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:	Interim report, March 2015
Previous report:	March 2014
Fellowship staff:	John Atwood, Project leader
(“Trainees”)	Lynn Tatnell, Assistant project leader
	Harriet Roberts, (fruit) and project management
	Maria Tzortzi, (weed biology)
	David Talbot, (ornamentals)
	Angela Huckle, (vegetables)
Location of project:	ADAS Boxworth
Industry Representative:	Wayne Brough, HDC
Date project commenced:	April 2011
Date project completed	March 2016
(or expected completion date):	

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   31.03.15

Report authorised by:

Dr Barry Mulholland

Head of Horticulture

ADAS UK Ltd

Signature   Date   31.03.15

Progress against objectives

Objectives

Objective	Original completion date	Actual completion date	Revised completion date
1. To develop and mentor four staff in weed biology and control	March 2016	in progress	
1.1 Train next generation horticulture consultants with an expertise in weed control	March 2016	in progress	
1.2 Graduate weed biologist recruited	June 2011	June 2011	
1.2.1 Graduate weed biologist trained and experience in horticultural weed research	March 2016	In progress	
1.3 Recognises the most common problem weed species associated with field crops (horticulture and arable), protected crops and ornamentals	Sept 2012	Sept 2012	
1.4 Understands the biology and current control strategies for the common weed species of a range of field crops (horticulture and arable), protected crops and ornamentals	Sept 2012	Sept 2012	
1.5 Visited at least 10 nurseries with J Atwood or another specialist weed control expert and discussed/reviewed control strategies for	March 2013	Completed, but recommend that visits should continue where thought beneficial	

Objective	Original completion date	Actual completion date	Revised completion date
key weeds on each nursery			
1.6 BASIS qualified	Sept 2013	Jan 2013. Suggest Maria is put forward in 2015	
1.7 Understands requirements for ORETO standard experimental work	Sept 2013	Sept 2013	
1.8 Designed experiment and drafted experiment protocol to satisfaction of ADAS Biometrician and ORETO Study Manager	Sept 2013	Sept 2013	
1.9 Organised and managed successful delivery of two experiments from agreed work packages	Sept 2013	Sept 2013	
1.10 Delivered consultancy advice to growers on control on weeds of the individuals' specialist work area protected crops and ornamentals on at least five problems	Sept 2014	In progress	
1.11 Drafted HDC Project Reports on at least two projects	Sept 2013	Sept 2013	
1.12 Submitted to HDC or elsewhere at least three proposals on R&D topics supported by growers	March 2014	Dec 2013	
m1.13 Drafted an HDC Factsheet on biology and control of specific weed species of	March 2013	At present, no specific requirement - will review in future	March 2016

Objective	Original completion date	Actual completion date	Revised completion date
horticultural crops in specialist work area			
1.14 Delivered at least three talks on weed control to nursery staff, grower groups or an HDC sponsored conference	Sept 2014	Sept 2013	
2. Deliver applied research and KT work packages	March 2016	In progress	
2.1.1 First pot screening for horticulture weeds set up	Oct 2011	May 2012 (1st set) Feb 2013 (2nd set)	
2.1.2 First pot screening completed	Aug 2012	March 2013	
2.1.3 Second pot screening for horticulture weeds set up	Oct 2014	May 2014	
2.1.4 Second pot screening completed	Aug 2015	Aug 2014	
2.2.1 First container plant screening trial set up	Oct 2012	July 2012	
2.2.2 First container plant screening trial completed	Sep 2013	Nov 2012	
2.2.3 Second container plant screening trial set up	Oct 2013	June 2013	
2.2.4 Second container plant screening trial completed	Sep 2014	Nov 2013	
2.2.5 Third container plant screening trial set up	Oct 2015	June 2014	
2.2.6 Third container plant screening trial completed	Sep 2016	Nov 2014	

Objective	Original completion date	Actual completion date	Revised completion date
2.3.1 First tree field herbicide trial set up	April 2012	April 2012	
2.3.2 First tree field herbicide trial completed	June 2013	Sept 2013	
2.3.3 Second tree field herbicide trial set up	April 2013	Replaced with herbicide trial in stocks for cut flowers, completed Sept 2013	
2.3.4 Second tree field herbicide trial completed	June 2013	Replaced with herbicide trial in stocks for cut flowers	
2.4.1 First vegetable herbicide trial set up	May 2013	March 2013	
2.4.2 First vegetable herbicide trial completed	Aug 2013	Sept 2013	
2.4.3 Second vegetable herbicide trial set up	May 2014	May 2014	
2.4.4 Second vegetable herbicide trial completed	Aug 2014	Aug 2014	
2.4.5 Third vegetable herbicide trial set up	May 2015		
2.4.6 Third vegetable herbicide trial completed	Aug 2015		
2.5.1 Top fruit herbicide trial set up	April 2015		
2.5.2 Top fruit herbicide trial completed	Sept 2015		
2.6.1 Ground cover trial set up	April 2013	In progress (initial trial run in 2012)	
2.6.2 Ground cover trial completed (Living mulch in Apple)	Aug 2015		Sept 2015

Objective	Original completion date	Actual completion date	Revised completion date
2.7.1 Perennial weed trial set up (initial pot tests)	March 2013	Delayed due to late spring	April 2013
2.7.2 Perennial weed trial completed (blackcurrant cover crop)	Sept 2015		
3. Set up a working group within the European Weed Research Society	March 2012	Not fully functional yet	March 2016

Summary of progress

A training programme has continued in 2014 with both general ADAS courses and more specific technical training. As the trainees have gained experience and are all now BASIS qualified, training has switched to some extent from more formal training events to individual coaching on specific aspects of the job. For the trainees based at Boxworth there continues to be the opportunity to gain further experience by working on a wide range of weed control projects not just those specifically planned through the fellowship. With increasing experience and confidence the trainees have been able to plan and run weed control experiments, present results at events across all sectors and, more recently, develop project proposals outside of the weeds fellowship.

Jessica Sparkes 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 has been promoted from scientific officer to replace Jessica. She has participated fully in the fellowship training activities and experiments and her appointment as weed biologist has now been made permanent.

The nursery stock experiments for 2014 were successfully planned and written up by David Talbot in the West Midlands. The third container nursery experiment (Objective 2.2) was brought forward due to industry concerns over the loss of Ronstar 2G and was concluded in September 2014. A follow up container nursery experiment and a field nursery stock is being planned by John Atwood and David Talbot for 2015 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 with growth studies, water and nitrogen usage and apple yields and will continue into 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 lettuce (Objective 2.4) and the use of weed reducing green manure treatments during 2014. These trials were based on growers' holdings. Further work on salad crops is under discussion for 2015 with both herbicide screening and continued monitoring of the green manure treatments. Angela Huckle also plans to build on an earlier herbicide screening project for rhubarb with further work in 2015 outside the fellowship project.

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 proposals for further work in 2015 outside of the fellowship managed by Harriet Roberts and more recent recruits to the ADAS ornamentals 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 a literature review on non-chemical methods for perennial weed control is being undertaken 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. Arrangements have been made for a David Talbot and John Atwood to visit northern Germany in September to study nursery weed control.

Initially through contacts made at the minor crops working group in 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 LWK Schleswig-Holstein, Germany.

Foreign 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

Eire

Tillage Crops KT and 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 being reached

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

Do remaining milestones look realistic?

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

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

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

Training undertaken

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

Expertise gained by trainees

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

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
- Developed experiment protocols for vegetable weed control projects in consultation with industry leading producer
- Developed experimental proposal for herbicide screening in rhubarb in consultation with producers and chemical manufacturers

David Talbot

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

Other achievements in the last year not originally in the objectives

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

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

Changes to project - Are the current objectives still appropriate for the Fellowship?

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

Grower Summaries

2.1.3 Second pot weed screen

Headlines

- HDC H25 was the most effective herbicide treatment against all weed populations when applied pre-emergence.
- HDC H25, applied post-emergence, at the three-to-four leaves stage reduced all three bittercress species populations by over 86%.
- All herbicide treatments performed better when applied pre-emergence.

Background and expected deliverables

The hardy nursery stock (HNS) industry faces challenges as a result of the limited number of herbicide active ingredients currently available and the lack of prospective new products. Furthermore, most of the herbicides used in HNS were developed primarily for use in other sectors; consequently there is often a lack of information about control of weeds specific to container-grown nursery stock production.

