Horticultural Fellowship Awards

Interim Report Form

Project title:	Weed control in ornamentals, fruit and vegetable crops – maintaining capability to devise sustainable weed control strategies
Project number:	CP 86
Project leader:	John Atwood, ADAS UK Ltd.
Report:	Interim report, March 2013
Previous report:	March 2012
Fellowship staff:	John Atwood, Project leader Lynn Tatnell, Assistant project leader
("Trainees")	Harriet Roberts, (fruit) and project management Jessica Sparkes, (weed biology) David Talbot, (ornamentals) Angela Huckle, (vegetables)
Location of project:	ADAS Boxworth
Industry Representative:	Wayne Brough, HDC
Date project commenced:	April 2011
Date project completed (or expected completion date):	March 2016

DISCLAIMER

AUTHENTICATION

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

John Atwood

Principal Horticultural Consultant

ADAS UK Ltd

Signature Date 27th March 2013

Report authorised by:

Dr Barry Mulholland

Head of Horticultural

ADAS UK Ltd

Signature Date 27th March 2013

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Progress Against Objectives

Objectives

Objective	Original Completion Date	Actual Completion Date	Revised Completion Date
1. To develop and mentor 4 staff in weed biology and control	March 2016	in progress	
1.1 Train next generation horticultural 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 (horticultural 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 (horticultural and arable), protected crops and ornamentals.	Sept 2012	Sept 2012	
1.5 Visited at least 10 nurseries with J Atwood or another specialist weed	March 2013	Completed, but recommend that visits should	

Objective	**Original Completion Date**	**Actual Completion Date**	**Revised Completion Date**
control expert and discussed/reviewed control strategies for key weeds on each nursery.		continue where thought beneficial	
1.6 BASIS qualified	Sept 2013	Jan 2013	
1.7 Understands requirements for ORETO standard experimental work.	Sept 2013	In progress	
1.8 Designed experiment and drafted experiment protocol to satisfaction of ADAS Biometrician and ORETO Study Manager.	Sept 2013	In progress	
1.9 Organised and managed successful delivery of two experiments from agreed work packages.	Sept 2013	In progress	
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	In progress	
1.11 Drafted HDC Project Reports on at least 2 projects.	Sept 2013	In progress	
1**.12** Submitted to HDC or elsewhere at least 3 proposals on R&D topics supported by growers.	March 2014	In progress	

Objective	Original Completion Date	Actual Completion Date	Revised Completion Date
1.13 Drafted an HDC Factsheet on biology and control of specific weed species of horticultural crops in specialist work area.	March 2013	At present, no specific requirement - will review in future	March 2016
1.14 Delivered at least 3 talks on weed control to nursery staff, grower groups or an HDC sponsored conference	Sept 2014	In progress, 2 completed	
2. Deliver applied research and KT work packages	March 2016	In progress	
2.1.1 1st pot screening for horticultural 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 horticultural 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
2.2.4 2nd container plant screening trial completed	Sep 2014		Nov 2013

Objective	**Original Completion Date**	**Actual Completion Date**	**Revised Completion Date**
2.2.5 3rd container plant screening trial set up	Oct 2015		June 2015
2.2.6 3rd container plant screening trial completed	Sep 2016		Sep 2012
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	In progress	
2.3.3 2nd Tree field herbicide trial set up	April 2013	Replaced with herbicide trial in stocks for cut flowers	
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	In progress	
2.4.3 2nd vegetable herbicide trial set up	May 2014		
2.4.4 2nd vegetable herbicide trial completed	Aug 2014		
2.4.5 3rd vegetable herbicide trial set up	May 2015		
2.4.6 3rd vegetable herbicide trial completed	Aug 2015		
2.5.1 Top fruit herbicide trial set up	April 2015		

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

Summary of Progress

A full training programme has continued in 2012 for the most recent recruits; Jessica Sparkes, Harriet Roberts and Angela Huckle with refresher training for the more experienced David Talbot. Training has consisted of general ADAS courses and more specific technical training. It is pleasing to note that all three recent recruits passed their BASIS qualification for horticulture in January 2013. David Talbot is already BASIS qualified. For the trainees based at Boxworth there has been the opportunity to gain further experience by working on a wide range of weed control projects not just those specifically planned through the fellowship.

The work programme continued through 2012 to March 2013 with pot herbicide screening experiments for specific horticultural weeds (Objective 2.1). As before, there were difficulties with germination of some of the weed species but the experiments were successfully completed in March 2013.

The nursery stock experiments for 2012 in the West Midlands were successfully planned and written up by David Talbot. The container nursery experiment (Objective 2.2) was concluded in November 2012 and the budded tree herbicide experiment (Objective 2.3) is still underway. A follow up container nursery experiment is being planned by David Talbot for 2013, further developing some treatments first tested in 2012 and introducing a new experimental compound.

A start was made looking at possible species to be grown as living mulches with potential for use within the crop rows of bush and top fruit (Objective 2.6). This work will be continued by Jessica Sparkes and Harriet Roberts in 2013 examining different species for growth parameters, nitrogen balance and water usage. Following pot trials during summer 2013, field sowings in commercial holdings are planned from autumn 2013.

Following liaison with the industry, Angela Huckle is planning a programme of herbicide trials for improved control of groundsel in salad leaf rocket (Objective 2.4). These trials are based on growers' holdings.

At the request of the cut flower industry, an additional project has been included in the programme of work for 2013. Angela Huckle and Jessica Sparkes will be managing a herbicide trial for stocks as cut flowers at the Cut Flower Centre Spalding in liaison with Lyndon Mason. This trial will be run instead of a second field tree herbicide trial, as it is thought that sufficient information will be gained from the first tree trial which runs for two seasons.

An experiment investigating the control of perennial weeds (Objective 2.7) by the allelopathic effects of cover crops will start in 2013, managed by Jessica Sparkes and follows a research area initially developed by Lynn Tatnell.

Liaison with researchers in other European countries has started (Objective 3.0). Angela Huckle attended a European Weed Research Society workshop on vegetable crops in Spain in September 2011 and made several useful contacts. Jessica Sparkes and Lynn Tatnell will be presenting posters on cover crops and herbicide resistance, respectively, at a European Weed Research Society Symposium in Turkey in June 2013 and Lynn will have a platform to present work on electrical weed control.

Initially through contacts made at the minor crops working group Brussels March 2012, John Atwood has made contact with researchers in the Netherlands and Germany and set up a sharepoint web site to share outline details of current research projects. Currently we have access to horticultural research reports from Germany and these have proved useful in developing treatments for the salad leaf rocket experiments.

The Netherlands

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

Ornamentals: Fons van Kuik

Vegetables: Rommie van der Weide, Marleene Riemens

Fruit: Bart Heijne

General (Principal contact): Corne Kempenaar

Germany

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

Vegetables (Princiapl contact): Ingeborg Koch

Fruits: Michael Glas

Vines: Friedrich Louis

Ornamentals: Bernd Böhmer

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

Milestones not being reached

The pot screening experiment for horticultural weed (Objective 2.1) was delayed due to poor germination of some of the weed seeds, but has now been completed.

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 and Germany. It is planned to continue building links with researchers in continental Europe through the life of the project by attendance at EWRS workshops and informal contacts, so a revised target of March 2016 is proposed.

Do remaining milestones look realistic?

1.5. Nursery visits (10). The milestone of 10 nursery visits has been met for the group as a whole. It is proposed to add further accompanied visits over the entire period of the fellowship project as the opportunity arises.

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 e.g. weed control in cut flowers.

1.14. Delivering talks; this aspect is now on track. Jessica Sparkes and Harriet Roberts have both presented talks at grower meetings. The HDC studentship conference will be another opportunity for presentations.

2.3.3. 2nd Field tree herbicide trial. This experiment has been replaced with a herbicide trial on 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, a seminar with an overseas researcher, attendance at conferences in the UK and abroad, 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 two years of the fellowship is summarised below:

Jessica Sparkes

- Improved background knowledge of UK agriculture and horticulture
- Experienced in weed resistance testing
- Seedling weed identification
- Giving consultancy advice
- Researched non-chemical weed control methods
- Gained BASIS qualification for Horticulture
- Spoken on weed control topic at grower meeting

Harriet Roberts

- Technical writing improved
- Experienced in contract management, protocol development, managing herbicide trials and drafting reports
- Seedling weed 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

Angela Huckle

- Networking with European researchers
- Staff management and quality systems
- Gave seminar to staff following visit to EWRS workshop in Spain
- Trained in weed control in nursery stock and fruit

- Gained BASIS qualification for Horticulture

David Talbot

- Increased confidence and skill 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 weed control in Rhubarb (SF 129), residual weed control in Raspberries (SF 119) and SCEPTRE projects on residual weed control in strawberries and perennial weed control in bush and cane fruit.

