control, and included a grower practice control of Totril in a tank mix with Starane 2 and Basagran SG. The same treatments were applied twice as per grower practice. (Tables 1 and 2). There was four-fold replication, and each plot was 5 m long and 3.0 m wide.

Table 1. Treatments applied to plots in 200 L water per hectare. Lincolnshire, 2015.

Treatment no.	Product	Rate
1	Untreated	-
2	Buctril	0.89 L/ha
3	Buctril + Afalon	0.53 L/ha + 0.3 L/ha
4	Buctril + Basagran SG	0.53 L/ha + 0.3 kg/ha
5	Buctril + Basagran SG + Starane 2	0.53 L/ha + 0.3 kg/ha + 0.3 L/ha
6	Totril	0.3 L/ha
7	Totril + Afalon	0.3 L/ha + 0.3 L/ha
8	Totril + Basagran SG	0.3 L/ha + 0.3 kg/ha
9 (Standard)	Totril + Basagran SG + Starane 2	0.3 L/ha + 0.3 kg/ha + 0.3 L/ha

Table 2. Active ingredients and approval status of products used in the trials. Lincolnshire, 2015.

Product	Active ingredient	Approval status	Application timing requirements
Totril	ioxynil 225 g/L	On label, to be withdrawn end August 2016	-
Buctril	bromoxynil 225 g/L	EAMU	BBCH 19
Afalon	linuron 450 g/L	EAMU	16 weeks before harvest
Basagran SG	bentazone 87% w/w	EAMU	Before 3 true leaf stage
Starane 2	fluroxypyr 200 g/L	EAMU	28 days before harvest

The crop in the trial area was managed as per commercial practice, including herbicide applications, until two true leaves was reached. At this leek growth stage the site was marked out and the experimental treatments were applied on 15 June. Weeds in the plots were at the growth stages of cotyledon to two true leaves. The same experimental applications were applied again on 30 June, and at this point the crop had reached four true leaves. The treatments were applied to the beds using an OPS sprayer and a 3.0 m boom with 02F110 nozzles, to achieve a medium spray quality at 200 L/ha, and sprays were applied early morning.

Assessments

The trial was assessed at each spray application timing and on three occasions post treatment; approximately two, four and six weeks after the application of the treatments; on 15 June, 30 June, 8 July, 29 July and 16 August. 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 weed cover, numbers of weeds per m^2 and weed species were also recorded. Data was analysed by ANOVA.

Results

All of the treatment combinations showed no or little phytotoxic effects to the leeks by six weeks after the 2^{nd} application (Figure 1), and no significant differences were seen between treatments. However at earlier assessments, two weeks after treatment those plots treated with Buctril and Afalon, and Totril alone showed damage below a commercially acceptable standard which was exhibited as stunting and yellowing by the former combination, and thinner plants when treated with Totril alone. The combination of Buctril, Basagran SG and Starane 2 and Buctril alone were also only just at an acceptable level of phytotoxicity at two weeks post application. The slight damage from this combination was mainly exhibited as stunting to the plants. At four weeks post-application, only the plots treated with Buctril and Afalon or Buctril, Basagran SG and Starane 2 showed continuing effects as yellowing and stunting but were recovering to a nearly commercially acceptable appearance at this point.