The main objective of this trial was to screen four herbicides for the control of common HNS weeds when applied either pre-emergence or post emergence at the three-to-four leaf stage.

Summary of the project and main conclusions

This two-part study was carried out in pots at ADAS Boxworth. The first experiment was carried out on nine common HNS weed species (**Table 1**) comparing six herbicide treatments and an untreated control (**Table 2**). All the herbicide treatments were applied pre-emergence within 24 hours after seed sowing. The second experiment was identical to the first, except that the herbicide applications were made post-emergence when weed species reached the three-to-four leaf growth stage. Both parts of the study were laid out in a fully randomised block design with five replicates. An untreated control and a commercial standard treatment, Flexidor 125 (isoxaben), were used as references for the assessments.

Table 1. Weed species investigated

Weed species	Common name
Cardamine hirsuta	Hairy bittercress
Cardamine flexuosa	Wavy bittercress
Cardamine corymbosa	New Zealand bittercress
Sagina subulata	Pearlwort
Senecio vulgaris (not triazine resistant)	Groundsel
Epilobium ciliatum	American willow herb
Stellaria media	Common chickweed
Poa annua	Annual meadow grass
Cerastium fontanum	Common mouse ear chickweed

Table 2. Treatment list

Treatment		Active ingredient	Rate
1	Untreated	-	-
2	Flexidor 125 (commercial std)	Isoxaben 125g/L	1.00 L/ha
3	HDC H25	-	-
4	HDC H27	-	-
5	HDC H22	-	-
6	Springbok	Metazachlor 200g/L + dimethenamid-p 200g/L	1.66 L/ha

Pre emergence experiment

HDC H25 was the most effective pre-emergence herbicide treatment against all weed populations. In particular, HDC H25 reduced all weed populations by 74% to 100% depending on the species. In contrast, the commercial standard Flexidor 125 controlled only two weed species, pearlwort and New Zealand bittercress by 100% and 71% respectively. HDC H25 and HDC H27 provided the same efficacy against annual meadow grass, reducing the population by 90%. However, HDC H27 was not effective against the other weed species. HDC H22 was the second most effective herbicide against American willowherb, after HDC H25, reducing the population by 64%. Springbok effectively reduced the population of pearlwort by 90% and New Zealand bittercress by 62%.

Table 3. Pre emergence - percentage reduction in weed number in relation to the untreated control

Species	**Percent reduction in weed number in relation to the untreated control (100% = complete control, 0% = no control)**				
	Flexidor 125	**HDC H25**	**HDC H27**	**HDC H22**	**Springbok**
Hairy bittercress	47	**100**	0	37	47
Flexuous bittercress	67	**85**	0	0	12
NZ bittercress	**71**	**81**	23	45	**62**
Pearlwort	**100**	**100**	0	**86**	**90**
Groundsel	9	**74**	0	13	31
American willowherb	0	**95**	0	**64**	43
Common chickweed	0	**98**	0	2	12
Annual meadow grass	0	**90**	**90**	32	29
Common mouse ear chickweed	0	**91**	**60**	32	13

Percentages in **bold** show statistical significance at the 95% level

Post emergence experiment

Results from the post-emergence treatments showed restricted efficacy compared with that of the same treatments applied pre-emergence. In particular, HDC H25 effectively reduced all three bittercress species but not the other weed species. Furthermore, Flexidor 125 provided 75% and 73% control of hairy bittercress and New Zealand bittercress respectively. No significant control was observed when these species were sprayed with HDC H27 or HDC H22. Springbok reduced the annual meadow grass population by 67%.

Table 4. Post emergence (three - true leaves) - percentage reduction in weed number in relation to the untreated control

Species	Percent reduction in weed number in relation to the untreated control (100% = complete control, 0% = no control)				
	Flexidor 125	**HDC H25**	**HDC H27**	**HDC H22**	**Springbok**
Hairy bittercress	**75**	**88**	50	29	42
Flexuous bittercress	51	**86**	17	8	16
NZ bittercress	**73**	**87**	21	8	23
Pearlwort	21	23	34	32	23
Groundsel	15	10	0	12	15
American willowherb	43	0	30	43	25
Common chickweed	0	0	0	0	5
Annual meadow grass	18	13	18	13	**68**
Common mouse ear chickweed	0	0	0	0	0

Percentages in **bold** show statistical significance at the 95% level

AHDB Horticulture will seek EAMU approvals for the most effective treatments for ornamental plant production.

Financial benefits

There are no financial benefits as yet as none of the herbicides tested are currently authorised for use over container-grown nursery stock.

Action points for growers

- When HDC H25 becomes available commercially it will be suitable for the control of a wide range of important HNS weeds and should form the basis of growers' herbicide programmes for container-grown HNS in the future.

- HDC H22 and Springbok should be considered for EAMUs enabling use in ornamental plant production over plants. Although both have gaps in their weed control spectra, they could be useful as follow up treatments in weed control programmes and growers should consider their adoption in the future.

2.2.5 Third HNS container screen

Headlines

- The new herbicides HDC H22, HDC H25 and HDC H27 and Springbok were found to be safe when applied after potting to a range of shrub species, with only *Olearia* suffering lasting damage from some treatments.
- The new liverwort and moss control product, Mosskade, was found to be safe when applied six weeks after potting to a range of shrub species.

Background and expected deliverables

The HNS (hardy nursery stock) industry is currently relying on relatively few herbicides to control weeds, leading to an increasing concern over the development of resistance. With the loss of Ronstar 2G (oxadiazon), there are very few summer treatments left that are available to the HNS industry to control a wide range of weeds after potting and during the growing season. Restrictions on the use of straight metazachlor products (e.g. Butisan S) have only complicated the situation further. Once supplies of Ronstar 2G have run out, the industry will be heavily dependent upon Flexidor 125 for weed control in the summer months. The major concerns with this are that Flexidor 125 does not control groundsel, willowherb or grasses and also the reliance on one herbicide increases the likelihood of weeds developing resistance to this active ingredient.

Results from HNS 139 and HNS 139a demonstrated how Dual Gold (S-metolachlor) could help increase control of weeds. However, the current EAMU only permits use of the product during May leaving a gap in control measures during the summer and autumn. HDC H22 from the SCEPTRE CP 77 programme has the characteristics (residual weed control with minimal contact activity) that could make it useful in ornamental plant production. Springbok was first trialled in a small scale in HNS 139 but it wasn't developed further for container-grown shrubs due to it having a similar efficacy to Butisan S. However, due to Springbok having a lower metazachlor content than Butisan S, together with the active ingredient, dimethenamid-p, it can be used at an effective application rate without exceeding the limit for metazachlor applications. Therefore it was felt that Springbok warranted further evaluation on a range of shrub species. Three further new products were made available for testing in 2014, including the granular product HDC H25 for general weed control, and a liverwort and moss control product Mosskade (plant derived substances). HDC H27 was included as an alternative granular product to be tested. This product is widely used in arable systems as a grass herbicide with efficacy against annual meadow grass and some broad leaved weeds.

All the herbicide treatments were also included in a second nursery trial and evaluated for weed control efficacy under project HNS PO 192. Results from this trial have been written up and will be available from the HDC during 2015.

The aim of this project was to determine crop safety of the new herbicides when applied as a summer treatment shortly after potting. The industry standard, Flexidor 125, and an untreated control were also included in the treatment list to allow comparisons to be made. No other herbicides were used within the trial. The plant subjects were monitored for phytotoxicity and any effects were recorded. These findings will underpin treatment recommendations.

Summary of the project and main conclusions

This trial was carried out at Wyevale Containers, Hereford. The aim was to cover a range of hardy nursery stock species that are commonly grown on commercial nurseries in the UK and assess their tolerance to applications of the new herbicides.

The trial was carried out in summer 2014. Treatments (**Table 1**) were applied, with the exception of Mosskade, on 3 July 2014 as a summer treatment after potting on. Mosskade was applied on 17 July 2014 as this is a contact acting liverwort herbicide so would not be applied as a residual treatment at potting. The plots were assessed for any damage or growth effects two, six and twelve weeks after treatment. Insufficient weeds were present to carry out weed assessments, so the primary focus of this trial was to assess crop safety.