Jessica Sparkes has undertaken a comprehensive literature review of non-chemical weed control methods for CRD. She has managed commercially funded herbicide trials in oilseed rape and winter wheat and has led a CRD funded project examining the economics of various non-chemical methods of weed control. She has also worked with ADAS colleagues running a commercial programme of screening for herbicide resistance in grass weeds such as black-grass.

Changes to Project

Are the current objectives still appropriate for the Fellowship?

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

Grower Summary

Headline

- Wing-P (dimethenamid–p + pendimethalin) has potential for use as a residual herbicide in nursery stock, both for container-grown and field–grown crops.
- Wing-P controls weeds such as groundsel (*Senecio vulgaris*) and American willowherb (*Epilobium ciliatum*) that are important in nursery stock and soft fruit production. Authorisation for use is being sought by the HDC for use in these crops.

Background

The HDC/EMT/HTA Horticultural Fellowship – Weeds is designed to provide training for four recently recruited ADAS consultants / researchers to develop specific expertise in weed control research, and thereby maintain research and consultancy expertise in the UK in this sector.

To help achieve this aim a programme of experimental work is planned and in the second year this has focused on the testing of new herbicide products for potential use in nursery stock production, both container-grown and field-grown. Herbicides were tested for control of specific weeds of particular importance in nursery stock and fruit soft fruit production and for phytotoxicity in container and field-grown nursery stock species.

Following encouraging results for efficacy against key weed species in year one of the fellowship project, seed-meal treatments were included in the container-grown nursery stock trial to test for phytotoxicity in commonly grown crop species.

Work relevant to fruit production was started in the second year with an initial screening of plant species with potential for use as a living mulch within crop rows of bush, cane and tree fruit.

Summary

Pot weed screen

In seeded pot experiments at ADAS Boxworth led by Harriet Roberts, two new herbicide treatments HDC H14 and Wing-P (dimethenamid-p + pendimethalin) were compared against Flexidor 125 (isoxaben) on eight common weeds of horticultural interest both pre and post emergence of the weeds in 2012-13 (Table 1). Wing-P gave good control of groundsel and annual meadow grass (*Poa annua*), neither of which were controlled by Flexidor 125; however Wing-P did not give effective control of any of the three bittercress species tested. HDC H14 delayed germination of the weed species tested but with the exception of mouse-ear chickweed (*Cerastium fontanum*) and pearlwort (*Sagina subulata*) did not give good pre-emergence control. It may have been adversely affected by the high organic level of the growing media. HDC H14 performed more consistently as a post emergence application performing well on three species of bittercress (*Cardamine hirsuta*, *C. corymbosa*, and *C. flexuosa*). Both Wing-P and HDC H14 showed better or equivalent control to Flexidor 125 as a post emergence treatment on weeds that were either 4-5 true leaf or 7-10 true leaf stage.

Table 1. Herbicide pot screen results (R resistant <40% control, MS moderately susceptible 40 -70 % control, S susceptible >70% control)

	Pre emergence			Post emergence		
Weed species	Wing P	HDCH14	Flexidor 125	Wing P	HDCH14	Flexidor 125
Bittercress, hairy	R	R	S	R	S	R
Bittercress, flexuous	R	R	S	MS	S	R
Bittercress, NZ	R*	R*	S	MS	R*	R
Groundsel	S	R	R	S	MS	S
Willowherb, American	S*	S*	R	R	S	R
Chickweed, common	R	R	S	MS	R	S
Annual meadow grass	S	R	R	R	R*	R
Chickweed, mouse-ear	MS	S	S	S	S	S
Pearlwort	MS	S	S	Not tested		

*Very low overall germination but some significant phytotoxicity to the weeds was observed, subsequently killing the few germinated seedlings

Container plant screening

A weed control trial led by David Talbot was carried out on container-grown nursery stock at Wyevale Container Plants, Hereford. The main objective of the trial was to assess the crop safety of new herbicides Wing-P and HDC H14 and a high glucosinolate mustard seed meal (*Sinapsis alba*) to a range of container-grown nursery stock species (Table 3). A commercial standard treatment; Ronstar 2G was included for comparison.

Table 2. Treatments used in HNS container trial 2012

Product name	**Active substance**	**Rate (L/ha or kg/ha)**	**Approval Status (Outdoor ornamentals)**
Untreated			
Wing-P	dimethenamid-p (212.5 g/L) + pendimethalin (250 g/L)	4.0 L	Not approved
HDC H14			Not approved
Sinapsis alba 'Braco' seed meal	glucosinolates	24g/3L pot or 20g/2L pot.	Used as a fertiliser
Ronstar 2G	oxadiazon (2% w/w)	200 kg/ha	Approved

Table 3. Plant cultivars tested

Aucuba japonica 'Variegata'	*Escallonia rubra* var. *macrantha*
Buddleja davidii 'Buzz Ivory'	*Hebe pinguifolia* 'Sutherlandii'
Buxus sempervirens	*Hydrangea macrophylla* 'Mariesii Perfecta'
Ceanothus thyrsiflorus 'Skylark'	*Hypericum* 'Hidcote'
Cistus x *pulverulentus* 'Sunset'	*Olearia macrodonta* 'Major'
Cornus alba 'Sibirica'	*Spiraea nipponica* 'Snowmound'
Cupressocyparis leylandii 'Excalibur Gold'	

The Wing-P treatment was relatively safe, only *Olearia* was slightly damaged with some tip burn to the growing points. HDC H14 and the *Sinapsis alba* seed meal treatments were more damaging and therefore may only be suitable for a limited number of container-grown nursery stock species at the rates used.

Interestingly, seed meal caused leaf scorch on *Hypericum* initially but plants grew away from the damage quickly, whereas damage took longer to show on other plant species (e.g. *Cistus*). It was noted that seed meal resulted in improved leaf colour in *Hydrangea* but the effect on *Escallonia* was inconsistent; scorching the foliage of the latter in some plots whilst improving foliage colour in others. It is known that the seed meal can act as a slow release nitrogen fertiliser.

Overall the most promising treatment was Wing-P and this treatment will be further tested in 2013 both alone and in tank mixture with Flexidor 125 in an attempt to achieve a full weed control spectrum. The Herbicide HDC H14 is still some way from market in the UK and as its potential applications appear more limited in container-grown nursery stock it will not be included in the 2013 experiments.

2.3 Tree field herbicide trial

A weed control trial led by David Talbot commenced in 2012 on field-grown *Malus*, *Prunus*, Quince and *Sorbus* at Frank P Matthews Ltd, Tenbury Wells.

This trial was carried out to assess nine herbicide treatments; seven of which were novel herbicides (Table 4). All treatments were combined with a standard programme of Devrinol (napropamide) and Flexidor 125 (isoxaben), and applied post planting to dormant tree rootstocks for budding. The control treatment was the Devrinol and Flexidor commercial standard without any additional treatment.

Table 4. Post-planting treatments used in field tree HNS trial 2012

Product	Active substance	Rate	Approval status outdoor ornamental
Chikara	flazasulfuron (25% w/w)	0.150 kg/ha	Not approved
Devrinol	napropamide (450 g/L)	7L/ha	Label
Flexidor 125	isoxaben (125 g/L)	2L/ha	Label
Gamit 36 CS	clomazone (360 g/L)	0.25 L/ha	LTAEU
HDC H13	not disclosed		Not approved
HDC H14	not disclosed		Not approved
HDC H15	not disclosed		Not approved
Ronstar Liquid	oxadiazon (250 g/L)	4 L/ha	Label
Sencorex WG	metribuzin (70% w/w)	0.75 kg/ha	LTAEU

Stomp Aqua	pendimethalin (455 g/L)	2.9L/ha	EAMU
Wing-P	dimethenamid-p (212.5 g/L) + pendimethalin (250 g/L)	4 L/ha	Not approved

EAMU – Extension of authorisation for minor use
LTAEU – Long term arrangements for extension of use

When recorded three months after treatment the growers standard treatment had weed cover of around 10% with predominant weeds including black bindweed (*Fallopia convolvulus*), knotgrass (*Polygonum aviculare*), groundsel and dandelion (*Taraxacum officinalis*). The best additional treatments for weed control were Ronstar Liquid, Chikara and Wing P with 1.25, 2.25 and 2.75% weed cover respectively. Although Chikara looked promising in terms of weed control it caused significant stunting to the *Malus* and moderate stunting to *Prunus*, *Quince*, and *Sorbus*. The experimental treatments will be applied again after the rootstocks are headed back this spring and the results will be monitored.

