Project title	Evaluation of potential alternatives for weed control in asparagus following the loss of herbicides
Project number:	FV 372
Project leader:	Cathy Knott (Herbicide Specialist) 55 Church St. Werrington Peterborough PE4 6QU Email: cathy.knott@btinternet.com
Report:	Final report, 31 March 2011
Previous report:	None
Key staff:	Philip Langley, G's, Sandfields Farms Andrew Hanger, Elsoms Seeds Ltd Cathy Knott
Location of project:	1. Elsoms Seeds Trial Ground, Spalding, Lincs. 2. Salford Priors, Worcestershire
Project coordinator:	Philip Langley, G's, Sandfields Farms Ltd., Manor Farm, Luddington, Warwickshire CV 37 9SJ
Date project commenced:	01 April 2010
Date project completed:	31 March 2011
Key words:	Asparagus, herbicides, Callisto (mesotrione), Sumimax (flumioxazin), BUK 9900H, tank-mix Stomp Aqua (pendimethalin) + HDC H1 + Goltix 90 (metamitron), pre-spear-emergence, post-harvest, fern

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

AUTHENTICATION

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

Catharine Knott
Herbicide consultant
Independent

Signature ..... Date .....

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GROWER SUMMARY

Headline

New herbicide solutions exist for weed control in asparagus offering the potential for SOLAs in the following uses:

- Applied pre-emergence of spears:

  Callisto, Sumimax, BUK 9900H and Goltix 90 controlled groundsel. Black nightshade was controlled by Callisto and BUK 9900H.

- Applied post-harvest:

  Callisto performed well on a range of weeds and Sumimax was effective on black nightshade. However, where fern was present, Callisto caused severe damage and Sumimax was also damaging.

Background and expected deliverables

Weeds in asparagus crops reduce the yield and quality of spears and delay crop maturity. Nettles and thistles also deter pickers. Some herbicides can cause damage and also affect quality. Effective herbicides simazine, terbacil and diuron have been lost as a result of the Pesticide Review 91/414/EEC and can no longer be used (although diuron may eventually become available again). There may be further losses under the new Regulation EC 1107/2009 where registration criteria will be hazard-based. In addition, herbicide dose rates may be reduced at product re-registration stage which may reduce their efficacy. Crop protection companies cannot justify the cost of the development and approval process for herbicides for minor, high value crops such as asparagus. There are nine selective herbicides remaining for asparagus, all of which are SOLAs. None of these herbicides are, or are likely to be, authorised for use during the harvest period.

Asparagus is a perennial crop which is grown for up to 10 years. Frequent use of the limited range of herbicides has led to a build-up of weed species that may escape control, and problems also occur where weed seeds are exposed when pickers disturb the soil. A survey of growers by the Asparagus Growers Association in 2004 reported that thistles, nettles, field bindweed and fat-hen were frequently occurring weeds with black nightshade, groundsel and

cleavers being the most serious problems. Since then, SOLAs for clopyralid (for thistles), metamitron (for groundsel) and clomazone (cleavers and groundsel), may have reduced the problem. Metamitron is authorised for pre-emergence and post-harvest use on newly planted asparagus, but only post-harvest use on established crops,. Growers suggest that control of black-nightshade and groundsel is still difficult.

The objectives of this project were to:

- identify alternative herbicides with the potential for SOLA applications to replace those lost in the EC Review for weed control in asparagus.
- evaluate herbicides applied pre-emergence of spears or post-harvest in a screening trial and to identify effective herbicides that are free of phytotoxic effects.
- select the most promising candidates with the aim of obtaining residues data so that HDC can submit applications for SOLAs.

This could provide a wider range of herbicides so that a weed control strategy using different herbicides at different timings would prevent the build up of certain species, and avoid weed resistance.

Summary of the project and main conclusions

Herbicide screening trials in 2010 were as follows:

Site 1 in newly planted crowns (Spalding) on light silt soil;
Site 2 a 6-year established commercial crop (Salford Priors) on a sandy clay loam.