Table 1. Treatment list (treatments applied to plots summer 2014 in 1000 L water/ha)

Treatment	**Active**	**Rate kg/ha or L/ha**	**Approval status**
Untreated	-	-	-
Flexidor 125	Isoxaben (125 g/L)	1	Approved
Mosskade	Starch, proteins, oils	100	Outside scope
Springbok	Metazachlor (200 g/L) + dimethenamid-p	1.66	LTAEU
HDC H22	Confidential	-	Not approved
HDC H25	Confidential	-	Not approved
HDC H27	Confidential	-	Not approved

Table 2 provides a summary for the subjects assessed in the trial, showing the species which are tolerant (T) to herbicide applications and the species which are either moderately susceptible (MS) or susceptible (S) to the herbicide applications. MS species may have shown some initial damage caused by the herbicide but they grew on to be saleable plants. The majority of subjects tested showed little or no damage or growth defects as a result of the herbicide treatments.

Table 2. Tolerance of HNS subjects to the herbicide applications (tolerant – T, moderately susceptible- MS, susceptible -S)

	Sensitivity						
Species	**Untreated**	**Flexidor 125**	**Springbok**	**H22**	**H25**	**H27**	**Mosskade**
Berberis darwinii	T	T	MS	MS	T	T	T
Escallonia 'Iveyi'	T	T	MS	T	T	T	T
Hebe vernicosa	T	T	T	T	T	T	T
Hydrangea macrophylla	T	T	T	T	T	MS	T
Ligustrum ovalifolium	T	T	T	T	T	T	T
Lonicera 'Red Tips'	T	T	MS	T	T	T	T
Olearia macrodonta major	T	T	S	S	T	MS	T
Phormium tenax	T	T	T	T	T	MS	T
Potentilla 'Primrose Beauty'	T	T	T	T	T	T	T
Prunus laurocerasus	T	T	T	T	T	T	T
Santolina chamaecyparissus	T	T	T	T	T	T	T
Viburnum tinus 'Gwenllian'	T	T	T	T	T	T	T

Very little damage was observed over the course of the trial across the majority of species. Springbok, HDC 22 and HDC H27 caused some damage to *Olearia* two weeks after treatment with some slight spotting (H27) and marginal necrosis of the young leaves (Springbok and HDC 22). The affected *Olearia* were slow to grow away from the damage caused by Springbok and HDC 22 and were still considered susceptible to these herbicides by 12 weeks after treatment.

Springbok also caused phytotoxic effects on *Berberis, Escallonia* and *Lonicera*, however all of these species had grown away from the initial damage by six weeks after treatment.

Berberis, Escallonia and *Lonicera* treated with Springbok were considered comparable with untreated controls by 12 weeks after treatment.

HDC H22 also caused commercially unacceptable damage on *Berberis* two weeks after treatment. However, treated plants were comparable with untreated plants by six weeks after treatment.

HDC H27 also caused some slight phytotoxic effects on *Hydrangea* and *Phormium* but plants grew away from this damage and were considered comparable with untreated controls by 12 weeks after treatment.

Figure 1. *Olearia* – phytotoxic effects of H22 two weeks after treatment

Figure 2. *Olearia* – phytotoxic effects of Springbok two weeks after treatment

Financial benefits

There are no financial benefits as yet from this experiment. If it is possible to obtain authorisation for use of the more promising treatments on container-grown nursery stock then it is likely that hand weeding costs will be saved. The likely cost of the herbicide however is not known yet.

Action points for growers

- The granular product HDC H25 will be a suitable replacement for Ronstar 2G for use after potting, being suitable for use with most shrub species. It is anticipated that HDC H25 will be available as a commercial product with a label approval for outdoor ornamental plant production in the near future.

- Springbok is authorised for use in ornamental plant production but the EAMU only permits pre-emergence use. A change in the EAMU is being sought to allow its use over container-grown HNS.

- HDC H22 is further away from commercialisation, but when available could be a useful summer herbicide for growers providing an EAMU could be obtained.

2.4.3 Baby leaf lettuce herbicide screen

Headlines

- Intruder applied pre-emergence then followed by a further application at three true leaves in addition to Kerb Flo gave a significant reduction in weed control while being crop safe to baby leaf lettuce.

- Care is needed with the post-emergence application timing of Intruder on light sandy soils as it can produce significant phytotoxic effects, expressed as plant stunting.

Background and expected deliverables

The control of weeds in short season baby leaf salad crops can be difficult, especially in a crop such as baby leaf lettuce which is sensitive to a number of commercially available herbicides. Crop rotations and soil fumigants such as Basamid (dazomet) are used to reduce the weed population before drilling a crop of baby leaf lettuce. However, a number of weeds can still be problematic, particularly Compositae species such as mayweed and groundsel, as well as other species such as thistle, nettle and fat hen. The weed pressure increases through the season, with more issues seen in the 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 fumigants in the future, additional herbicides for use in baby leaf lettuce are needed to increase the range of weeds controlled. The aim of the trial was to test additions to the current standard Kerb Flo (propyzamide), in programmes for crop safety and efficacy to widen the spectrum of weed control.

The main objective of the trial was to assess the crop safety of two herbicides; Intruder (chlorpropham) and Dual Gold (S-metalochlor) to be used as an addition to the standard Kerb Flo treatment to improve control of annual weeds in drilled baby leaf lettuce grown for salad leaf. Supplementary objectives were to see if the timing of application affected the efficacy and crop sensitivity. All herbicides used in the trials are available to growers to use as EAMU approvals on outdoor crops.

Summary of the project and main conclusions

The experiments were carried out on commercial field crops of Red Batavia baby leaf lettuce in Wiltshire and Kent, both drilled on the 15 July and harvested on 15 August and 22 August 2014 respectively. Soil fumigation has been used in the past at both of the sites. The soil at Wiltshire was a sandy loam, while the soil in Kent was a silt loam. The trials were a fully randomised block design with seven treatments combining different application timings of Intruder and Dual Gold in addition to Kerb Flo, including a grower practice control of Kerb Flo applied pre-emergence (**Table 1**). There was no 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 listed in **Table 2**.

Table 1. Treatment list (treatments applied to plots in 500 L water per hectare)

	Treatment timing		
Treatment no.	**Pre-emergence (at Kerb application) Timing 1**	**At 1-2 TL Post-emergence Timing 2**	**At 3-4 TL Post-emergence Timing 3**
1 (Grower practice)	Kerb Flo 3.5 L/ha	-	-
2	Kerb Flo 3.5 L/ha + Intruder 1.9 L/ha	-	-
3	Kerb Flo 3.5 L/ha + Intruder 1.9 L/ha	Intruder 1.9 L/ha	-
4	Kerb Flo 3.5 L/ha + Intruder 1.9 L/ha	-	Intruder 1.9 L/ha
5	Kerb Flo 3.5 L/ha	Intruder 1.9 L/ha	Intruder 1.9 L/ha
6	Kerb Flo 3.5 L/ha	Dual Gold 0.7 L/ha	-
7	Kerb Flo 3.5 L/ha	-	Dual Gold 0.7 L/ha

Table 2. Major weed species at the trial sites

Wiltshire		Kent	
Weed species	Common name	Weed species	Common name
Capsella bursa-pastoris	Shepherds purse	Cirsium arvense	Creeping thistle
Diplotaxis tenufolia	Volunteer wild rocket	Chenopodium album	Fat hen
Polygonum aviculare	Knot-grass	Chenopodium polyspermum	Many seeded goosefoot
Senecio vulgaris	Groundsel	Diplotaxis tenufolia	Volunteer wild rocket
Sonachus sp.	Sow-thistle	Fallopia convolvulus	Black-bindweed
Stellaria media	Common chickweed	Mercurialis annua	Annual mercury
Tripleurospermum inodorum	Scentless mayweed	Senecio vulgaris	Groundsel
Urtica urens	Small nettle	Solanum nigrum	Black nightshade
		Sonachus sp.	Sow-thistle
		Tripleurospermum inodorum	Scentless mayweed

The Timing 1 Intruder treatments were applied pre-emergence on 15 July at Wiltshire and 22 July at Kent using an OPS sprayer and a 1.5 m boom with 02F110 nozzles, to achieve a medium spray quality at 500 L/ha. The Kerb Flo was then applied by the grower as per current commercial practice using a self-propelled 24 m boom sprayer. Post–emergence Timing 2 and 3 treatments were applied on 31 July and 7 August, when the crop had reached the two true leaf stage and three to four true leaf stage respectively at Wiltshire. The post-emergence treatments were applied on 30 July and 7 August in Kent, when the crop was at one true leaf and three true leaves respectively. The trial was assessed approximately seven to 14 days after the application of each of the treatment timings and at harvest, on 31 July, 7 August and 15 August in Wiltshire, and 30 July, 7 August and 22 August at the Kent site. All plots in each trial were assessed for crop safety, percentage emergence of the crop, percentage weed cover and weed species present.