Living mulch pot screen

A preliminary pot-based study led by Jessica Sparkes was conducted at ADAS Boxworth in spring/summer 2012 to evaluate the potential of four living mulch species for inclusion in 2013 trials. The living mulches tested included *Trifolium repens*, *Medicago lupulina*, *Festuca rubra*, *Lotus corniculatus* and a mixture of *F. rubra* and *L. corniculatus*. The purpose of this preliminary experiment was to determine if these species could be suitable for use as living mulches in top fruit and thus should be included in future studies. To be considered potentially suitable the living mulch should be low-growing and form a dense ground cover. Three sowing densities were tested which corresponded with the commercial recommendation, half the commercial recommendation and double the commercial recommendation for each species. After the living mulches were well established they were cut back to 3 cm and allowed to re-grow. This encouraged a dense cover across the soil surface in several of the treatments. None of the species tested grew more than 20 cm tall. Overall, all of the species included showed promise and will be taken forward in 2013. Germination of all species was lower than hoped so the lowest sowing density will be excluded from future work.

Financial Benefits

Further work is needed to obtain an authorisation for the use of Wing-P in ornamental and soft fruit production before it can be recommended to growers. Therefore there are no financial benefits at this stage.

Action Points

- Wing-P has good potential for use as a summer herbicide for the control of groundsel and annual meadow grass in ornamentals and soft fruit production but its use will depend on obtaining an authorisation for use in these crops.

Future projects

In year 3 (2013) there will be seven experimental projects:

- Control of groundsel in salad leaf rocket – novel herbicide combinations
- Herbicide screening for residual weed control in transplanted stocks for cut flowers
- Phytotoxicity testing of new active ingredients in a container-grown nursery stock, on a commercial nursery
- Control of perennial weeds by growing allelopathic crops in the preceding fallow
- Control of perennial weeds in Peony for cut flowers
- Residual effects from herbicides used for perennial weed control before planting fruit crops
- Water usage and nitrogen balance in living mulch species with potential for in-row planting in bush and top fruit

Science Section

Objective 2.1 - Pot weed screen

To test two new herbicides for the control of common HNS weeds pre-emergence and post-emergence at the three to four true leaf growth stage.

Introduction

Weed control in container-grown nursery relies on relatively few herbicide active ingredients with no new herbicides being developed for HNS. This is because it is a relatively small market, and developing herbicides safe to such a diverse range of species is a complex and expensive process. Weed control is currently reliant on old chemistry and actives from other sectors, these do not always suit the diverse growing systems employed by HNS growers, or do not have a complete weed control spectrum and the limited number available in the nursery stock growers armoury may lead to herbicide resistance developing. This trial has identified two new herbicide products developed for alternate markets and tests the actives efficacy against the nine most common weeds in containers.

Materials and methods

The trial was laid out in a fully randomised block design with treatments replicated five times. Each plot consisted of one 1 L pot, each seeded with 50 seeds of one of nine weed species; shown in **Table 1**. The treatment list is shown in **Table 2**. For the pre-emergence applications, treatments were applied immediately after the seeds were sown and watered in. Treatments being applied at three to four true leaf stages were applied to the individual species as they reached the appropriate growth stage. Herbicides were applied on 12 June 2012 to plots in 1000 L water/ha with a knapsack sprayer with appropriate boom and nozzle. Data were analysed by ANOVA.

Due to poor germination in the 2012 pre-emergence tests for American willowherb (*Epilobium ciliatum*), mouse-ear chickweed (*Cerastium fontanum*) and procumbent pearlwort (*Sagina procumbens*) an additional experiment was carried out in the glasshouse in February 2013 for these species but substituting heath pearlwort (*Sagina subulata*) for procumbent pearlwort (*S. procumbens*) as viable seed of the latter was unavailable.

Table 1. Weed species assessed in pot experiments – ADAS Boxworth 2012-13

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

Table 2. Herbicide treatments applied to weed species in pot experiments – ADAS Boxworth 2012-13

Number	Treatment	Product rate
1	Untreated	
2	Wing-P (dimethenamid-p (212.5 g/L) + pendimethalin (250 g/L))	4 L/ha
3	HDC H14	Not disclosed
4	Flexidor 125 (isoxaben 125 g/L)	1 L/ha

Results

Percentage germination in the untreated pots in the 2012 experiment was quite variable ranging from 6.8% for flexuous bittercress to 54.8% for groundsel. As a result of the poor germination, tests on American willowherb, mouse-ear chickweed and pearlwort, were postponed and completed in February 2013.

Table 3. Pre-emergence application 12 June 2012 – Percentage germination and phytotoxicity score three and six weeks after treatment, averaged by species. (9 - no effect, 5 – moderate levels of leaf damage weed stunted but likely to recover, 1 – dead)

Species	Treatment	% Germination 3 WAT	% Germination 6 WAT	Phytotoxicity score 6 WAT
Cardamine hirsuta	1	10.8	14.0	9.0
	2	1.2	21.2	8.6
	3	0.0	25.2	8.6
	4	0.0	1.2	8.0
Cardamine flexuosa	1	6.8	17.6	9.0
	2	0.0	21.2	8.0
	3	0.0	20.0	8.4
	4	0.0	1.6	7.5
Cardamine corymbosa	1	17.2	16.0	9.0
	2	0.0	21.6	8.4
	3	0.0	18.4	9.0
	4	0.4	0.4	9.0
Poa annua	1	14.8	14.0	9.0
	2	0.0	0.8	7.0
	3	14.4	18.4	8.4
	4	17.6	17.2	9.0
Senecio vulgaris	1	54.8	30.0	9.0
	2	4.8	4.4	8.3
	3	29.6	22.0	7.2
	4	28.0	20.8	6.6
Stellaria media	1	17.6	15.2	9.0
	2	1.2	21.2	8.0
	3	2.0	22.8	8.0
	4	0.0	2.0	6.0
Herbicide treatment x species 2 way ANOVA	**P value**	**<0.001**	**<0.001**	**<0.001**
	LSD (90 df)	**9.646**	**9.324**	**1.103**

Table 4. Pre-emergence application 5 February 2013 – Percentage germination and phytotoxicity score three and six weeks after treatment, averaged by species. (9 - no effect, 5 – moderate levels of leaf damage weed stunted but likely to recover, 1 – dead)

Species	**Treatment**	**% Germination 2 WAT**	**% Germination 5 WAT**	**Phytotoxicity score 5 WAT**
Cerastium fontanum	1	5.0	7.5	8.5
	2	2.5	2.5	2.0
	3	6.0	0.5	1.0
	4	1.0	0.5	9.0
Epilobium ciliatum	1	1.5	0.5	9.0
	2	1.5	0.5	1.2
	3	0.5	0.0	1.0
	4	3.0	4.0	9.0
Sagina subulata	1	68.0	71.5	8.7
	2	31.5	18.0	1.2
	3	75.5	3.5	1.2
	4	6.5	2.0	6.0
Herbicide treatment x species 2 way ANOVA	**P value**	**<0.001**	**<0.001**	**ns 0.089**
	LSD (33 df)	**7.851**	**7.929**	**2.541**

Post emergence treatments were applied on 9 July 2013 when the majority of species were at four to five true leaves. The chickweed and the groundsel however were slightly more advanced with eight to ten true leaves. American willowherb, hairy bittercress and mouse-ear chickweed had low germination, these species were re-sown and germinated in a glasshouse then moved outside for a week before spraying on 30 July 2012.