Herbicide Treatments *(applied in 200l/ha water volume)*

Site 1 newly planted crowns

Herbicide Product	*Active Ingredient*	*Dose product l/ha*
1. untreated	-	
Pre-emergence		
2. Callisto	mesotrione	1.5 L
3. Sumimax	flumioxazin	0.1 L
4. BUK 9900H	confidential	4.0 l
5. Stomp Aqua + Goltix 90 + HDCH1	pendimethalin + metamitron + confidential	3.3 l + 2.2 kg + 2.0 L
Post-harvest (fern and spears not removed)		
6. Callisto	mesotrione	1.5 L
7. Sumimax	flumioxazin	0.1 L
8. BUK 9900H	confidential	4.0 l
9. Stomp Aqua + Goltix 90 + HDCH1	pendimethalin + metamitron + confidential	3.3 l + 2.2 kg + 2.0 L
Full fern		
10. Goltix 90 +oil	metamitron + oil	2.2 kg + 0.2 L

Site 2 established 6-year crop

Herbicide Product	*Active Ingredient*	*Dose product l/ha*
1. untreated	-	
1a. Roundup Biactive	*glyphosate*	*4.0 L*
Pre-emergence		
2. Callisto	mesotrione	1.5 L
3. Sumimax	flumioxazin	0.1 L
4. BUK 9900H	confidential	4.0 l
5. Stomp Aqua + Goltix 90 + HDCH1	pendimethalin + metamitron + confidential	3.3 l + 2.2 kg + 2.0 L
11. Dual Gold	s-metolachlor	1.4 L
12. Goltix 90	metamitron	2.2 kg
13. Flexidor + Sencorex	isoxaben + metribuzin	1.75 l + 0.9 kg
14. HDC H1	confidential	2.0 L
Post-harvest most fern and spears removed		
6. Callisto	mesotrione	1.5 L
6a. Callisto + Roundup Biactive	mesotrione + glyphosate	1.5 l + 4.0 L
7. Sumimax	flumioxazin	0.1 L
7a. Sumimax + Roundup Biactive	flumioxazin+ glyphosate	0.1 L+ 4.0 L
8. BUK 9900H	confidential	4.0 l
8a. BUK 9900H + Roundup Biactive	confidential+ glyphosate	4.0 l + 4.0 L
9. Stomp Aqua + Goltix 90 + HDCH1	pendimethalin + metamitron + confidential	3.3 l + 2.2 kg + 2.0 L
9a. Stomp Aqua + Goltix 90 + HDCH1 + Roundup Biactive	pendimethalin + metamitron + confidential+ glyphosate	3.3 l + 2.2 kg + 2.0 L+ 4.0 L
Full fern		
10. Goltix 90 + oil	metamitron + oil	2.2 kg + 0.2 L

Crop safety

Herbicides pre-emergence of spears

All herbicides tested were safe to newly planted crowns of asparagus at Site 1 – no herbicide effect was observed on spear emergence or damage to emerged spears. Counts in mid-July (10 asparagus plants per plot) showed that numbers of new spears and live buds just below ground were not reduced by any of the herbicide treatments - numbers were related to herbicide efficacy and percentage (%) weed cover and demonstrated the detrimental effect of weeds on the crop. The highest numbers of buds were for tank-mix treatment 6, where plots remained virtually weed-free.

The herbicides were all safe to the 6-year established crop at Site 2.

Post-harvest herbicides

At Site 1, the safety of herbicides on spears and fern was evaluated to see whether removal would be necessary. Callisto 1.5 l/ha caused severe damage, bleaching of fern with several primary shoots dying. Only a very few buds (below soil level) survived. Sumimax was slower to act and was also too damaging to fern and reduced bud numbers.

The following treatments appear to be safe to spray when fern is present: BUK 9900H and the tank-mix Stomp Aqua + Goltix 90 + HDC H1 had very little effect on the asparagus fern although a slight kink in the stems of occasional asparagus stems developed, possibly caused by pendimethalin. Goltix 90 + oil had no effect on the asparagus fern.

At Site 2, post-harvest plots were split so that treatments were applied with or without Roundup Biactive 4.0 l/ha. In a commercial situation in a weedy crop, glyphosate would be added to a tank-mix of residual herbicide(s). The fern and most spears were cut back, but a small number, 2-6 cm high, remained when post-harvest treatments were applied. Remaining spears suffered slight temporary effects: bleaching from Callisto; stunting from Sumimax and slight distortion from BUK 9900. These effects soon grew out. If fern and most spears are removed it appears to be safe to use any of these herbicides, but **caution is advised particularly with Callisto on newly planted crops.** Treatment with Goltix + oil, applied later to fern, was also safe.

Weed control

Herbicides pre-emergence of spears

There were 11 weed species at Site 1, mainly *Chenopodium* spp., knotgrass, red dead-nettle, small nettle and a late flush of annual meadow-grass. All herbicides gave excellent control of fat-hen, fig-leaved goosefoot, red dead-nettle, small nettle, shepherds purse and chickweed. The knotgrass that escaped control with Callisto 1.5 l/ha and Sumimax 100 ml/ha over-ran plots and neither herbicide controlled a late flush of annual meadow-grass. BUK 9900H 4.0 l/ha was more effective on these weeds but did not control mustard. The best control was with the tank-mix Stomp Aqua + Goltix 90 + HDC H1. Seven weeks after application a few weeds began to emerge on treated plots, so even in the absence of soil disturbance during harvesting in this first year crop, herbicides may not persist until a post-harvest treatment can be applied.