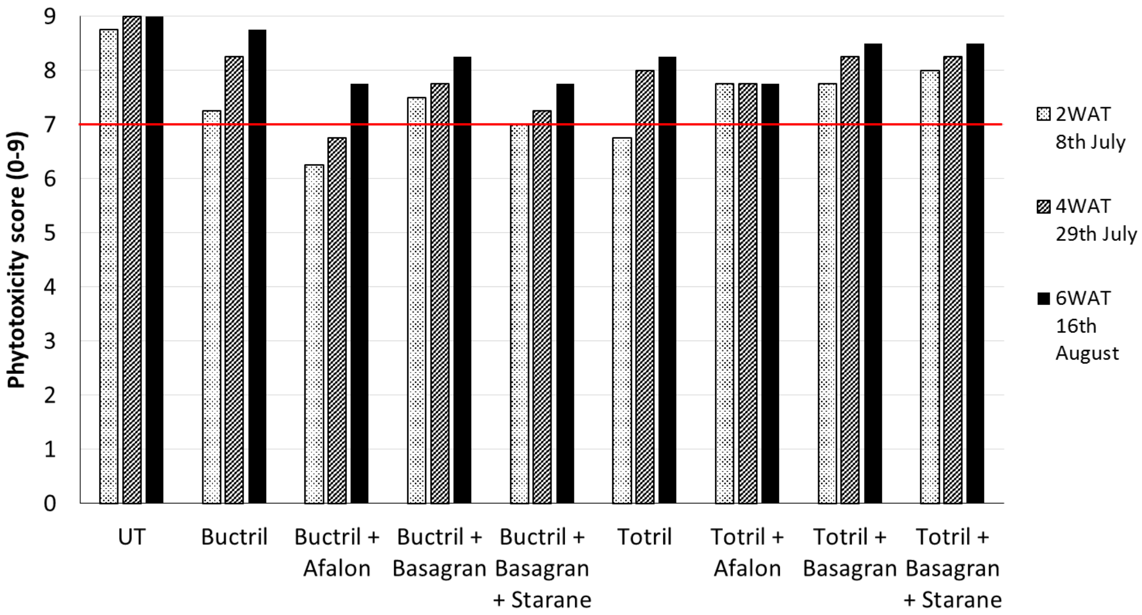


Figure 1. Phytotoxicity scores at two, four and six weeks after application for treatments applied to leeks, Lincs, 2015 (red line marks the level at which phytotoxicity effects are commercially acceptable, * = significantly different from the untreated).

No significant differences in weed control were seen at assessments completed at least two weeks post-application. However, there were significant reductions in weed numbers by all treatments at the assessment completed at the 2nd application timing, but at that assessment weed levels were low in the untreated plots at only 15 weeds per m^2 (Figure 2). Germination of weeds in the trial remained low due to the dry weather through June and July, but increased in August when showers returned and gave a flush of weeds at the final assessment. There were no significant differences at the final assessment, but the data shows a trend by all treatments for a reduction in weed numbers, with the 3-way tank mixes of Totril or Buctril in combination with Basagran SG and Starane 2 giving the lowest weed counts at the final assessment. The level of weed control given by Buctril and the Buctril tank-mixes was similar when compared with Totril and the Totril tank-mixes which it is replacing.