Table 5. Post-emergence application 9 or 30* July 2012 – Phytotoxicity scores 1, 2 and 6 weeks after treatment average by species (9 - no effect, 5 – moderate levels of leaf damage weed stunted but likely to recover, 1 – dead)

Species	**Treatment**	**Average phytotoxicity score 1 WAT**	**Average phytotoxicity score 2 WAT**	**Average phytotoxicity score 6 WAT**
*Cardamine hirsuta**	1	9.0	9.0	9.0
	2	7.4	6.2	7.2
	3	6.6	2.8	1.0
	4	6.8	6.4	6.8
Cardamine flexuosa	1	9.0	9.0	9.0
	2	8.4	8.0	4.8
	3	4.8	2.0	1.8
	4	7.0	5.2	8.8
Cardamine corymbosa	1	9.0	9.0	9.0
	2	8.4	7.8	5.0
	3	5.2	5.6	8.2
	4	7.8	7.0	8.0
*Cerastium fontanum**	1	9.0	9.0	9.0
	2	7.6	0.0	1.0
	3	6.4	0.0	1.0
	4	7.6	1.8	1.0
*Epilobium ciliatum**	1	9.0	9.0	9.0
	2	7.8	8.4	8.8
	3	2.6	0.0	1.0
	4	6.6	8.8	9.0
Poa annua	1	9.0	9.0	9.0
	2	9.0	8.8	8.8
	3	4.6	5.8	7.2
	4	8.6	9.0	7.8
Senecio vulgaris	1	9.0	9.0	9.0
	2	8.0	7.2	3.0
	3	6.6	7.8	4.0
	4	8.8	7.6	3.0

Species	Treatment	Average phytotoxicity score 1 WAT	Average phytotoxicity score 2 WAT	Average phytotoxicity score 6 WAT
Stellaria media	1	9.0	9.0	9.0
	2	7.8	5.8	4.0
	3	5.2	4.8	6.2
	4	6.8	3.2	3.4
Herbicide treatment x species 2 way ANOVA	**P value**	**<0.001**	**<0.001**	**<0.001**
	LSD (124 df)	**1.3606**	**2.165**	**2.884**

Discussion

Pre-emergence control

Wing-P gave good control of groundsel and annual meadow grass neither of which was controlled by Flexidor 125. The few groundsel and annual meadow grass seedlings that did germinate in the Wing-P pots showed phytotoxicity symptoms including leaf twisting and later, yellowing (**Figures 1** and **2**). This is a useful result, as there is a need for summer applied herbicides for the control of weed species which are resistant to Flexidor 125. Although both Wing-P and HDC H14 delayed germination of the three bittercress species and common chickweed, neither provided adequate control. All four species were well controlled by Flexidor 125.

The delayed pre-emergence tests on American willowherb, heath pearlwort and mouse-ear chickweed were completed in February 2013. Flexidor 125 gave almost complete control of heath pearlwort and both Wing P and HDC H14 gave good but slightly delayed control. With both Wing-P and HDC H14 some pearlwort seedlings germinated but didn't develop and after three weeks the leaves became chlorotic and the seedlings subsequently died (**Figure 3**). American willowherb again showed very poor germination so it was not possible to determine with certainty pre-emergence efficacy of the test species, however both test treatments caused chlorosis of the few germinated seeds (**Figure 4**) compared with the untreated and Flexidor 125 treatment suggesting some efficacy. Flexidor 125 gave better initial control of mouse-ear chickweed compared with Wing-P and HDC H14 but in both treatments seedlings that emerged showed significant phytotoxicity symptoms and subsequently died (**Figure 5**).

Figure 1. Twisted growth on groundsel following Wing P application

Figure 2. Twisted growth on annual meadow grass following Wing P application

Figure 3. Yellowed leaves on heath pearlwort following HDC H14 application

Figure 4. Yellowed leaves on willowherb following Wing P application

Figure 5. Phytotoxicity on mouse-ear chickweed following Wing P application

Post emergence control

Both Wing-P and HDC H14 gave better or equivalent post-emergence control for all the weed species tested compared with Flexidor 125. HDCH 14 in particular performed better as a post emergence application than as a pre-emergence treatment. HDC H14 gave excellent control of both hairy and flexuous bittercress although it took six weeks to kill the plants. It also gave complete control of American willowherb and along with Wing P very good control of mouse-ear chickweed.

Figure 6. *Cardamine corymbosa* treatment 1, 2 top 3, 4 bottom from left

Figure 7. *Cardamine hirsuta* treatment 1-4 left to right

Figure 8. *Cardamine flexuosa* treatment 1, 2 top 3, 4 bottom from left

Figure 9. *Cerastium fontanum* treatment 1-4 left to right

Figure 10. *Epilobium ciliatum* treatment 1-4 left to right

Figure 11. *Poa annua* treatment 1-4 left to right

Figure 12. *Senecio vulgaris* treatment 1, 2 top 3, 4 bottom from left

Figure 13. *Stellaria media* treatment 1-4 left to right

Wing P severely scorched New Zealand bittercress, flexuous bittercress, groundsel and chickweed but did not completely kill any of these species.

Conclusions

Wing-P gave good control of groundsel and annual meadow grass, neither of which were controlled by Flexidor 125; however Wing-P did not give effective control of any of the three bittercress species tested. HDC H14 delayed germination of the weed species tested but did not give pre-emergence control of any species except mouse-ear chickweed. It may have been adversely affected by the high organic level of the growing media as it has generally performed better in field soils. HDC H14 performed more consistently as a post emergence application performing well on all species of bittercress. Both Wing-P and HDC H14 showed better or equivalent control to Flexidor 125 as a post emergence treatment on weeds that were either four to five true leaf or eight to ten true leaf stage.

Objective 2.2 – Container hardy nursery stock herbicide screen

To test two herbicides and a high glucosinolate seed meal mulch for crop safety in comparison with a commercial standard herbicide.

Introduction

Two herbicides and a seed meal treatment were identified as having potential for use in container-grown nursery stock in pot screening experiments at ADAS Boxworth during 2011 and 2012. This trial evaluated the crop safety of herbicides Wing-P and HDC H14 and a seed meal (*Sinapsis alba* 'Braco') high in glucosinates as summer treatments applied to a range of deciduous and evergreen HNS species. Ronstar 2G was used for comparison as a commercial standard treatment. Products included in the trial were applied to recently potted plants; any weeds were removed by hand prior to the application of these treatments.

Materials and methods

The trial was laid out in a randomised split plot design with two treatment factors (i) weed control treatments (five treatments) and (ii) crop species (13 species) with four replicate blocks; totalling 20 plots. Each plot contained five pots of each species included within the trial. Plots were 1.5 m wide and 4 m long divided into 14 sub plots each containing five plants of each crop species. There was a pathway of 0.5 m to allow access to apply treatments, prevent drift and to carry out assessments.

The plant species and cultivars included in the trial are shown below (**Table 6**)

Table 6. Plant cultivars tested

Aucuba japonica 'Variegata'	*Escallonia rubra* var. *macrantha*
Buddleja davidii 'Buzz Ivory'	*Hebe pinguifolia* 'Sutherlandii'
Buxus sempervirens	*Hydrangea macrophylla* 'Mariesii Perfecta'
Ceanothus thyrsiflorus 'Skylark'	*Hypericum* 'Hidcote'
Cistus x *pulverulentus* 'Sunset'	*Olearia macrodonta* 'Major'
Cornus alba 'Sibirica'	*Spiraea nipponica* 'Snowmound'
Cupressocyparis leylandii 'Excalibur Gold'	

Berberis 'Maria' were also originally included in the trial but had to be excluded as they had dried out a little too much a few days after the treatments were applied and it was felt that it would not be possible to assess herbicide damage / crop safety on this plant species.

Wing-P and HDC H14 were applied to the respective plots using a 1.5 m boom sprayer in 1000 l/ha on 23/08/12. Seed meal had been weighed out into individual plastic bags and 20 g and 24 g were applied to two and three litre pots respectively. Ronstar 2G was applied to the surface of treated pots with a pepper pot shaker. The treatment details are shown below (**Table 7**).

Table 7. Treatments used in HNS container trial 2012

Product name	**Active substance**	**Rate (L/ha or kg/ha)**	**Approval Status** **(Outdoor ornamentals)**
Untreated			
Wing-P	dimethenamid-p (212.5 g/L) + pendimethalin (250 g/L)	4.0 L	Not approved
HDC H14			Not approved
Sinapsis alba ‘Braco’ seed meal	glucosinolates	24g/3L pot or 20g/2L pot.	Used as a fertiliser
Ronstar 2G	oxadiazon (2% w/w)	200 kg/ha	Approved

Unfortunately the exceptionally wet summer impacted upon this trial with 87 mm of rain falling on 24 August 2012. This flooded all the trial plots; luckily the pots did not float around and stayed within individual plots. Nursery staff kindly stood the pots up when the flood subsided; apart from the *Ceanothus* being infected with *Phoma* no other detrimental effects were encountered. No further data was collected from *Ceanothus* as it was not possible to make an accurate assessment.