At site 2 there were high populations of the target species black nightshade (260 plants/m^2) and groundsel (41 plants/m^2) in the established crop. Callisto 1.5 l/ha (treatment 2) and BUK 9900H 4.0 l/ha (treatment 4) performed best on these two weeds. Here control of groundsel was 100% with Callisto (mesotrione) 1.5 l/ha; 84% Sumimax 100ml; 92% BUK 9900H at 4.0 l/ha; and 89% with Goltix 90 2.2 kg/ha. Sumimax and Goltix pre-emergence were not effective on black nightshade. Efficacy of HDC H1 2 l/ha on both weeds was poor. The components of the tank-mix (treatment 5): Goltix 90 2.2 kg was mainly responsible for the 89% control of groundsel; Stomp Aqua 3.3 l/ha for 81% black nightshade control. Dual Gold 1.4 l/ha (treatment 11) and the tank-mix of Flexidor (1.75 l/ha) + Sencorex (0.9 kg/ha) (treatment 13) were effective on black nightshade in this trial, but inadequate on groundsel. The poor control of groundsel supports observations that groundsel may have become resistant to Sencorex (metribuzin) at this site and currently there is no other active that is effective on groundsel approved for use pre-spear-emergence in an established crop. All treatments gave excellent control of populations of fat-hen (46 plants/m^2) with the exception of Dual Gold, which was inadequate.

Post-harvest herbicides

At Site 1, no herbicides were applied pre-emergence to these plots and weeds were very large at the post-harvest timing. Callisto 1.5 l/ha was the most effective treatment leaving only 10% of the plot covered by weeds - a reduction from the total cover of 86% before

treatment. Most species were killed: fat-hen, small nettle, red dead-nettle, shepherd's purse, groundsel, and chickweed. Knotgrass, annual meadow-grass and speedwells were less well controlled. The weeds were too large for control with Sumimax – although it caused severe damage to fat-hen, this re-grew. Sumimax had little effect on knotgrass (present in low numbers) or annual meadow-grass. The tank-mix Stomp Aqua (3.3 l/ha) + Goltix 90 (2.2 kg/ha) + HDC H1 2.0 l/ha) gave good weed control and caused scorch and stunting of fat-hen and fig-leaved goosefoot, but their stems remained green and plants did not die. Red dead-nettle, small nettle, chickweed and shepherd's purse suffered severe scorch and died as did the low numbers of annual meadow-grass. BUK 9900H had little contact activity and control of emerged weeds was poor. Weeds were too advanced for control with Goltix 2.2 kg/ha + oil.

At Site 2, a pre-emergence herbicide was applied overall to these plots. However, before post-harvest experimental treatments were applied, groundsel plants were 15-25 cm tall, with flower buds, black nightshade at 2-5 true leaf stage. Roundup Biactive alone and in tank-mixes (6a - 9a), controlled the large groundsel and black nightshade that were present at the time of application. Herbicides Callisto and Sumimax had good contact as well as residual activity; the quickest effect was with Callisto on groundsel, but with Sumimax on black nightshade. Control of black nightshade was excellent 42 days after treatment with Callisto or Sumimax, good for BUK 9900 and just acceptable for the tank-mix treatment 9.

New Herbicides: Current Approval Status (December 2010)

Herbicide	*Product and formulation*	*Company*	*Dose product/ha*	*Authorised UK or other Status*
mesotrione	Callisto 100 g/l SC	Syngenta	1.5 l	Annex 1, maize UK, linseed (asparagus in USA)
flumioxazin	Sumimax etc. 300 g/l SC	InterFarm	0.1 l	Annex 1, wheat UK; SOLA UK onions, peas, carrots (asparagus in USA)
Confidential	BUK 9900H	confidential	4.0 l	No UK authorization yet for any crop. (residues data for asparagus in Germany)
pendimethalin	Stomp Aqua 455g/l CS	BASF	2.9 l	SOLA UK asparagus Stomp Aqua and others pre-spear-emergence and post-harvest.
metamitron	Goltix 90 WG 90% w/w	Makhteshim	2.2 kg	SOLA Goltix 12 wks after planting asparagus
s-metolachlor	Dual Gold 960 g/l SC	Syngenta	1.4 l	Annex 1, maize UK
isoxaben	Flexidor 125 125 g/l SC	Landseer	1.75 l	Voluntarily withdrawn use until 31 Dec 2012, SOLA UK asparagus
metribuzin	Sencorex WG 70% w/w WG	Bayer CropScience	0.9 kg	SOLA UK asparagus
confidential	HDC H1	confidential	2.0 l	HDC H1 no EU authorization yet
glyphosate	Roundup Biactive 360g/l SL	Monsanto	4.0 l	Approved UK pre-emergence of spears and post-harvest