Results

Intruder was the most crop safe treatment at both sites (**Figure 1**), but crop safety varied with site, soil type and application timing. The crop was of marketable quality at harvest whichever application timing of Intruder was used at the silt loam site in Kent, with the lowest phytotoxicity score seen when it was applied pre-emergence in addition to Kerb Flo. However, in Wiltshire greater levels of crop damage were seen. When Intruder was applied at two true leaves, either in a programme with an additional pre-emergence or at three to four true leaf timing, then the damage to the crop was commercially unacceptable (**Figure 2**). This increased crop sensitivity could be due to herbicides behaviour in the sandy loam soil and care over the application timing is needed on these soils. Overall, the safest application timing at both sites was to apply Intruder pre-emergence in addition to the grower standard Kerb Flo.

Dual Gold caused significant phytotoxicity at both sites which was exhibited as stunting when applied at two true leaves. However, at the Wiltshire site only, Dual Gold was crop safe when applied at three to four true leaf stage. This was unexpected as higher crop sensitivity is usually greater on sandy textured soils.

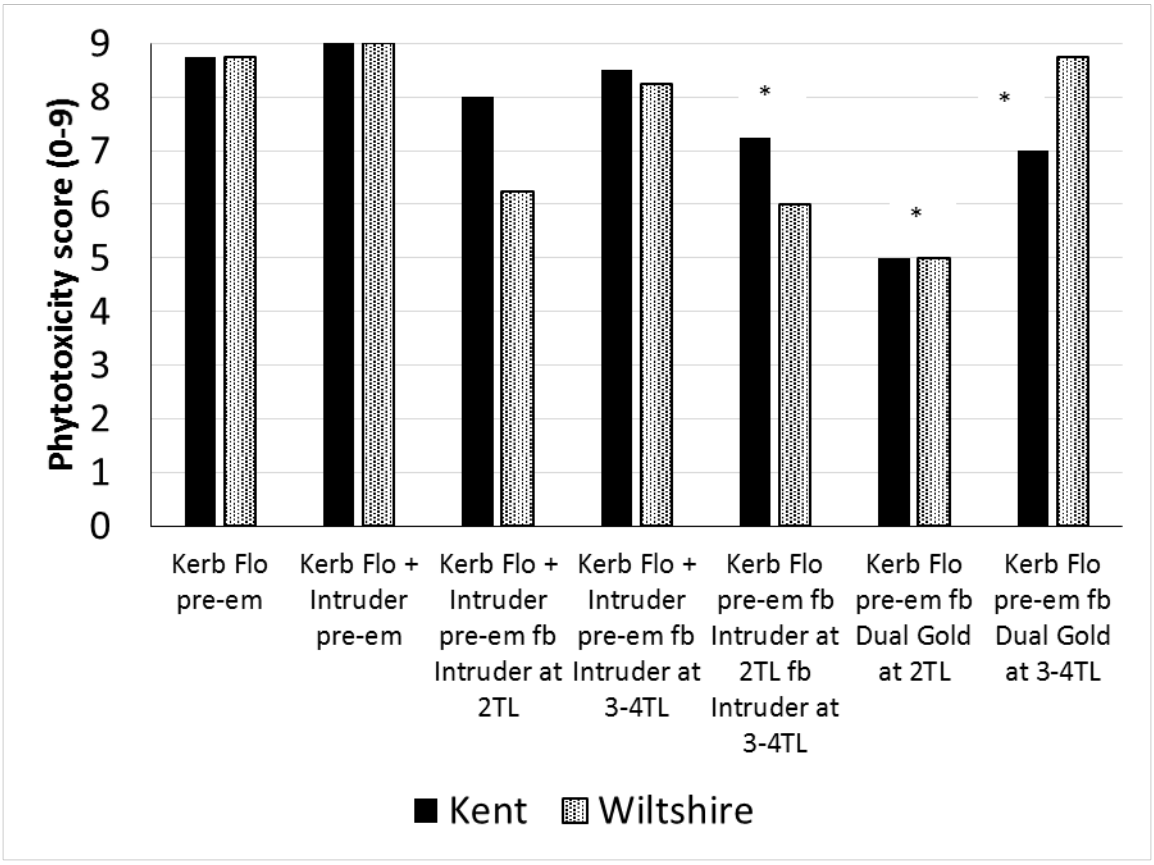

Figure 1. Phytotoxicity scores for treatments applied to baby leaf lettuce, Wilts and Kent, 2014 (fb = followed by, * = significantly different from the grower standard)

Figure 2. Plots stunted by applications of Dual Gold and Intruder when applied at two true leaves, Wilts, 2014

Intruder also gave the highest crop stand, but as with the phytotoxicity scores the effect on plant population varied with site, soil and application timing. Plant population was little affected whichever application timing of Intruder was used at the silt loam site in Kent, with the highest crop stand seen when it was applied pre-emergence in addition to Kerb Flo and again at two true leaves. In Wiltshire a greater effect of application timing on crop stand was seen, and when Intruder was applied at two true leaves, either in a programme with an additional pre-emergence or three to four true leaf timing, then the plant population was reduced by between 12 and 19% compared with the grower standard. Considering effects at both sites, overall the highest crop stand was seen when Intruder was applied pre-emergence in addition to the grower standard Kerb Flo.

Dual Gold gave significant reductions in crop stand at the Kent site, reducing plant population by 8 and 17%. However, when applied at three to four true leaves at the Wiltshire site little difference in crop stand was seen between Dual Gold treated plots and those treated with the grower standard.

The overall percentage of weed at the Kent site was higher with 18% plot cover in the grower standard plots compared to 9% in Wiltshire (**Figure 3**). However, in both trials the addition of Intruder applied post-emergence at any timing was most effective at reducing weed populations further in addition to the grower standard. Intruder applied pre-emergence gave no extra benefit in weed control over the current grower standard.

The addition of Dual Gold to the grower standard gave no extra benefit in weed control, and in Wiltshire, weed cover was higher in plots treated with this product. However, this may have been due to the lack of competition as crop cover was reduced by phytotoxic effects.