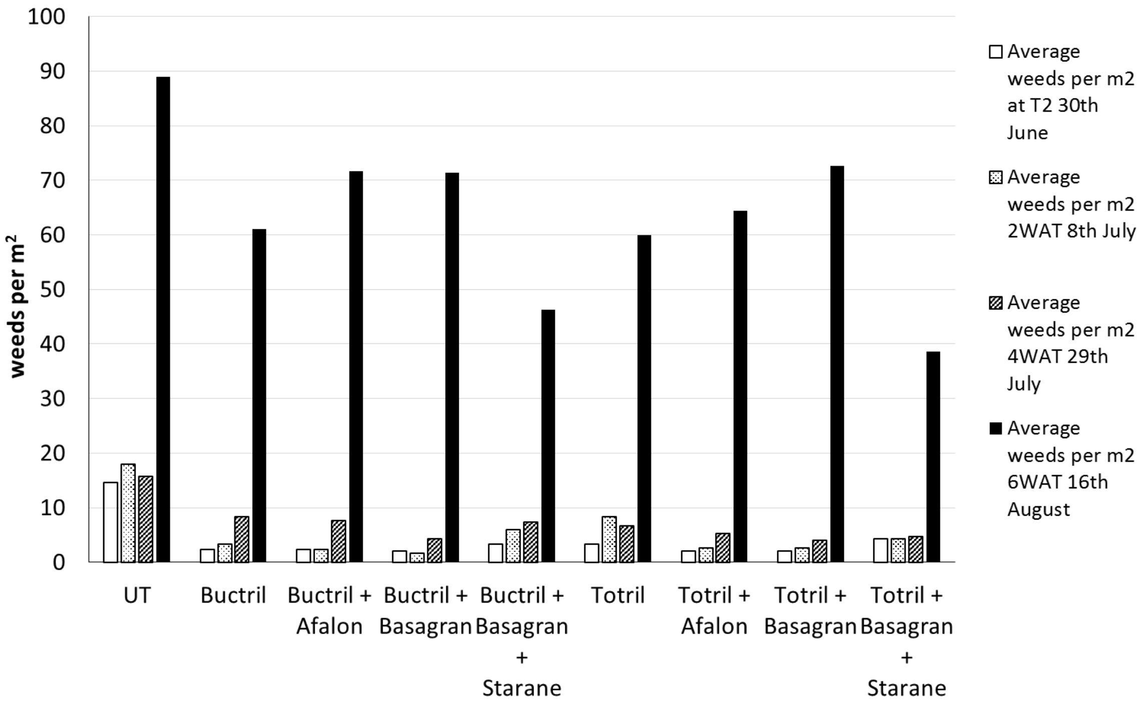


Figure 2. Weeds per m^2 at the 2nd application, and two, four and six weeks after treatments were applied to leeks, Lincs, 2015 (* = significantly different from the untreated).

Discussion

Buctril has been approved recently for use on leeks to fill the gap that will be left in programmes when the approval for Totril is lost in August 2016. There were crop safety issues in alliums with another form of bromoxynil which led to approvals on alliums being withdrawn by the manufacturer due to crop safety issues. All of the treatment combinations showed no or little phytotoxic effects to the leeks by six weeks after the 2nd application (Table 3), and no significant differences were seen between treatments. However, we took care to spray early morning before weather got too hot, and in a practical commercial situation operators would not always be able to avoid spraying in higher risk situations such as midday in hot sun, to take advantage of spray opportunities when windows of application are restricted. This may have highlighted more differences or given greater phytotoxicity.

Table 3. Mean scores for phytotoxicity, weed count and weed cover in leek herbicide screens six weeks after the 2nd herbicide applications – Lincs, 2015.

Treatment	Phytotoxicity (0-9)	weed count (m^2)	weed cover (%)
Untreated	9.0	89.0	45.0
Buctril	8.7	61.0	35.3
Buctril + Afalon	7.7	71.7	21.5
Buctril + Basagran SG	8.3	71.3	23.3
Buctril + Basagran SG + Starane 2	7.7	46.3	14.9
Totril	8.3	60.0	19.3
Totril + Afalon	7.7	64.3	21.8
Totril + Basagran SG	8.5	72.7	24.3
Totril + Basagran SG + Starane 2	8.5	38.7	17.2
F pr.	NS	NS	NS
l.s.d (24 d.f)	-	-	-

Nevertheless, some differences in crop safety were seen at two and four weeks after the final spray applications. Those plots treated with Buctril and Afalon, and Totril alone showed damage above a commercially acceptable standard which was exhibited as stunting and yellowing by the former combination, and thinner plants when treated with Totril alone. The combination of Buctril, Basagran SG and Starane 2 and Buctril alone were also only just at an acceptable level of phytotoxicity at two weeks post application. The slight damage from this combination was mainly exhibited as stunting to the plants. At four weeks post-application, only the plots treated with Buctril and Afalon or Buctril, Basagran SG and Starane 2 showed continuing effects as yellowing and stunting but were recovering to a nearly commercially acceptable appearance at this point.

When comparing the two products, Buctril and Totril used alone give similar results in phytotoxic effects. But when Buctril is combined in a tank mix with either Afalon, or Basagran SG and Starane 2 then there is a slight increase in phytotoxicity scores at 4 weeks after treatment, and length taken to recover from the sprays when compared to the tank-mixes with Totril. Scores are reduced to 6.75 to 7.25 for leeks treated with these Buctril tank-mixes, compared to scores of 7.75 and 8.25 for the Totril tank-mixes at this assessment. But, as aforementioned the affected plots recovered and grew through this effect over the following month.