Financial benefits

Without suitable herbicides, asparagus production costs could be prohibitive. Safe and effective alternatives to herbicides lost as a result of the EC Review have been found and these can benefit the industry in the following ways:

- Labour savings, and the high cost of hand-weeding would be avoided.
- New actives could provide growers with alternatives for weed control.
- A wider range of herbicides for this perennial crop will enable a weed control strategy using different herbicides at different timings and years to avoid build-up of certain species and also avoid herbicide resistance.

Residues data and SOLAs will need to be sought and this may involve additional costs, although it may be possible to obtain residues data for asparagus from other countries.

Action points for growers

Asparagus is a perennial crop which is grown for up to 10 years. Frequent use of a limited range of herbicides has led to a build-up of weed species that may escape control. Weed seeds are also exposed where pickers disturb soil. A wider range of herbicides will enable a weed control strategy using different herbicides at different timings and this could avoid build up of certain weed species. Groundsel may have already developed resistance to products containing metribuzin as a result of repeated use - currently, no other active is approved for groundsel control pre-spear-emergence in an established crop. In glasshouse tests on groundsel samples collected from four commercial crops, Stephen Moss of Rothamsted Research has recently confirmed very high resistance to simazine (included as a standard) and partial resistance of groundsel to both metribuzin and metamitron, with many plants damaged but surviving field rates of both herbicides. In contrast, all plants of a susceptible standard were killed by all four rates used (0.5, 1, 2, 4 x field rate). He says this pattern is consistent with classic triazine resistance, which usually confers partial cross-resistance to triazinone herbicides.

There are herbicides that appear to be safe when applied to asparagus crops:

- Applied pre-emergence of spears:

  Groundsel controlled by Callisto, Sumimax, BUK 9900H and Goltix 90. Black nightshade controlled by Callisto and BUK 9900H.

- Applied post-harvest:

  Callisto performed well on a range of weeds and Sumimax was effective on black nightshade. Where fern was present Callisto caused severe damage and Sumimax was also damaging.

These herbicides are not available for asparagus yet because residues data for SOLAs will be required. Products containing mesotrione and flumioxazin are authorised for use pre-spear-emergence and post-harvest in asparagus in the USA. There are also residues data for BUK 9900H from the EU, a foliar-acting herbicide would be needed in tank-mix (and fern removed) for post-harvest use. BUK 9900H has no UK registration yet for any crop (December 2010). A SOLA for Goltix applied pre-spear-emergence for groundsel control could also be helpful. HDC has applied for a SOLA for Callisto, but **caution is advised particularly with Callisto on newly planted crops.**

Label and weed susceptibility trials information from other countries is available in appendix 2 of the full report but growers are advised to treat this information with caution. Growers can get a copy of the full report by contacting the HDC: hdc@hdc.ahdb.org.uk

SCIENCE SECTION

Introduction

Weeds in asparagus crops reduce yield and quality of spears and delay maturity. Nettles and thistles also deter pickers. Some herbicides can cause damage and also affect quality. Effective herbicides simazine, terbacil and diuron have been lost as a result of the Pesticide Review 91/414/EEC and can no longer be used (although diuron may eventually become available again). There may be further losses under the new Regulation EC 1107/2009 where registration criteria will be hazard-based. In addition, herbicide dose rates may be reduced at product re-registration stage and this will reduce efficacy. Crop protection companies cannot justify the cost of the development and approval process for herbicides for minor, high value crops such as asparagus. There are nine selective herbicides remaining for asparagus, all of which are SOLAs. None of these herbicides are, or are likely to be, authorised for use during the harvest period.

Asparagus is a perennial crop which is grown for up to 10 years. Frequent use of the limited range of herbicides has led to a build-up of weed species that may escape control, and problems also occur where weed seeds are exposed when pickers disturb soil. A survey of growers by the Asparagus Growers Association in 2004 reported that thistles, nettles, field bindweed and fat-hen were frequently occurring weeds and black nightshade, groundsel and cleavers were the most serious problems. Since then, SOLAs for clopyralid (for thistles), metamitron (for groundsel) and clomazone (cleavers and groundsel), may have reduced the problem. Metamitron is authorised for pre-emergence and post-harvest use on newly planted asparagus, but only post-harvest use on established crops,. Growers suggest that control of black-nightshade and groundsel is still difficult.