Results

Wing-P

Wing-P appeared to be relatively safe in this trial only damaging the growing tips of *Olearia,* (**Figure 14**) damage was visible two weeks after treatment (WAT) and remained clearly visible at 12 WAT. Commercially acceptable damage was noted on *Cornus;* this species is known to be sensitive to herbicide damage but the plants grew away from any damage by six WAT.

Figure 14. Tip damage on Olearia following Wing P application

HDC H14

Unfortunately HDC H14 proved to be more damaging causing the most severe damage (leaf edge scorch) on *Buddleja,* which would have rendered crops unsalable (**Figure 15**).

Figure 15. Leaf edge scorch on *Buddleja davidii* 'Buzz Ivory' following HDC H14 treatment

Damage was noted on other species and is listed in order of severity. Damage on *Ceanothus* was noted at two WAT but no further observations were possible due to *Phoma* infection. *Olearia* was also damaged by HDC H14; the damage was first noted two WAT and got slightly worst by six WAT with no improvement by 12 WAT. Damage did not show until six WAT on *Aucuba,* when marginal leaf scorch was noted, damage was still clearly visible 12 WAT. Commercially acceptable damage was noted on *Spiraea* two weeks after treatment but had got worst by the time the six WAT assessment was carried out; although damage was less obvious by 12 WAT the level of damage was still unacceptable. *Escallonia* was also slightly damaged with symptoms becoming most obvious six WAT before the plants started to grow away from the herbicide damage. *Hydrangea* was slightly damaged but had grown away from damage by six WAT when they were considered comparable with untreated controls.

***Sinapsis alba* ‘Braco’ seed meal**

Figure 16. Foliage yellowing on *Hebe* (LHS) following treatment with seed meal mulch

Figure 17. Marginal leaf scorch on *Buxus* from seed meal treatment

The mustard seed treatments caused a degree of damage on every single species within the trial. Damage was detected on most plant species at the first assessment two WAT, generally plants either grew away from the damage (e.g. *Hypericum* and *Cornus* which were initially damaged, however plants quickly grew away from the leaf scorch and only had very slight signs of damage by 12 WAT) or damage got worst as time went on (e.g. *Hebe* which showed some slight phytotoxic damage two WAT whilst damage had progressed by six WAT and was recorded as severe damage, there were no signs of recovery by 12 WAT, as shown above (**Figure 16**), the plant on the right is untreated. *Buddleja* was also severely damaged by seed meal, plants were unmarketable by six WAT and had not really improved by 12 WAT). Phytotoxic symptoms took longer to develop on *Aucuba* and *Buxus;* there was no sign of damage two WAT on either of these species and plants were considered comparable to untreated controls. By six WAT damage was clearly visible on both *Aucuba* and *Buxus,* this treatment caused a marginal leaf scorch on *Aucuba* which turned the leaf margins black / brown and resulted in dull foliage colour and marginal leaf scorch in *Buxus* (as shown in **Figure 17**).

Cistus, Olearia and *Spiraea* showed some phytotoxic damage two WAT, however symptoms were worst six WAT, with a slight recovery by 12 WAT although the plants were still un-saleable. Seed meal caused some damage in treated *Cupressocyparis* and one plot of *Hydrangea* two WAT but *Hydrangea* grew away from the damage quickly and in fact were better quality than untreated controls by six WAT. Seed meal seemed to dramatically improve the leaf colour of *Hydrangea,* creating a similar effect to some plant growth regulators that are used in the production of *Hydrangea* grown on the continent; this positive effect was still noticeable by 12 WAT and would have increased saleability. A similar effect was noted on *Escallonia* but marginal leaf scorch also occurred on up to 50% of the plants which would have rendered them unsalable unless a lot of hand cleaning was carried out to remove scorched leaves. Individual plants that were not scorched had a better leaf colour than untreated controls. *Cupressocyparis* plants had a mean score which made them not quite commercially acceptable by 12 WAT. Although *Ceanothus* were only scored at two WAT the mean score for the plants was also not quite commercially acceptable.

Hydrangea were damaged by Ronstar 2G granules, this was not surprising as the product label carries the instruction not to treat *Hydrangea.* No other species within the trial were damaged by this treatment.

Weed control was not assessed as part of this trial.

Phytotoxicity was scored on a 0 – 9 scale with 0 representing plant death, 7 representing commercially acceptable damage and 9 being comparable with the controls.

The tables (**Tables 8-10**) below list the mean scores given to all species and treatments at two, six and 12 WAT, when compared to controls.

Table 8. Average phytotoxicity score by species two WAT (9 - no damage, 0 - dead)

	Scores												
Treatment Number	*Auc*	*Bud*	*Bux*	*Cea*	*Cis*	*Cor*	*Cup*	*Esc*	*Heb*	*Hyd*	*Hyp*	*Ole*	*Spi*
1	9	9	9	9	9	9	9	9	9	9	9	9	9
2	9	9	9	9	9	8.75	9	9	9	9	9	4	9
3	9	4	9	4	9	4.75	9	9	9	9	9	4.5	8.25
4	9	4.5	9	7.75	7	4.75	8.25	7	7.67	7.75	3.3	4.5	5.75
5	9	9	9	9	9	9	9	9	9	5.75	9	9	9

Table 9. Average phytotoxicity score by species six WAT

	Scores												
Treatment Number	*Auc*	*Bud*	*Bux*	*Cea*	*Cis*	*Cor*	*Cup*	*Esc*	*Heb*	*Hyd*	*Hyp*	*Ole*	*Spi*
1	9	9	9	-	9	9	9	9	9	9	9	9	9
2	9	9	9	-	9	9	9	9	9	9	9	4	9
3	4.5	2	9	-	7.75	6	9	9	9	8.5	9	4	4
4	4	2.5	7.3	-	3	9	8.25	6.25	2	9	6	4	4
5	9	9	9	-	9	9	9	9	9	5.75	9	9	9

Table 10. Average phytotoxicity score by species 12 WAT

	Scores												
Treatment Number	*Auc*	*Bud*	*Bux*	*Cea*	*Cis*	*Cor*	*Cup*	*Esc*	*Heb*	*Hyd*	*Hyp*	*Ole*	*Spi*
1	9	9	9	-	9	9	9	9	9	9	9	9	9
2	9	9	9	-	9	9	9	9	9	9	9	5	9
3	4.5	2	9	-	9	9	9	9	9	8.75	9	4	5.75
4	4	2.75	4.67	-	3.67	9	7.25	7	2	9	7	4.25	5.5
5	9	9	9	-	9	9	9	9	9	7.75	9	9	9

Discussion

Wing-P was the safest of the new herbicides in this trial, it only damaged one plant species; *Olearia* and will be taken forward in this year's trials to screen crop safety on other HNS species. The fact that Wing-P has pre emergence activity against important nursery weeds such as groundsel (*Senecio vulgaris*) and annual meadow grass (*Poa annua*) could be very useful. Wing-P will also be tank mixed with Flexidor 125 to improve the weed control spectrum of both products this year. Wing-P may be an alternative post emergence herbicide where Flexidor 125 is not an option for the control of groundsel (*Senecio vulgaris*) and mouse ear chickweed *(Cerastium fontanum)* seedlings.

HDC H14 caused crop damage on a range of species and its pre-emergence activity appears to be poor in growing media with a high organic matter content, as used in container production. However other trials carried out as part of the Horticulture Fellowship (see section Objective 2.1) have found HDC H14 to have post emergence activity against bittercress species (*Cardamine flexuosa* and *C. hirsuta)* and willowherb which could be extremely useful. The fact that the herbicide has post emergence activity against the aforementioned weed species up to 10 true leaves could also be an important finding.

Mustard seed meal is supplied in pelleted form after the oil had been extracted. The pellets are extremely hard and had to be put through a food processor to turn them into a meal to use as mulch. This is quite a labour intensive process and would need to be mechanised and carried out by the supplier as few growers would have the time to ‘process’ pellets into seed meal.

In this trial, precise weights of seed meal were applied per pot, growers would apply seed meals over the top of freshly potted crops in a similar way to Ronstar 2G granules. Therefore it would be difficult to accurately apply a safe rate to each pot in order to prevent crop damage; the fact that meal contains various sized particles would also complicate application. Moulds growing on the seed meal pose another challenge, particularly when using seed meals under protection during winter. As the seed meal degrades it forms an undesirable crust on the surface of the pot that might need to be removed prior to dispatch, increasing labour costs. Mixing seed meals with bark may get around this problem but the vibration in a bark topping machine could potentially shake seed meal out of the bark during the application process, resulting in uneven application which would pose additional problems.