No significant differences in weed control were seen at assessments completed at least two weeks post-application. Germination of weeds in the trial were low due to the dry weather through June and July, but increased in August when showers returned and gave a flush of weeds at the final assessment. There were no significant differences at the final assessment, but the data shows a trend by all treatments for a reduction in weed numbers, with the 3-way tank mixes of Totril or Buctril in combination with Basagran SG and Starane 2 giving the lowest weed counts at the final assessment (Table 3). The level of weed control given by Buctril and the Buctril tank-mixes was similar when compared with Totril and the Totril tank-mixes which it is replacing.

Conclusions

- At six weeks after treatment all treatment combinations were crop safe, but it should be noted that the herbicides were applied when risk of scorch to the crop would be lowest.
- The greatest level of phytotoxicity was seen when Buctril was tank mixed with Afalon (linuron).
- Buctril gives a similar level of weed control to Totril both as a standalone product and in tank mixes.
- The 3 way tank mixes with Totril or Buctril gave the greatest numerical reduction in weeds but this was not significantly significant.

Knowledge and Technology Transfer

- HDC/EMT/HTA Horticultural Fellowship award day presentation 28 April 2011
- HDC/EMT/HTA Horticultural Fellowship Studentship day 6 July 2011
- Presentation to HDC HNS Panel 31 January 2013
- HDC News article; March 2013
- 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)
- HDC news article July 2014 - 2013 results
- Cover crop grower event, 4 November 2014 - hosted by Essex water and FWAG - Presented blackcurrant cover crops work
- BCPC weed review 2014, 11 November 2014 - Presented on 'Novel approaches to weed control in Commercial fruit production' covering SCEPTRE and Fellowship research
- HDC News article February 2015 - 2014 results for nursery stock

- Summer 2015, AHDB horticulture grower magazine article reviewing vegetable and fruit weed control trials 2014
- AHDB Horticulture open day 28 June 2015 on the Fellowship Baby leaf salads trials at The Lettuce Company in Sussex
- AHDB Horticulture, 23 February 2016, pest, disease and weed ornamentals conference. Presentation including work on Foamstream for weed control
- AHDB Horticulture grower magazine Spring 2016, article reviewing vegetable and fruit weed control trials 2015

Appendices

Angela Huckle's Training Log

Date	Training activity	Trainer
23/6/11	Asparagus Growers Agronomy Day – crop protection options	Philip Langley
4-8/9/11	Attended joint workshop of the EWRS working groups, Weed management systems in Vegetables and weed management in arid and semi-arid climates	Various speakers
06/02/12	Soil management workshop	Selwyn Richardson
10/2/12	Group meeting and HNS technical training	John Atwood
23-24/05/12	Effective Consultancy workshop	Chris Bowerman
30/5/12	Boxworth open day – electric weeder, hot foam weed control	Various
5/7/12	SCEPTRE weeds open day at Kirton, demonstration of herbicide trials, precision sprayer development for residual herbicide application and electric weeder demo	Cathy Knott, Andy Richardson,
10/7/12	Visit to Barfoot Farms to discuss weed control and herbicide options in Rhubarb	Chris Creed, Neil Cairns and Matt Kettlewell
12/7/12	Seminar on US weed research followed by visits to fellowship trials at Boxworth and other herbicide trials locally	Dr Tim Miller – Washington State university