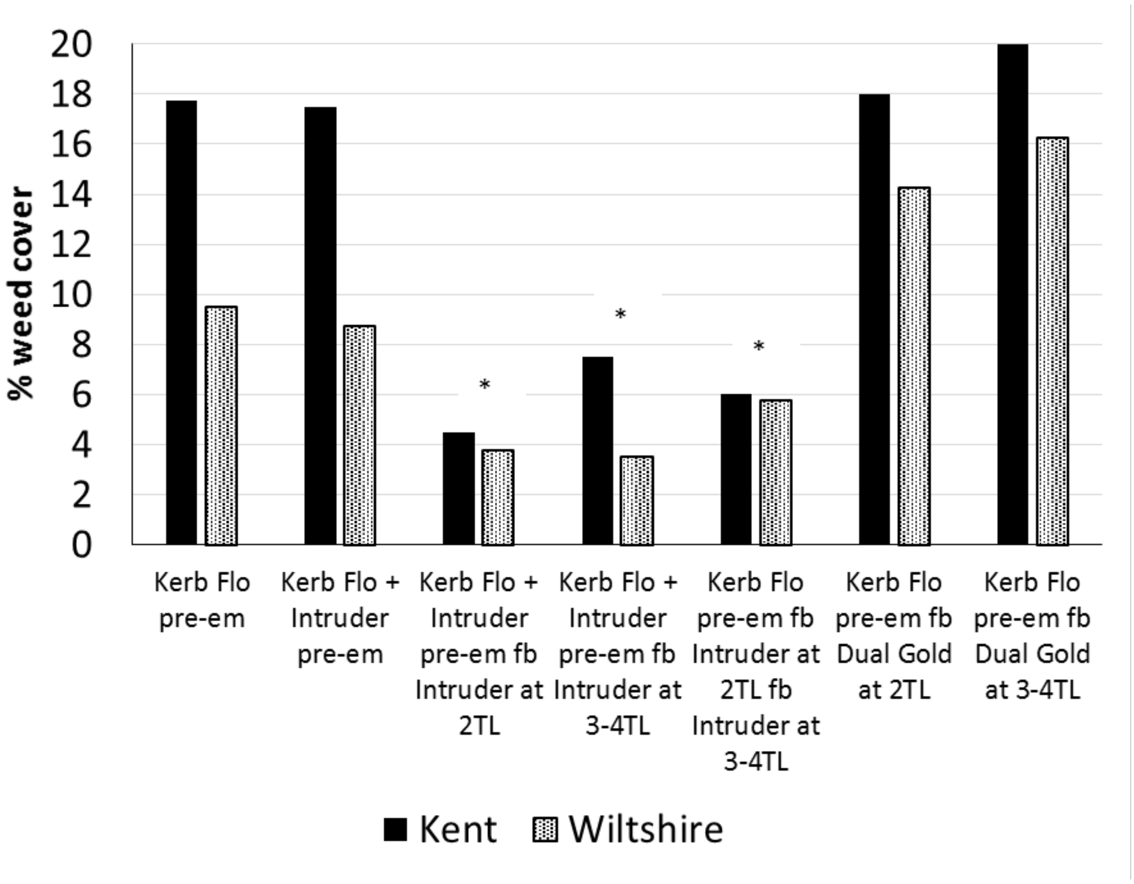

Figure 3. Percentage weed cover, Wiltshire and Kent. 2014. (fb = followed by, * = significantly different from the grower standard, the grower standard and treatment 5 also have significantly less weed than the Dual Gold treatments)

The most troublesome weeds at each site were not fully controlled, but their percentage ground cover was reduced by the application of Intruder at post-emergence timings and in the trial at Wiltshire chickweed appeared to be controlled by the application of Intruder.

Financial benefits

Intruder is approved for use on baby leaf lettuce under an EAMU and if added to the current grower standard application of Kerb Flo then the percentage of weed cover in a crop could be significantly reduced. This significant reduction in weed cover would reduce the time needed for hand weeding, and could potentially save up to £150/ha, reducing the cost of hand weeding from £200/ha to just £50/ha based in the percentage of weed reduction seen in the trial.

Action points for growers

- Intruder has better crop safety potential than Dual Gold when used as a supplementary treatment to Kerb Flo and could be considered for use in weed control programmes.

- The most effective timing of Intruder for weed control while maintaining crop safety, was an application at pre-emergence in tank mix with Kerb Flo, followed by a further application of Intruder at three true leaves.

- All post-emergence applications of Intruder significantly reduced the percentage of weed cover, but not all timings were safe to the crop with applications at two true leaves causing significant phytotoxicity especially on the sandy loam at the Wiltshire site. Therefore caution is required when the product is used on sites with these soil types

- Dual Gold was not crop safe when applied at Kent, and as there were no appreciable benefits in weed cover reduction is not recommended.

2.6 Living mulches in apple orchards

Headlines

- Creeping red fescue alone and in mixture with birdsfoot trefoil suppressed the weed population to the same level as the herbicide standard treatment.
- No significant differences in yield or tree growth were recorded among all the investigated treatments.

Background and expected deliverables

Living mulches are crops established either prior to or at the same time as the main crop, with the objective of improving soil conditions and suppressing pernicious weeds. 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. In this investigation however their ability to suppress weed populations was the prime focus, utilising a low growing weed suppressive living mulch instead of maintaining the conventional herbicide strip. This approach could become increasingly important as herbicide availability becomes more limited in light of the ongoing changes in pesticide legislation (Sustainable Use Directive, Water Framework Directive and endocrine disruptor review). Alternative systems therefore need to be investigated. It is essential that the appropriate living mulch is selected, to avoid excessive competition for water and nutrients, which can be damaging to the crop.

Summary of the project and main conclusions

The main objective of this 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 fruit diameter, branch extension growth and leaf nutrient content. This was the first year of the study and it will be completed in 2016. Alongside this study, a second smaller-scale container experiment was carried out to investigate the effect of living mulches on soil moisture under controlled conditions.

Orchard trial

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 apple variety coming into its third leaf was selected and a fully randomised block design was used with seven treatments, including an untreated control, and four replicates. The treatment list is shown in **Table 1**. Each plot was 1.7 m wide and 2.5 m long and consisted of three apple trees per plot with a 1.25m gap between plots.

Table 1. Treatment list

Treatment no.	**Common name**	**Scientific name**	**Sowing density (g/ m^2)**
1	White clover	*Trifolium repens*	1.4
2	Black medic	*Medicago lupulina*	1.6
3	Creeping red fescue	*Festuca rubra*	7.5
4	Birdsfoot trefoil	*Lotus corniculatus*	1.4
5	Creeping red fescue + birdsfoot trefoil	*Festuca rubra + Lotus corniculatus*	7.5 + 1.4
6	Untreated	-	-
7	Herbicide treatment**	-	-

* Seed requirement per plot was doubled, due to wet conditions at sowing date.
** Details of the herbicide treatment are shown in **Table 2**.

Table 2. Herbicide treatment - application plan

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
Roundup Biactive	Glyphosate	Post-harvest (November)	5.0	300.0

The site was marked out and the living mulch seeds were sown on 8 November 2013. The herbicide treatment was applied over the respective plots on 17 March 2014. A tank mixture of Ronstar Liquid and Harvest, was sprayed using a Knapsack OPS sprayer in a water volume of 300 L/ha. On 27 March 2014, the leguminous living mulches were re-sown due to poor establishment. The percentage of living mulch cover per plot was assessed on 13 December 2013, 17 March 2014, 9 May 2014, 18 June 2014 and finally on 1 October at harvest day. The percentage weed cover per plot was also recorded on the same dates as the living mulch assessments, with the exception of 13 December 2013 due to a very low weed population being present. At harvest (1 October 2014), the average diameter of 10 apples per plot, the extension growth of five branches per plot and the yield per plot, were recorded. Maturation testing and post-harvest grading for one block of the trial was conducted by Worldwide Fruit Ltd. Soil moisture recording and leaf sampling for analysis was carried out in June. Soil samples were taken at the beginning of the trial and again in June to investigate any changes in soil nutrient status.

Soil water content trial

This trial was carried out in a polythene tunnel at ADAS Boxworth. A fully randomised block design was used, consisting of the same living mulch species as the apple orchard experiment, with four replicates **(Table 3)**. A total of 24 five-litre pots were filled with Clover substrate and watered to field capacity before sprinkling seeds evenly on the substrate surface. Each pot was given precisely 300 ml of water to ensure the accuracy of the soil moisture assessment. When the living mulches reached the flowering stage, 300 g of soil were sampled from each pot and assessed for water content by recording the weight of each sample before and after drying in an oven at 100 degrees C for 48 hours.

Table 3. Treatment list

Treatment no.	**Common name**	**Scientific name**	**Sowing density (g/m^2)**	**Seed required per container (g)**
1	White clover	*Trifolium repens*	1.4	1.0
2	Black medic	*Medicago lupulina*	1.6	1.2
3	Creeping red fescue	*Festuca rubra*	7.5	0.3
4	Birdsfoot trefoil	*Lotus corniculatus*	1.4	1.0
5	Creeping red fescue + birdsfoot trefoil	*Festuca rubra* + *Lotus corniculatus*	7.5 + 1.4	0.3 + 1.0
6	Untreated	**-**	-	-

Results

Results showed, that all the living mulches, except birdsfoot trefoil, formed a dense and even cover under the apple trees. All the treatments significantly suppressed the weed population compared with that of the untreated plots (p value <0.001). However, only creeping red fescue and its mixture with birdsfoot trefoil were similarly effective to the herbicide standard treatment in supressing the weed population on 18 June 2014. In addition, at harvest, 1 October 2014, the creeping red fescue was better than the herbicide treatment which had lost its persistence by this stage (**Figure 1**).