The seed meal caused crop damage in every single species contained within this trial; the rates were calculated; pro rata based on the surface of the growing media exposed using the rates found to be safe on 9 cm *Clematis* liners in HNS 175. It seems as though these rates may have been too high for some of the species in this trial, and that different levels of glucosinolate affect different plants in different ways.

Conclusions

Wing P could potentially be a very useful herbicide in the future production of HNS and is being taken forward into this year's trial. Additional plant species will be screened for crop safety. Depending on the outcome of future trials, steps may need to be taken to secure this herbicide for use in HNS container production in the UK.

Cornus in this trial were well established 3L plants with little if any soft growth at the time of application, Wing-P could potentially be more damaging on other cultivars, on softer growth or on younger plants e.g. liners. If an EAMU for the use of Wing P on ornamentals was granted there is a need to carry out further trials before treating *Cornus* and indeed other HNS species.

HDC H14 use as a summer treatment is limited as the product has no residual activity against import weeds of container HNS nurseries. Despite this, the post emergence action against relatively large (up to 10 true leaves) problematic nursery weeds may be worthy of further investigation. Generally residual herbicides are safer if applied when plants are dormant. HDC H14 could have potential for use a late winter clean up before crops dormancy breaks.

Seed meals need to be available for growers to purchase in a useable form (as a meal containing uniform sized granules rather than pellets) if they are to be widely used by growers. More work needs to be done to determine the crop safety of *Sinapsis alba* seed meal and whether lower rates would contribute to weed control on species susceptible to damage. Application methods would need to be developed to minimise variability in the rate of seed meal applied to container grown stock. Given the extent of crop damage and the challenges outlined in the discussion it is difficult to imagine *Sinapsis alba* seed meal becoming commercially available. The difficulty of using a biological product (that is naturally variable) as a herbicide complicates matters further. To be sold as a bioherbicide the product would need to be authorised for use by the HSE. This would require the production of a relatively expensive data package for a product that is far from perfect; which seems unlikely, given the reasons discussed above.

Objective 2.3 - Tree field trial

To test nine residual herbicides for crop safety and efficacy when used in addition to a standard nursery herbicide programme in field grown budded tree production.

Introduction

Weed control in field-grown nursery stock has relied on the same few active ingredients for a number of years. Data on the crop safety of new / novel herbicides is often limited and is a key factor limiting uptake when growers plan herbicide programmes. The gradual withdrawal of the LTAEU has impacted on the herbicides that HNS growers can use making it important to screen alternative products as they become available.

This trial evaluated seven novel herbicides and two standard herbicides in conjunction with a standard programme for weed control and crop safety when applied after planting field grown maiden trees. If the actives look promising they may be made available for use either through mutual recognition (if authorised in Europe) or EAMUs (Extensions of Authorisations for Minor Use).

The rootstocks in this trial were planted in spring 2012 and treated with novel and standard herbicides; they were budded in July, prior to being treated with a standard herbicide programme. The rootstocks were headed back in late winter 2013 and a top up application of the herbicide treatments were applied whilst trees were still dormant during March 2013. These results will be reported in next year's annual report.

Materials and methods

The trial was laid out in a fully randomised block design with four fold replication. Each plot was 3.5 m wide and 2.4 m long and contained four species of rootstocks, planted in rows spanning all plots within the trial. The species of rootstock were *Malus* 'MM106', *Prunus* 'Colt', Quince A and *Sorbus aucuparia.* The host nursery's standard herbicide programme was applied post planting on 4 April 2012 and comprised of Devrinol (napropamide) applied at 7.0 L/ha, and Flexidor 125 (isoxaben) applied at 2.0 L/ha. Additional standard and novel residual herbicides were applied to the respective plots using a 3.5 m boom sprayer in 400 L/ha of water over the top of the trees (whilst still dormant) on 13/04/12. The treatment list is shown below in **Table 11**.

Table 11. Treatments (in addition to the nursery standard Devrinol + Flexidor 125) applied 13 April 2012

Treatment number	Product name	Active substance	Rate (L/ha or kg/ha)
1	No additional treatments		
2	Stomp Aqua	pendimethalin (455 g/L)	2.9 L
3	Ronstar Liquid	oxadiazon (250 g/L)	4.0 L
4	Chikara	flazasulfuron (25% w/w)	0.150 kg
5	Gamit 36 CS	clomazone (360 g/L)	0.25 L
6	HDC H13		
7	HDC H14		
8	HDC H15		
9	Sencorex WG	metribuzin (70% w/w)	0.75 kg
10	Wing-P	dimethenamid-p (212.5 g/L) + pendimethalin (250 g/L)	4.0 L

Results

No phytotoxicity was noted two weeks after treatment; a very slight reduction in growth was noted on *Sorbus* at both nine and 12 weeks after treatment (WAT) in one of the four plots treated with Stomp Aqua. This was considered commercially acceptable.

Chikara caused obvious stunting on all four species in one of the plots (**Figure 18**); a reduction in vigour was also noted on other plots treated with Chikara. Phytotoxicity (as a reduction in vigour) was not apparent until 12 WAT. There had been heavy rainfall during this period.

Figure 18. Stunting from Chikara on *Malus*

Phytotoxicity was scored on a 0 – 9 scale with 0 representing plant death and 9 being comparable with the controls. Table 12 shows that Chikara resulted in a mean score of 4.75 on *Malus*; this equates to reduced growth or vigour when compared to controls. Chikara also caused a slight reduction in growth or vigour on the other species in the trial; *Prunus, Quince* and *Sorbus,* when compared to controls.

Table 12. Average phytotoxicity scores (9 - no effect, 7 - commercially acceptable, 0 - plant death) 12 WAT following experimental treatments

Treatment	***Malus***	***Prunus***	***Quince***	***Sorbus***
1. No additional treatments	9	9	9	9
2. Stomp Aqua	9	9	9	8.75
3. Ronstar Liquid	9	9	9	9
4. Chikara	4.75	6	6.25	6.75
5. Gamit 36 CS	9	9	9	9
6. HDC H13	9	9	9	9
7. HDC H14	9	9	9	9
8. HDC H15	9	9	9	9
9. Sencorex WG	9	9	9	9
10. Wing-P	9	9	9	9

Note there was insufficient variation between replications to undertake an anova analysis of the results.

Table 13. Average percentage weed cover 9 and 12 WAT following experimental treatments

Treatment	**9 WAT**	**12 WAT**
1. No additional treatments	1.75	10.25
2. Stomp Aqua	1.0	3
3. Ronstar Liquid	0.5	1.25
4. Chikara	0.75	2.25
5. Gamit 36 CS	1.5	5.25
6. HDC H13	0.75	4
7. HDC H14	1.0	4.50
8. HDC H15	1.0	7.50
9. Sencorex WG	1.0	7.25
10. Wing-P	0.5	2.75
P value	**0.141**	**0.083**
LSD (27 df) (10% probability)	**ns**	**4.8**

The average weed cover is shown in **Table 13**. The nursery standard treatment performed well at the nine WAT assessments with only 1.75% weed cover. Although some of the additional treatments, notably Wing-P, appeared to give a further improvement in weed control at this stage, the differences were not significant. By the 12 WAT assessment the standard treatment was starting to lose efficacy at 10.75% weed cover with predominant weeds being black bindweed (*Fallopia convolvulus*), knotgrass (*Polygonum aviculare*), groundsel and dandelion (*Taraxacum officinalis*), and the additional treatments of Ronstar Liquid, Stomp Aqua, Chikara and Wing P in particular improved control to between 1.25% and 3%. Chikara, Wing P, HDC H13, HDC H14 and Gamit 36 CS were the only novel treatments with sufficient residual activity to significantly improve control at the 12 WAT assessments, Chikara being the most effective followed by Wing-P.

Discussion

None of the herbicide treatments in this trial showed any signs of crop damage at the first assessment, two WAT. The most damaging herbicide, Chikara did not appear to suppress the growth of the treated crops until 12 weeks after treatment.

All treatments provided good weed control with less than 5% weed cover on all plots at nine WAT. Percentage weed cover at 12 WAT was greatest on the control plots that had received only the nursery standard with no additional treatments. Ronstar Liquid was the most effective supplementary treatment followed by Chikara (where crop growth was reduced in all species within the trial), Wing-P and Stomp Aqua.