Date	Training activity	Trainer
19/7/12	BASIS induction day	Swallowfield consulting
3/8/12	Introduction to maize growing, agronomy and weed control	Simon Draper, Maize growers association
15/8/12	Barfoot farms visit – introduction to cucurbit agronomy and weed problems	Matt Kettlewell, Barfoot Farms
4/9/12	Introduction to top fruit growing and weed control	Chris Nicholson
5/9/12	Visits to fellowship trial sites Wyevale and Matthews of Tenbury Wells – Weed management training in HNS and tree nursery	David Talbot and John Atwood
27/9/12	Asparagus agronomy and establishment	Chris Creed, John Beeren (Beeren plant products)
3/10/12	British Carrot Growers Assoc event – demonstration of cultivation equipment, precision hoes, spray equipment and hooded sprayers	Various
11/10/12	Elsoms Open Day – demonstration of vision guided spray system for volunteer potatoes in allium crops	Nick Tillett
11/10/12	Rijk Zwaan/BASF Open Day – demonstration of use of new herbicides in programmes for veg crops	Simon Townsend and Rob Storey
October – December 2012	BASIS commercial horticulture	Swallowfield consulting
22/11/12	Weed identification training	Sarah Cook, Lynn Tatnell and Denise Ginsburg

Date	Training activity	Trainer
3/12/12	Crop protection training day -	Various (ADAS and external)
5/12/12	Fellowship planning meeting and fruit weed training	John Atwood
5/2/13 – 6/2/13	ADAS internal Fruit training course	Various (ADAS and external AgChem. Reps and EMR researchers)
27/2/13	Asparagus agronomy event including weed control	Various - Limseeds
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	Cathy Knott and Andy Richardson

Date	Training activity	Trainer
	SCEPTRE vegetable weed control trials carried out in association with ABC	
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
12/12/13	Attended and presented at RDPE workshop on salad residue reduction	
28/1/13	RDPE workshop on cultivations, soil and nutrient management in brassicas including cover crops	Ken Smith and Clive Rahn
11/6/14	Attended Cereals event	Various
26/6/14	Attended SCEPTRE weeds trial open day	Cathy Knott
4/9/14	Hosted and co-ordinated Sweetcorn N and P trials open days – role of nutrition for crop growth and better weed control	Dr Richard Weightman and Neil Cairns

Date	Training activity	Trainer
29/9/14 – 1/10/14	Coordinated BCGA event	
8-9/10/14	Elsoms open day – demonstrated SCEPTRE trials and update on weed control in brassicas – Agrii and BASF trials, vision guided spray systems	Various – including Chris Creed and Simon Townsend (BASF) and Rob Storer
16/10/14	RDPE workshop on cultivations, soil and nutrient management in brassicas including cover crops - Cornwall	Ken Smith and Clive Rahn
12/11/14	HDC leafy salads roadshow	Various
16/01/15	Weeds fellowship planning and meeting with Adrian Jackson to discuss Belchim active ingredients	John Atwood & Adrian Jackson
28/01/15	Brassica and leafy salads conference	Various
3/02/15 – 4/02/15	ADAS internal Fruit training course	Various (ADAS and external AgChem. Reps and EMR researchers)
19/02/15	Leek Growers Association Agronomy day – presented SCEPTRE leek rust trial results	Various
24/02/15	SCEPTRE conference –results from SCEPTRE trials including Cathy Knott and Andy Richardson's weed trials	Various including Cathy Knott and Andy Richardson
25/02/15	Asparagus growers technical update meeting - agronomy	Ton Smolders - Limseeds

Date	Training activity	Trainer
4/03/15	Farmsmart expo	Various precision farming companies
26/03/15	British Carrot Growers Association Technical afternoon	Various
7/05/15	Led grower walk on the AHDB Rhubarb Herbicide trials in Yorkshire	Angela Huckle and Chris Creed
23/5/15 – 30/5/15	Asparagus Growers Association Study Tour – Canada and USA, including visit to herbicide trials	Paul Banks and Bernie Solymar, Dr. David Wolwyn Simcoe Research Station + Growers. Dr John Bakker and Dr Bernard Zandstra - Michigan Asparagus Research station
11/06/15	Cereals	Various – chemical companies and sprayer companies
23/06/15	Grower tour of Hammond Produce with Welsh farmers on Welsh government training course	Philip Lilley and Chris Creed
28/06/15	Hosted and led an open day on the fellowship Baby leaf salads trials at The Lettuce Company in Sussex	Angela Huckle and John Atwood
7/07/15	Fellowship training day on baby leaf salads trials at Vitacress and rhubarb trial at Barfoots	Angela Huckle, John Atwood and Neil Cairns
18/8/15 – 20/8/15	Visited courgette, rhubarb and asparagus growers and discussed agronomy, Southall & sons, S & A growers, Arnold farms and Rectory farm	Chris Creed, David Talbot, Paul Southall, Arnold farms and Claire Donkin