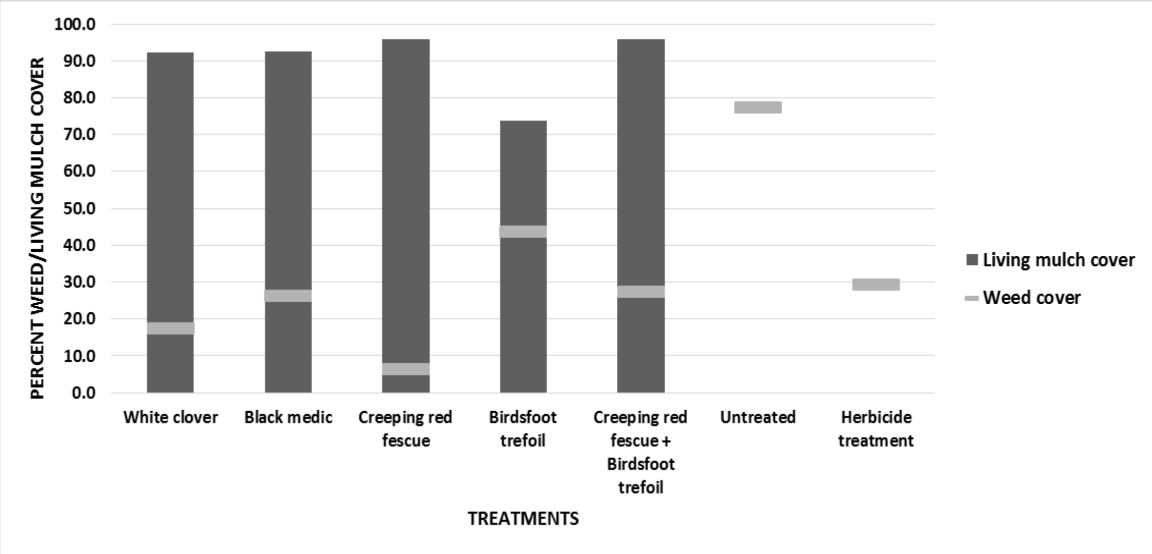

Figure 1. Living mulches percentage cover compared with that of weed population, during the final assessment on the 1 October 2014

Average starch levels in the fruit were similar for all the treatments and were in the normally-accepted range of 70 – 75% required for storage when starch is converted to sugars and the apples become marketable.

Leaf nutrient analysis results (**Table 4**) showed that, white clover and the standard herbicide treatment had higher nitrogen availability compared with that of the other treatments. Available phosphorous, potassium or calcium were in the optimum range for all the treatments. All plots, except those with white clover or creeping red fescue, had a slight magnesium deficiency. However, boron deficiency was recorded for all treatments with the untreated and birdsfoot trefoil plots having the lowest concentrations. Apples, prefer a slightly-acidic to neutral soil. Results showed that pH was maintained with only slight differences between treatments which could be a result of their spatial separation. The leguminous mulches increased soil nitrogen availability, in contrast to creeping red fescue plots. Birdsfoot trefoil treated plots showed a slightly lower level of potassium.

Table 4. Soil and leaf main nutrient status, June 2014

Treatment	Soil pH	P	K	Mg	Available N	Leaf N
White clover	7.4	84.6	252	125	26.4	2.01
Black medic	7.2	86.2	257	167	38.2	1.86
Creeping red fescue	7.2	87.0	268	150	10.6	1.60
Birdsfoot trefoil	6.8	84.4	240	150	27.7	1.70
Creeping red fescue + birdsfoot trefoil	7.3	86.8	259	174	22.0	1.60
Untreated	7.3	93.4	268	173	32.4	1.92
Standard herbicide treatment	7.3	92.8	283	165	41.0	2.17

Soil water content results showed that, the herbicide treated plot held most water. Of the living mulches, black medic retained the most water in the soil. In contrast, white clover reduced soil water content to below the untreated control plot despite extensive weed growth (**Figure 2**).

The container experiment supported the orchard trial soil water content results.

Plots with creeping red fescue alone or in the mixture, had the greatest proportion of apples within the optimal grade range (70% and 72% respectively) but no statistically significant differences were observed in plot yield. Similar branch extension growth was recorded in all treatments.

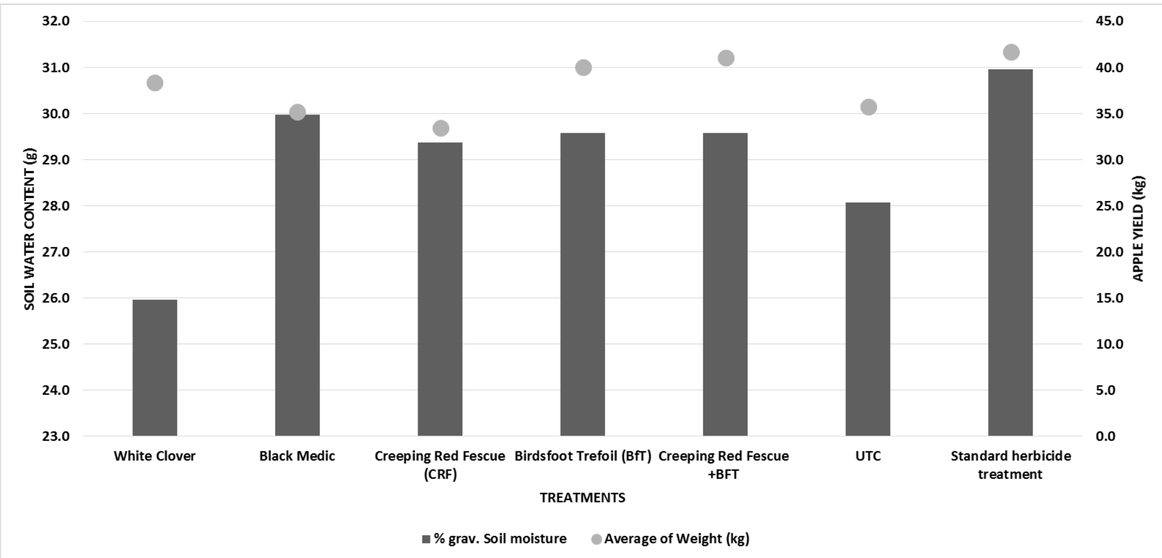

Figure 2. Soil water content and average apple yield

Figure 3. The trial lay out with the herbicide treated plot on the left and creeping red fescue plot on the right. June 2014

Financial benefits

An economic appraisal will be carried out in 2015/16 when the trial is completed to assess the costs and benefits of utilising a living mulch over maintaining a herbicide stip. This could represent a very viable approach for organic growers and conventional growers if approvals for certain herbicide actives are revoked.

Action points for growers

- Creeping red fescue with or without birdsfoot trefoil could be used by organic growers to suppress the weed population as effectively as a herbicide treatment.
- An additional nitrogen application may be required when using some of these living mulch species, particularly in young orchard, as they will compete for nutrients.

2.7.2 Cover crops for weed suppression prior to planting blackcurrant

Headlines

- All the cover crops tested suppressed both perennial and annual weeds at the autumn assessments after sowing in May.
- The grass legume mixes were more suppressive than the buckwheat and similar to the maize game cover treatment.

Background and expected deliverables

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 roots, rhizomes and stolons and will spread these parts to other areas of the field or to other fields. In a perennial crop, control of perennial weeds within the row presents a real challenge.

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 result in contamination at harvest and damage harvesting machinery by getting caught in the mechanisms. Perennial weeds are currently controlled in blackcurrants by hand weeding or band 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 this and the loss of certain active ingredients in the past five years (e.g dichlobenil), and the future threats to actives due to the Sustainable Use Directive, Water Framework Directive and endocrine disrupter review, there is a real need to develop 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, improved 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, while 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.

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 of the project and main conclusions

The cover crops included in the trial (**Table 1**) were; buckwheat (cv. Kora), a rye grass and red clover mix, a creeping red fescue and black medic mix and the grower control which was maize game cover. An untreated control was also included. The plot containing buckwheat was split into two (sub plots A and B). The buckwheat in sub plot A was allowed to die back naturally and re-seed, while in sub plot B, the buckwheat was cut down after flowering and incorporated shallowly, as this is meant to increase the allelopathic activity of this species (**Table 1**). This was delayed till September so some reseeding took place in sub plot B also. The trial was set up in 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.

Table 1. Cover crop treatment list sown in May 2014

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

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

A pre-treatment assessment was carried out prior to sowing to determine the weed population over the plots. Weed species present included scentless mayweed (*Tripleurospermum inodorum*), annual meadow grass (*Poa annua)*, American willowherb (*Epilobium ciliatum)*, groundsel (*Senecio vulgaris)*, common chickweed (*Stellaria media)* and perennials; 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 part A of the Buckwheat plot and the maize game cover plot were mown in September. **Figure 1** shows the cover crops in September after mowing.

The GPS coordinates of the plot corners have been logged and the trial will be monitored and assessed for differences in weed populations in 2015 once the area has been cultivated and blackcurrants planted by the host grower.