After budding and after the 12 WAT assessment weeds were spot treated with Harvest (glufosinate-ammonium) and a standard herbicide treatment: Venzar Flowable (lenacil) applied at 3L/ha + Flexidor 125 (isoxaben) applied at 2L/ha were applied over the top of the crop to all treatment plots (2-10). A phytotoxicity assessment was carried out a month later and no crop damage was noted.

Conclusions

Most residual herbicides are generally much safer when applied over the top of dormant HNS, particularly deciduous crops. Residual herbicides bind to soil particles and are not generally taken up by plant roots. All of the products tested within this trial, with the exception of Chikara, appear to be safe on the crops that they have been applied to so far. Past experience has shown that some residual herbicides can leech through the soil profile. The exceptionally wet summer of 2012 has highlighted the importance of carrying out trials in different seasons, over a number of years, in order to get comprehensive results.

It is thought that the exceptionally wet weather during the summer of 2012 caused Chikara to leech through the soil profile into the tree's root zone, enabling uptake. This caused a marked reduction in the growth of *Malus* rootstocks and a moderate reduction in the growth of *Prunus, Quince* and *Sorbus* rootstocks. Chikara was used under an experimental permit in this trial. Chikara is only authorised for use as a total herbicide in non-cropped areas and therefore cannot be applied over crops. Further experience needs to be gathered in order to determine if this active can play a role as a residual herbicide within crop production in the future.

Of the additional herbicides used in this trial to supplement the grower's standard programme, Ronstar Liquid, Wing-P and Stomp Aqua stood out as the most effective without causing damage. Of these, Stomp Aqua is the cheaper product, has an EAMU and would be a cost effective addition. Wing-P however could provide a broader weed control spectrum than Stomp Aqua and an EAMU should be applied for.

Objective 2.6 - Living mulch pot screen

Introduction

Living mulches are slow growing plant species that are established into a crop. They can provide many benefits to a crop (e.g. improved soil structure, nutritional, pest protection) and have been shown to suppress weeds. There are several risks to using living mulches (e.g. crop competition) so careful selection of the mulch species is crucial. This preliminary experiment aimed to evaluate whether four plant species may be suitable for use as living mulches in top fruit and therefore be worth including in more complex studies in 2013.

Materials and methods

This experiment was carried out at ADAS Boxworth from June to August 2012 in 3L pots which were kept in an outdoor netted hard standing area. The experiment was a fully factorial randomised design consisting of four replicates of four living mulch species plus a combination of two species and three sowing densities (**Table 14**).

Table 14. Treatment list

Treatment no.	Common name	Scientific name	Sowing density
1	White clover	*Trifolium repens*	0.35 g/m^2
2	White clover	*Trifolium repens*	0.7g/m^2
3	White clover	*Trifolium repens*	1.4 g/m^2
4	Black medic	*Medicago lupulina*	0.4 g/m^2
5	Black medic	*Medicago lupulina*	0.8 g/m^2
6	Black medic	*Medicago lupulina*	1.6 g/m^2
7	Creeping red fescue	*Festuca rubra*	3.75 g/m^2
8	Creeping red fescue	*Festuca rubra*	7.5 g/m^2
9	Creeping red fescue	*Festuca rubra*	15 g/m^2
10	Birdsfoot trefoil	*Lotus corniculatus*	0.35 g/m^2
11	Birdsfoot trefoil	*Lotus corniculatus*	0.7 g/m^2
12	Birdsfoot trefoil	*Lotus corniculatus*	1.4 g/m^2
13	Creeping red fescue + Birdsfoot trefoil	*Festuca rubra* + *Lotus corniculatus*	3.75 g/m^2 + 0.35 g/m^2
14	Creeping red fescue + Birdsfoot trefoil	*Festuca rubra* + *Lotus corniculatus*	7.5 g/m^2 + 0.7 g/m^2
15	Creeping red fescue + Birdsfoot trefoil	*Festuca rubra* + *Lotus corniculatus*	15 g/m^2 + 1.4 g/m^2

Pots were filled with Clover Container compost and watered to field capacity before seeds were surface sown. All pots remained outside through the duration of the experiment and were watered as required to ensure that the substrate did not dry out. Four weeks after sowing the living mulches were cut to 3 cm and the cuttings were laid on the soil surface as a mulch. Date of first emergence and visual assessments of growth were recorded.

Results

Sowing densities, based on the commercial recommendations appeared low when scaling down to pot size. As such the number of plants which emerged in each pot was lower than hoped for with some species, particularly those which were sown with the lowest seed rates. Initial growth of all plant species appeared thin but following cutting and a period of re-growth the percentage soil coverage was greatly improved (**Table**). The growth of all species remained reasonably low to the soil surface with no treatment reaching more than 20 cm tall.

Table 15. Percentage soil coverage of living mulch species before and after cutting

Treatment no.	Common name	Sowing density	Mean percent soil cover – pre-cutting	Mean percent soil cover – post-cutting
1	White clover	0.35 g/m^2	18.75	55
2	White clover	0.7g/m^2	58.75	90
3	White clover	1.4 g/m^2	72	97.5
4	Black medic	0.4 g/m^2	5.5	36.25
5	Black medic	0.8 g/m^2	6.75	48.75
6	Black medic	1.6 g/m^2	22.5	71.25
7	Creeping red fescue	3.75 g/m^2	6.25	36.25
8	Creeping red fescue	7.5 g/m^2	18.75	70
9	Creeping red fescue	15 g/m^2	46.25	87.5
10	Birdsfoot trefoil	0.35 g/m^2	1.5	18.75
11	Birdsfoot trefoil	0.7 g/m^2	11.75	43.75
12	Birdsfoot trefoil	1.4 g/m^2	40	81.25
13	Creeping red fescue + Birdsfoot trefoil	3.75 g/m^2 + 0.35 g/m^2	28.75	60
14	Creeping red fescue + Birdsfoot trefoil	7.5 g/m^2 + 0.7 g/m^2	25	71.25
15	Creeping red fescue + Birdsfoot trefoil	15 g/m^2 + 1.4 g/m^2	45	83.75

Discussion

To be considered a potential living mulch, the plant species in question needs to be low growing and able to achieve a good ground cover. All species included in this preliminary experiment appear suitable based on these criteria and will therefore remain in future experiments. The lowest sowing density however will be excluded as a greater ground cover is desired. Trials in 2013 with these species will examine, in more depth, the water requirement, growth rate, nutrient requirements and weed suppressive ability.

Conclusions

All species included in the preliminary experiment will be taken forward in 2013 experiments. A greater ground cover is required and therefore the lowest sowing density will be excluded in the future.

Knowledge and Technology Transfer

A presentation was undertaken to the HDC HNS panel on the 31 January 2013 and an HDC News article was prepared for the March 2013 issue.

Appendices

Appendix 1. Training logs

Angela Huckle - 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 demonstration	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
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

Date	Training activity	Trainer
27/9/12	Asparagus agronomy and establishment	Chris Creed, John Beeren (Beeren plant products)
3/10/12	British Carrot Growers Association 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 vegetable crops	Simon Townsend and Rob Storey
October – December 2012	BASIS commercial horticulture	Swallowfield consulting
12/11/12	Visit to Vitacress, Andover to discuss weed control in salad leaf production	John Atwood
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	Various

Harriet Roberts - training log

Date	Training Description	Trainer
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

Date	Training Description	Trainer
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
07/12/11	Weed identification course	Sarah Cook and Denise Ginsburg
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 – Lowaters nursery and Double H Nurseries	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	Dr Tim Miller – Washington State university

Date	Training Description	Trainer
	Boxworth and other herbicide trials locally	
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
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
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

Jessica Sparkes -training log

Date	Training activity	Trainer
Aug 2011-ongoing	Grass weed resistance testing	Lynn Tatnell
15/09/11	Field visit with agronomist (weed identification)	Gerald Collini
13/09/11	Contract management training	Mandy Howell/ Richard Laverick