Date	Training activity	Trainer
16/9/15 -17/9/15	Studentship conference inc visits to Haygroves, apple grower and Pixley Berries	Various
14-15/10/14	Elsoms open day – demonstrated SCEPTRE trials and update on weed control in brassicas – Agrii and BASF trials, vision guided spray systems	Various – including Chris Creed and Simon Townsend (BASF) and Rob Storer
4/11/15 – 5/11/15	Onion and carrot conference	Andy Richardson and various speakers and agronomists and sprayer providers
17-18/11/15	Nutrient management planning training to maintain FACTS	Paul-Newell Price and John Williams
25/11/15	Presented results from the rhubarb herbicide trials at a Rhubarb Grower meeting	Angela Huckle, Viv Powell and Chris Creed
8/2/16	Presented wild rocket trials data at The Lettuce Company. Weed control in outdoor leafy salads – Update on trials work, discussion of problems and priorities,	Angela Huckle, Liz Johnson and Sam Coates
29/2/16	Soft Fruit PYO discussion group – gave talks on rhubarb herbicide trials and asparagus study tour	Angela Huckle, Janet Allen and Scott Raffle
2/3/16	Meeting with Dow to discuss future herbicide approvals	

Harriet Roberts' Training Log

Date	Training activity	Trainer
5/10/2009	Statistical training	Chris Dyer
8/12/2009	ORETO training	Sarah Cook and Alan Redrup
2-3/3/12	Technical writing course	Jeremy Wiltshire, Tom Pope
24/4/12	Staff management and systems training	Fiona Clarke, David Laverick
24/5/11	Rhubarb weed control and trial assessments	Chris Creed
10/5/11	Training visit with fruit consultant – General advisory visit strawberries and raspberries PYO	Janet Allen
13/6/11	Training visit with fruit consultant – General advisory visit strawberries and raspberries	Robert Irving
13/7/11	Bittercress and Pearlwort ID and seed collection	Denise Ginsberg
21/7/12	Effective time and project management	Jill Bamford
3/8/11	Training visit with fruit consultant – General advisory visit strawberries and raspberries	John Atwood
17/8/11	Training visit with fruit consultant – General advisory visit strawberries and raspberries	John Atwood
7/9/11	Training visit with fruit consultant – General advisory visit strawberries and raspberries	John Atwood
15/9/11	Raspberry herbicides and trial assessment	John Atwood
22-23/9/12	Effective consultancy training	Chris Bowerman

Date	Training activity	Trainer
07/12/11	Weed identification course	Sarah Cook and Denise Ginsberg
27/1/12	Training visit with fruit consultant – General advisory visit blackcurrants	John Atwood
1/2/12-2/2/12	ADAS Fruit training – update on trials results and details from chem. companies on products	John Atwood and external speakers from Bayer and BASF
06/02/12	Soil management workshop	Selwyn Richardson
10/2/12	Group meeting and HNS technical training	John Atwood
20/4/12	Grower visits – weed management in strawberries	Robert Irving
30/5/12	Boxworth open day – electric weeder, hot foam weed control	Various
20/6/12	Training visit with fruit consultant – General advisory visit strawberries and raspberries	John Atwood
27/6/12	Blackcurrant herbicide trial assessments	John Atwood
4/7/12-5/7/12	HDC studentship conference – Low waters nursery and double H	HDC
6/7/12	Raspberry herbicide trial assessments	John Atwood
12/7/12	Seminar on US weed research followed by visits to fellowship trials at Boxworth and other herbicide trials locally	Dr Tim Miller – Washington State university
19/7/12	BASIS induction day	Swallowfield consulting
25/7/12	Fruit focus	Various
1/8/12	Training visit with fruit consultant – General advisory visit strawberries and raspberries	John Atwood
4/9/12	Introduction to top fruit growing and weed control	Chris Nicholson