Untreated plot

Buckwheat plot – mown in the foreground, uncut behind

Rye- grass + red clover mix

Maize game cover

Creeping red fescue + black medic mix

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

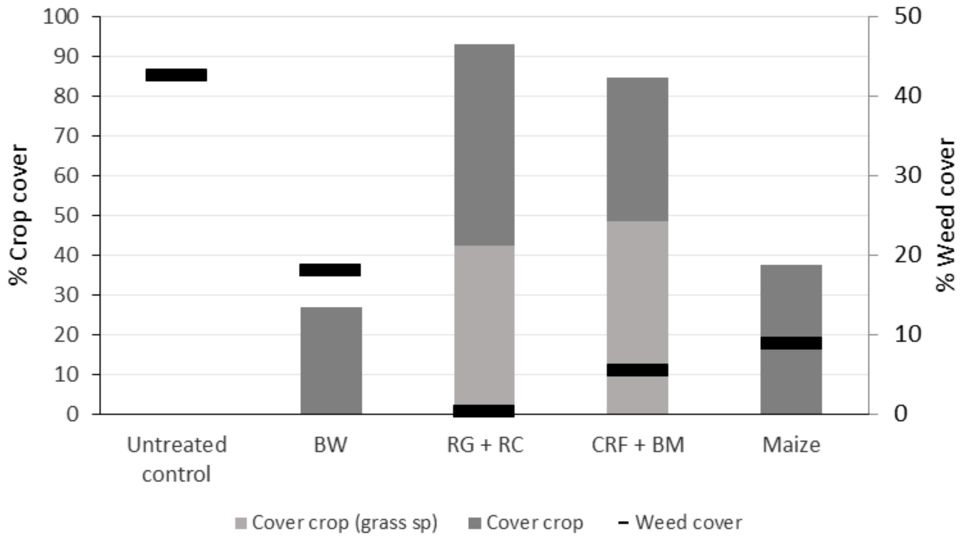

Figure 2. Results of the November 2014 weed and cover crop assessment

Results so far have shown that all of the crop cover species tested can effectively suppress many of the annual weed species present along with some perennial weeds. Success seems to be determined by the rate of establishment and density of cover achieved by the cover crop. **Figure 2** shows the results from the assessment carried out in November. At both the June and November assessment, the buckwheat plot was the least suppressive 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 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 buckwheat was also the only cover crop which did not show an increase in the level of docks.

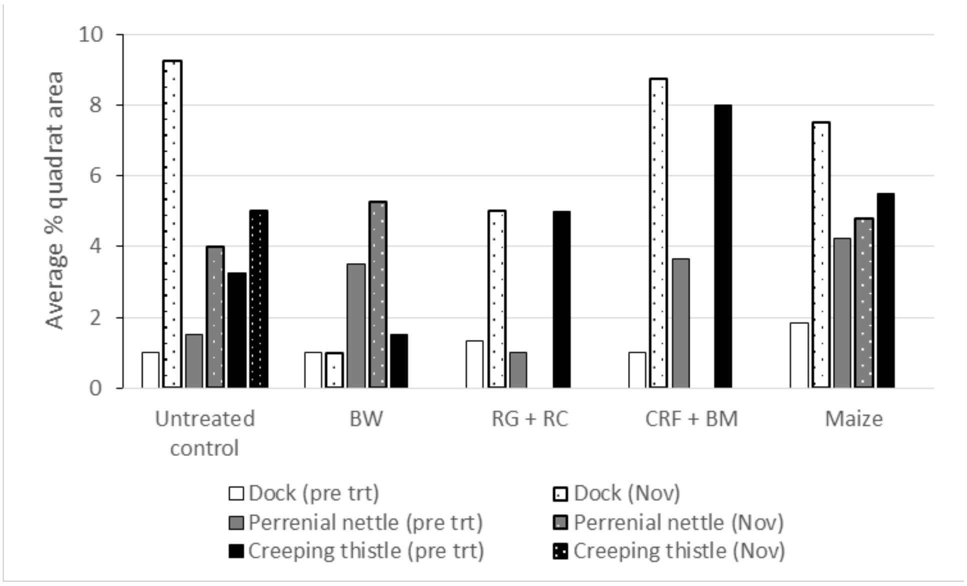

Figure 3. Comparison of percentage cover of perennial weeds at the pre cultivation/sowing assessment and the November assessment six months after sowing

The cover crops assessed within this trial are showing promise with regards to weed suppression. The trial is ongoing and the area will be cultivated and planted with blackcurrants in February 2015. Assessments of weed and blackcurrant establishment through the 2015 growing season will be made, along with soil analyses to determine any benefit in terms of organic matter or nutrition as a result of the cover crop treatments.

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 initial crop establishment and growth has not yet been assessed.

Action points for growers

- Growers should 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 (dazomet) 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 suppressed the percentage weed cover to 5% during establishment of the cover crops.

- There was no weed in any of the cover cropped areas assessed before the cover crops were incorporated in October.

- Buckwheat alone gave the least weed suppression, but all plots that contained the species alone or in a mix had the lowest soil mineral nitrogen prior to winter, minimising any potential pollution risk.

Background and expected deliverables

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 employed include 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 fumigants such as Basamid (dazomet) is uncertain and there is increasing interest in the use of alternative methods for weed suppression such as the use of 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, improved 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 who 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 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 of the project and main conclusions

The work was carried out on the site of 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 of increasing soil fertility and also reducing the 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 machinery belonging to 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
1	Grass and clover ley Italian ryegrass cvs. Danergo, Dracar, Fox, red clover cv, Milvus (grower standard)	Lolium multiflorum +Trifolium pratense	22.5 kg/ha
2	Buckwheat cv. Kora	Fagopyrum esculentum	100 kg/ha
3	Red clover cv. Formica	Trifolium pratense	25 kg/ha
4	Clover and grass/buckwheat cvs as above	Lolium multiflorum + Trifolium repens/Fagopyrum esculentum	22.5 and 100 kg/ha
5	Red clover/Buckwheat cvs as above	Fagopyrum esculentum/Trifolium pratense	25 and 100 kg/ha

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 weed species and percentage weed cover were also recorded at these assessments. A final assessment to record cover crop establishment, percentage 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 (*Sonachus sp),* scentless mayweed (*Tripleurospermum inodorum),* small nettle (*Urtica urens)* and common field-speedwell (*Veronica persica).*

Results

As this was 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 (**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 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 in hindsight a different mix may have been used as it does not respond well to being mown before it seeds. Nevertheless, there may still be treatment differences into the following year and all areas are being assessed in 2015 once the commercial spinach crops are 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.

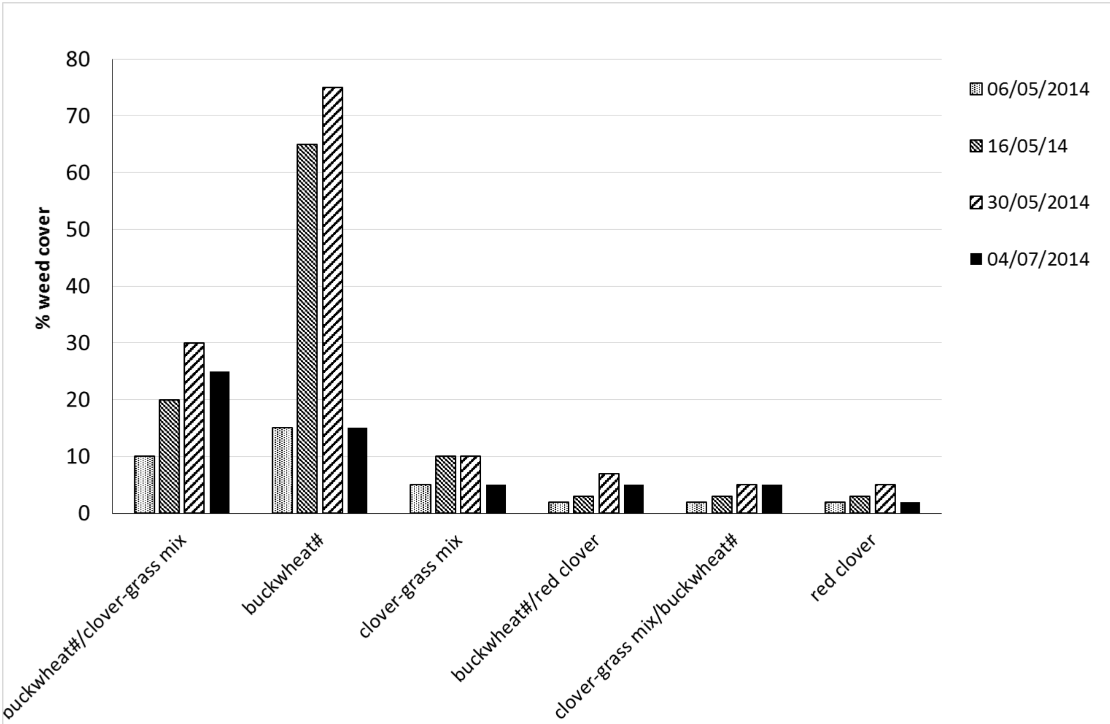

Figure 2. Percentage weed cover between the six cover crop treatments from May to July, Wiltshire, 2014. (# buckwheat was replaced by white clover after 4 July as it failed to re-establish)