Date	Training activity	Trainer
Aug 2011 – Oct 2011	Non-chemical weed control literature review	
20/10/11	Field visit with agronomist	Gerald Collini
01/11/11	Risk assessment training	David Knowles
15/11/11	Boxworth Farming Association meeting	
28/11/11	Field visit with agronomist	Gerald Collini
07/12/11	Weed identification course	Sarah Cook/Denise Ginsburg
13/12/11	HL Hutchinson Annual Conference	
19/12/11	Personal effectiveness and time management	
25/01/12	UK Weeds Liaison Group meeting	
06/02/12	Soil management workshop	Selwyn Richardson
10/02/12	Weed control in nursery stock	John Atwood
15/01/12	Networking workshop	Sue Tonks
28/02/12	Agriculture training workshop	Susan Twining/John Elliot
12/03/12	Biopesticides workshop	James Clarke
30/04/12	Health and safety workshop	
03/05/12	Profitable resource management workshop	
16/05/12	Field visit – organic blackcurrants	Lynn Tatnell
23-24/05/12	Effective Consultancy workshop	Chris Bowerman
30/05/12	Boxworth Open Day	
18/06/12	Bayer weed screen- Cambridgeshire	Bayer technical staff
12/07/12	Horticultural weeds seminar with Tim Miller (WSU)	John Atwood
18/07/12	HDC perennial herbaceous meeting	
19/07/12, 16-18/09/2012, 6-8/10/12, 27-29/11/12, 10-14/12/12	BASIS training	David Godsmack, Gerry Hayman
03/08/12	Maize workshop (including weed control)	Maize Growers Association
23/08/12	Field visits – blackcurrants and mixed PYO fruit	John Atwood

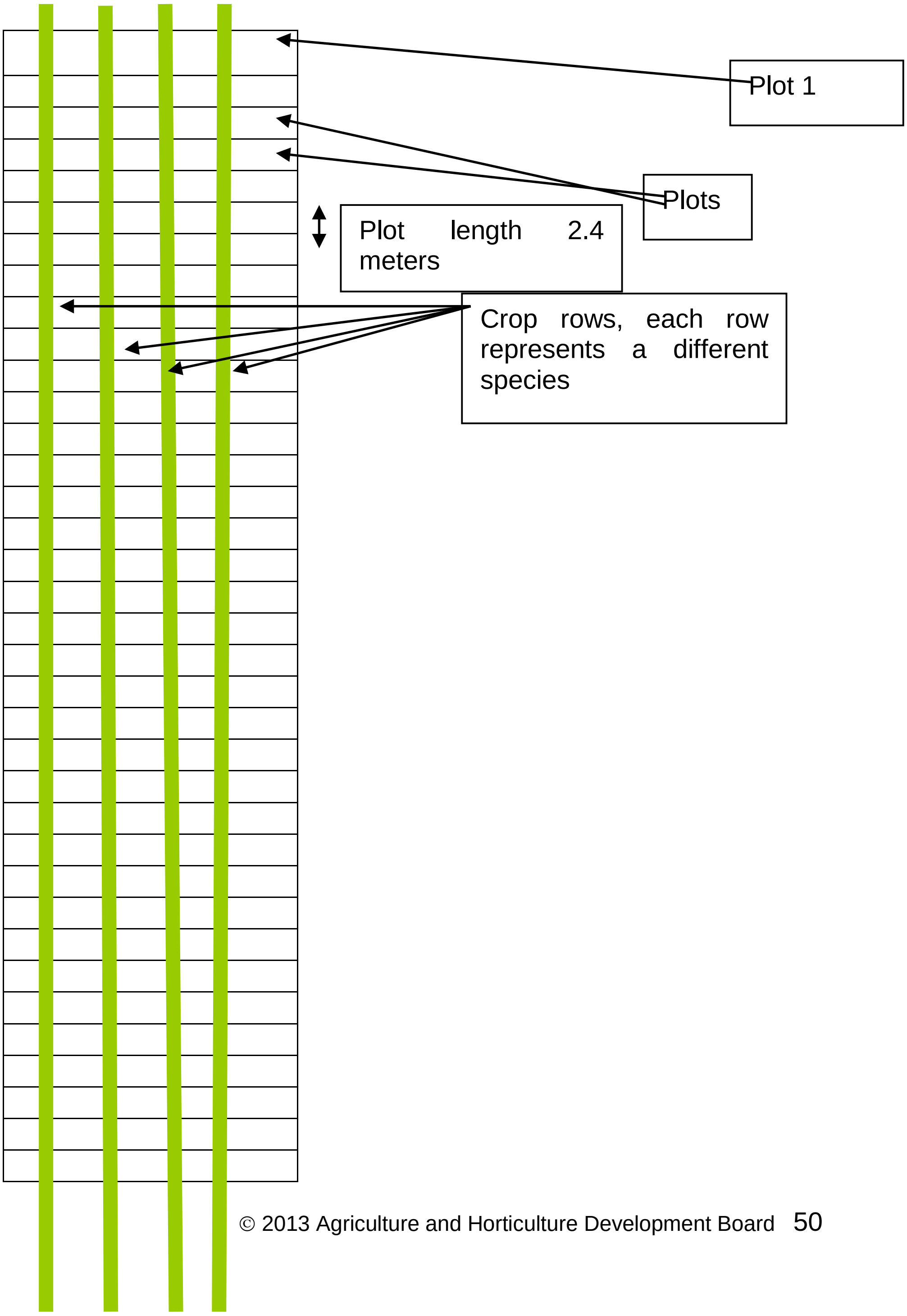
Date	Training activity	Trainer
04-05/09/12	Top fruit and HNS training	Chris Nicholson, John Atwood and David Talbot
08-10/10/12	Presentation skills training	Chris Bowerman
24/10/12	BCPC Weeds Review – annual meeting	Various speakers
30/10/12	Field vegetable visit – brassicas	
12/11/12	Visit to Vitacress, Andover to discuss weed control in salad leaf production	John Atwood
15/11/12	HDC *Narcissus* Technical Seminar	Various speakers including Cathy Knott re weed control
03/12/12	Crop protection seminar	Various speakers including CRD, DuPont and Bayer
05/12/12	Weed control in fruit	John Atwood
19/12/12	ORETO training	Sarah Cook
28/02/13	UK Weed Liaison Group annual meeting	Various speakers
14-15/03/13	Field vegetable visits	Mark Tinsley

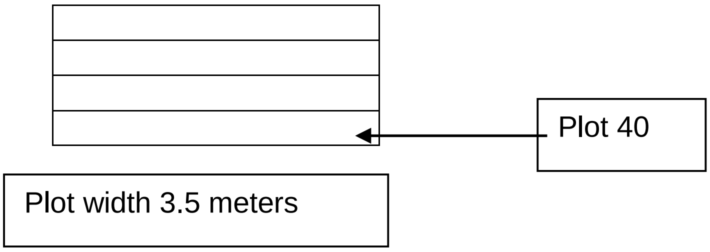
David Talbot - training log

Date	Training activity	Trainer
26/10/11	Seminar at ADAS Boxworth to discuss the topics covered at the European Weed Research Society Meeting in Huesca, Spain 4 – 8 September 2011.	Angela Huckle, John Atwood and Lynn Tatnell
17/11/11	Autumn weed identification course (broadleaf weeds and grass weeds), ADAS Boxworth.	Sarah Cook, Lynn Tatnell and Denise Ginsburg
10/02/12	Weed management meeting, ADAS Boxworth. Training on weed control in nursery stock.	John Atwood
11/12/12	Advisory visit, weed control in nursery stock	John Atwood
12/07/12	Horticultural weeds seminar with Tim Miller (WSU)	John Atwood
05/09/12	HNS weed control training visit Wyevale Container Plants Hereford and F. P. Matthews Tenbury Wells	John Atwood
05/12/12	Weed control in fruit	John Atwood

Date	Training activity	Trainer
19/12/12	ORETO training	Sarah Cook

Appendix 2. Plot layout field tree herbicide experiment – F.P. Matthews





RANDOMISATION

PLOT	TREATMENT
1	5
2	2
3	6
4	7
5	3
6	10
7	9
8	8
9	1
10	4
11	1
12	7
13	6
14	4
15	10
16	8
17	2
18	9
19	5
20	3
21	1
22	3
23	7
24	6
25	2
26	9
27	4
28	5
29	8
30	10
31	10
32	6
33	8
34	9
35	1
36	2
37	5

38	3
39	7
40	4

Appendix 3. Plot layout container plant herbicide experiment – Wyevale Containers Ltd.

(Large numbers represent the treatments and small numbers the plot numbers)

I	$_{1}$2	$_{2}$1	$_{3}$4	$_{4}$3	$_{5}$5
II	$_{6}$1	$_{7}$3	$_{8}$2	$_{9}$5	$_{10}$4
III	$_{11}$3	$_{12}$4	$_{13}$2	$_{14}$1	$_{15}$5
IV	$_{16}$3	$_{17}$2	$_{18}$4	$_{19}$5	$_{20}$1