Date	Training activity	Trainer
5/9/12	Visits to fellowship trial sites Wyevale and Matthews of Tenbury Wells – Weed management training in HNS and tree nursery	David Talbot and John Atwood
12/9/12	Training visit with fruit consultant – General advisory visit strawberries and raspberries	John Atwood
October – December 2012	BASIS commercial horticulture	Swallowfield consulting
3/12/12	Crop protection training day -	Various (ADAS and external)
5/12/12	Fellowship planning meeting and fruit weed training	John Atwood
31/1/13	Presented the fellowship results to the HDC HNS panel	
5/2/13 – 6/2/13	ADAS internal Fruit training course	Various (ADAS and external AgChem. Reps and EMR researchers)
5/3/13	HDC Fruit agronomists day	Various
6/3/13 – 9/3/13	Under 40's fruit growers conference to Warsaw Poland – visits to Polish growers, propagators, juicers and the horticultural research institute at Skierniewice	Various
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

Date	Training activity	Trainer
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	
November 2013	Submission and acceptance of 3 HDC fruit research proposals	
11/2/14	Presented novel weed control trial results to the amenity forum	
1/3/14	Production of ORETO protocol for alternate HDC strawberry Herbicide trial SF151 XBM 6873	Sarah Cook
26-28/5/14	Attended IOBC Soft fruit IPM conference, Trento Italy – presented orally and a posted on herbicides in raspberry	
Spring Summer	Regularly shadows agronomy visits to soft fruit holdings with colleagues	John Atwood and Janet Allen
4/11/14	Attended cover crop grower event – hosted by Essex water and FWAG - Presented blackcurrant cover crops work	FWAG, Kings/Frontier, Essex water
13/11/14	BCPC weed review 2014 – Presented on 'Novel approaches to weed control in Commercial fruit production' covering SCEPTRE and Fellowship research	Various

Date	Training activity	Trainer
14/11/14	Weeds fellowship + cut flower herbicide review and planning meeting	John Atwood
02/12/14	Meeting with Cheminova – review of ADAS Trials work in 2013/14 and presentation of Cheminiova herbicide portfolio	Barrie Hunt
Autumn/Winter	Submission as lead of 5 year HDC research program for cane fruit. Support on 2 others strawberry disease and Tree fruit IPM	
9/12/14	RDPE "Optimising Spray Technology for Ornamental Plant production" workshop	David Talbot & Bill Basford
16/01/15	Meeting with Belchim – review of ADAS Trials work in 2013/14 and presentation of Belchim herbicide portfolio	Adrian Jackson
Spring/Summer 2015	Joint advisory work with Chris Creed advising At Littywood farm Staffordshire on all aspects of strawberry and raspberry production	Chris Creed
Summer 2015	Covering Janet Allen's advisory visits whilst she is on leave	Janet Allen

David Talbot's Training Log

Date	Training activity	Trainer
26/10/11	Meeting at ADAS Boxworth to discuss the topics covered at the European Weed Research Society Meeting in Huesca, Spain 4 – 8 September 2011.	Angela Huckle
17/11/11	Autumn Weed identification course (broadleaf weeds and grass weeds), ADAS Boxworth.	Dr Sarah Cook, Denise Ginsburg
10/02/12	Weed management meeting, ADAS Boxworth. Training on weed control in Nursery stock.	John Atwood
12/07/12	Meeting with Tim Miller of Washing State University to discuss international weed control stratergies.	Dr Tim Millar
23/07/12	Project management Training at ADAS Boxworth.	Dr Erika Wedgwood & Dr Tim O'Neil
05/09/12	Fellowship training on weed control in the West Midlands.	John Atwood
19/12/12	ORETO Training / refresher at ADAS Boxworth	Dr Sarah Cook
7&8/03/13	FACTS NMP module	Susie Holmes & David Godsmark
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.
02/12/13	Presented results from fellowship trials at HDC Weed control workshop	John Atwood