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 leaching risk 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 (Soil Index in brackets)

Treatment	**pH**	**Organic matter (%)**	**Available N (kgN/ha)**	**P (mg/L)**	**K (mg/L)**	**Mg (mg/L)**
Grass and clover ley (grower standard)	7.4	3.8	131.8 (4)	103 (6)	490 (4)	91 (2)
Buckwheat cv. Kora	7.1	4.4	47.1 (0)	104 (6)	468 (4)	102 (3)
Red clover cv. Fprmica	7.3	4.7	112.4 (3)	108 (6)	602 (5)	106 (3)
Clover and grass/buckwheat	7.3	5.0	46.1 (0)	104 (6)	577 (4)	98.5 (2)
Buckwheat/clover and grass	7.0	4.8	56.6 (0)	106 (6)	589 (4)	105 (3)
Red clover/buckwheat	7.2	4.4	69.4 (1)	115 (6)	575 (4)	110 (3)

The trial is still ongoing and the areas where the cover crop treatments were sown will be monitored for effects on the following crop, soil nutrient status and effects on weeds in Spring 2015 as the commercial salad leaf spinach crops are sown.

Financial benefits

Using cover crops as a tool to help control weeds in salad crops could reduce fertiliser, labour and soil fumigant treatment application costs if they are successful. However a full assessment of the economic benefit cannot be made yet, as the effect on weed populations in the subsequent commercial crop and also on establishment and growth of that crop has not yet been assessed.

Action points for growers

- 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 year.

2.9 Crop safety of pre-planting herbicide treatments for perennial weed control in fruit

Headline

- Preliminary results suggest both Forefront T (aminopyralid + fluoxypyr) and Dow Shield 400 clopyralid could have potential for use on sites with high levels of perennial weeds prior to planting fruit crops. Currently, approval for aminopyralid products exclude this use.

Background and expected deliverables

Control of perennial weeds in soil grown soft fruit systems is a considerable cost, so 'starting clean' is important to avoid perennial weeds competing with the crop, hindering harvest and costing money through hand removal of weeds. Glyphosate is currently the most commonly applied herbicide used prior to cultivations before fruit establishment. However certain other chemicals, particularly in the picolinic acid family of herbicides, could offer better control of broad-leaved dock, curled dock, creeping thistle, spear thistle, common nettle, dandelion, creeping buttercup and ragwort when preparing land for fruit crops. It is important to establish that use of such products does not present any danger to later planted fruit crops. The objective of this trial was to assess the crop safety of the active ingredients aminopyralid and clopyralid on three fruit crops (strawberry, raspberry and blackcurrant) when applied as pre-planting treatments.

Summary of the project and main conclusions

An area of grassland on a strip of headland located at ADAS Boxworth was treated with one of three herbicides in either June or September 2013 in a fully randomised replicated trial design with an untreated control (**Table 1**). The plots were then rotovated in March 2014 and five plants of each of raspberry cv. Octavia, strawberry cv. Elegance and blackcurrant cv. Ben Gairn were planted. The whole area was then treated with a residual herbicide mix of Flexidor 125 at 2 L/ha and Stomp Aqua at 2.9 L/ha. Plants were assessed for phytotoxicity each month, for three months using a 0-9 scale where zero represented plant death and nine no effect. Weed control was assessed prior to cultivation in January and at each of the monthly phytotoxicity assessments from May to July 2014.

Table 1. Treatment list (treatments applied at 200L water /ha – ADAS Boxworth 2013/14)

No.	Treatment	Rate L/ha	Timing	Active
1	Untreated	-	-	-
2	Roundup	5 L/ha	Early June 2013	Glyphosate (360 g/L)
3	Roundup	5 L/ha	Sept 2013	Glyphosate (360 g/L)
4	Forefront T	2 L/ha	Early June 2013	Aminopyralid (30 g/L) + fluroxypyr (240 g/L)
5	Forefront T	2 L/ha	Sept 2013	Aminopyralid (30 g/L) + fluroxypyr (240 g/L)
6	Dow shield 400	0.5 L/ha	Early June 2013	Clopyralid (400 g/L)
7	Dow shield 400	0.5 L/ha	Sept 2013	Clopyralid (400 g/L)

Plant establishment was very variable regardless of treatment, which was probably due to the exceptionally wet winter experienced in 2013/14 which meant the heavy boulder clay soils at the site remained very wet and difficult to cultivate. Consequently planting conditions were not ideal for establishment. The trial was also hampered by rabbit and other rodent damage, despite the use of electric fencing.

Table 2. Average plant phytotoxicity scores July 2014

	July plant phytotoxicity score		
Treatment	Raspberry	Strawberry	Blackcurrant
Untreated	9.0	9.0	9.0
Roundup June	9.0	9.0	8.7
Roundup Sept.	9.0	8.9	9.0
Forefront t June	9.0	9.0	9.0
Forefront T Sept.	9.0	9.0	9.0
Dow shield June	9.0	9.0	9.0
Dow shield Sept,	9.0	8.0	9.0

The trial site at planting – April 2014

The trial site in July 2014

Figure 1. Images of the trial at planting and in July 2014

Raspberry – May 2014

Strawberry – May 2014

Blackcurrant – May 2014

Raspberry – July 2014

Strawberry – July 2014

Blackcurrant – July 2014

Figure 2. Images of treated raspberry, strawberry and blackcurrant in May and July 2014

Despite these difficulties, no clear or consistent phytotoxic effects were observed from either of the experimental treatments applied in either June or September, which is promising for fruit growers (**Table 2**). In terms of weed control, unfortunately the site chosen did not yield as many perennial species as hoped to truly test these products. However Dow Shield applied in September tended to show better control of the weed species present than Forefront T, but Roundup showed greater control of the predominantly grass species present (**Figure 3**).

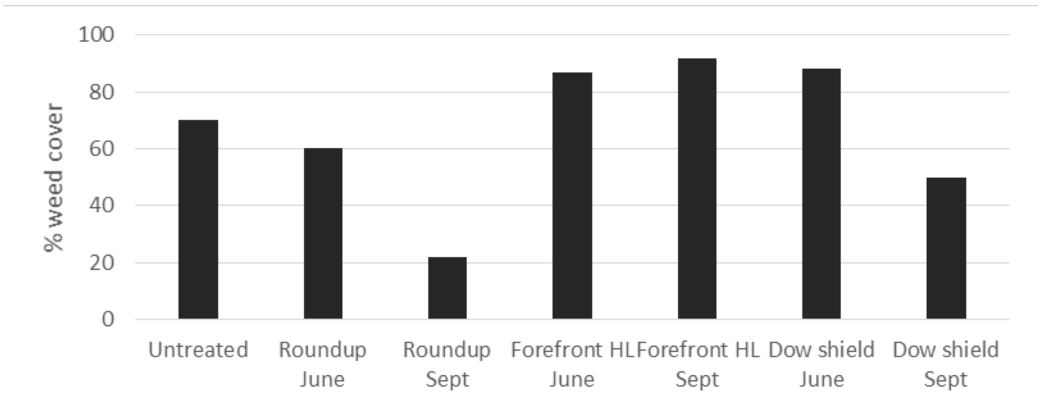

Figure 3. Average percentage weed cover per plot– January 2014

These preliminary results suggest both aminopyralid and clopyralid could have potential for use prior to planting fruit crops on sites with high levels of perennial weeds. Although Dow Shield can be used in this way, at present the conditions of approval for aminopyralid products exclude this use.

Financial benefits

None have been identified to date. A further trial would be required to confirm safety under more commercial conditions, and changes in the authorisation of aminopyralid to permit its use on a wider range of following crops would be required.

Action points for growers

- No action points have yet been identified.