Date	Training activity	Trainer
04/12/13	Fellowship meeting to discuss outcomes of 2013 work and plan 2014 work	John Atwood
08/08/14	Meeting to discuss the registration of Winch granules and the products use in the future	John Atwood, Paul Sopp, Sally Egerton (Dow)
23-26/9/14	Attended IPPS conference: Denmark “The Digital Nursery”	Various
16/10/14 and 9/12/14	Led RDPE “Optimising Spray Technology for Ornamental Plant production” workshop	David Talbot & Bill Basford
14/11/14	Weeds fellowship + cut flower herbicide review and planning meeting	John Atwood
20/11/14	Expert Witness Training	Geoffrey Fairfoull, Mark Talbot & Neil Pickard
16/01/15	Weeds fellowship planning and meeting with Adrian Jackson to discuss Belchim active ingredients	John Atwood & Adrian Jackson
13/5/15	Bedding and pot plant centre open day	David Talbot and Jill England
23/6/15	Bedding and pot plant centre open evening	David Talbot and Jill England
7/07/15	Fellowship training day on baby leaf salads herbicide trials at Vitacress and rhubarb trial at Barfoots. Introduction to vegetable production at Barfoots from the farm manager	Angela Huckle, John Atwood and Neil Cairns
18/8/15	Visited courgette, rhubarb and asparagus growers and discussed agronomy, Southall & sons and Arnold farms	Chris Creed, David Talbot, Paul Southall, and Arnold farms

Date	Training activity	Trainer
	HTA/AHDB Hort Tree and hedging event at Wellesbourne – presenting PGR trials work. John Atwood presented weed control trial on Crataegus	David Talbot and John Atwood
9/9/15	German meeting with H Losing looking at weed control	J Atwood and H Losing
16/9/15 - 17/9/15	Studentship conference inc visits to Haygroves, Man of Ross to view apple production and Pixley Berries	Various
7-9/10/15	IPPS Europe Conference	Various
13 – 15/01/16	International advances in pesticide application, Barcellona, Spain.	Various

Maria Tzotzi's Training Log

Date	Training activity	Trainer
2013	Autumn Weed identification course (broadleaf weeds and grass weeds), ADAS Boxworth.	Dr Sarah Cook, Denise Ginsburg
2014	Project management Training at ADAS Wolverhampton.	Fiona Clarke
2014	Crop walks throughout a growing season.	Sarah Cook
04/06/2014	NIAB open day – Weed management trials.	Various
04/06/2014	Hutchinsons open day – Weed management trials.	Various
11/06/2014	Attending at cereals event.	Various
1/07/2014	NIAB open day and Science Event.	Various
11-12/09/2014	Being an efficient consultant training.	Chris Bowerman
16-17/09/2014	HDC studentship conference.	HDC
4/11/14	Attended cover crop grower event – hosted by Essex water and FWAG - Presented blackcurrant cover crops work.	FWAG, Kings/Frontier, Essex water

Date	Training activity	Trainer
13/11/14	BCPC weeds review conference	Various
14/11/14	Weeds fellowship + cut flower herbicide review and planning meeting	John Atwood
16/01/15	Weeds fellowship planning and meeting with Adrian Jackson to discuss Belchim active ingredients	John Atwood & Adrian Jackson
27/01/2015	Contract law	Andrew Walker
04-05/03/2015	EWRS workshop ‘Optimising herbicide use in an IWM content’ – Presented lining mulches in apple orchards work	EWRS
Various dates	Crop walk with	Robert Irving