The aims of this project are:

- To identify alternative herbicides with potential for SOLAs to replace those lost in the EC Review for weed control in asparagus.
- To evaluate herbicides applied pre-emergence of spears or post-harvest in a screening trial and to identify effective herbicides free of phytotoxic effects.
- To select the most promising candidates with the aim of obtaining residues data so that HDC can submit applications for SOLAs.

This could provide a wider range of herbicides so that a weed control strategy using different herbicides at different timings could prevent build up of certain weed species and avoid resistance problems. Herbicide screening trials in asparagus were therefore conducted to establish potential treatments for weed control and crop safety. Trials in asparagus, cv. Gijnlim, were conducted at two sites for one year. Target weeds were: groundsel, Polygonums, fat-hen and small nettle at Site 1; groundsel and black nightshade at Site 2.

Candidate herbicide treatments were selected on the basis of known effectiveness and safety in other crops, information from other EU Member States and the USA. Callisto (mesotrione) and Sumimax (flumioxazin) are available to US asparagus growers and residues data is available for BUK 9900H constituents. Only herbicides with a future were selected and we are hoping that pendimethalin and flumioxazin will survive the hazard criteria in the new regulation EC 1107/2009.

Materials and methods

Herbicides: Current Approval Status (December 2010)

Herbicide	*Product and formulation*	*Company*	*Dose product/ha*	*Authorised UK or other Status*
mesotrione	Callisto 100 g/l SC	Syngenta	1.5 l	Annex 1, maize UK, linseed (asparagus in USA)
flumioxazin	Sumimax etc. 300 g/l SC	InterFarm	0.1 l	Annex 1, wheat UK; SOLA UK onions, peas, carrots (asparagus in USA)
Confidential	BUK 9900H	confidential	4.0 l	No UK authorization yet for any crop. (residues data for asparagus in Germany)
pendimethalin	Stomp Aqua 455g/l CS	BASF	2.9 l	SOLA UK asparagus Stomp Aqua and others pre-spear-emergence and post-harvest.
metamitron	Goltix 90 WG 90% w/w	Makhteshim	2.2 kg	SOLA Goltix 12 wks after planting asparagus
s-metolachlor	Dual Gold 960 g/l SC	Syngenta	1.4 l	Annex 1, maize UK
isoxaben	Flexidor 125 125 g/l SC	Landseer	1.75 l	Voluntarily withdrawn use until 31 Dec 2012, SOLA UK asparagus
metribuzin	Sencorex WG 70% w/w WG	Bayer CropScience	0.9 kg	SOLA UK asparagus
confidential	HDC H1	confidential	2.0 l	HDCH1 no EU authorization yet
glyphosate	Roundup Biactive 360g/l SL	Monsanto	4.0 l	Approved UK pre-emergence of spears and post-harvest

Asparagus, cv. Gijnlim, was grown according to normal commercial practice. Overhead irrigation was applied after residual herbicides were sprayed at Site 1 so that crop damage could be assessed.

Trials Design

There were three replicates of each treatment and an untreated plot.
At Site 1 each plot was 4 m long x 2 m wide bed with 2 rows per plot. Asparagus crowns were planted by hand 30cm apart within the row, covered and the bed was rolled with a light Cambridge roll. At Site 2 plots were 6 m long, 1.5 m wide and asparagus was grown in ridges with 1 ridge per plot.

Trial site, soil type, planting date

Site 1 was on a silt loam soil (light soil ADAS classification) at Elsoms seeds trial ground near Spalding, South Lincolnshire. Asparagus crowns were planted 16 April 2010. Site 2 was in an established commercial asparagus crop in its sixth year for G's, on field Hughes 21, near Salford Priors, Warwickshire on a sandy clay loam soil.

Herbicide Treatments (+ = tank-mix)

At **Site 1,** single herbicide treatments pre-emergence or post-harvest.

Herbicide Product	*Active Ingredient*	*Dose product/ha*
1. untreated	-	
Pre-emergence		
2. Callisto	mesotrione	1.5 l
3. Sumimax	flumioxazin	0.1 l
4. BUK 9900H	confidential	4.0 l
5. Stomp Aqua + Goltix 90 + HDC H1	pendimethalin + metamitron + confidential	3.3 l + 2.2 kg + 2.0 l
Post-harvest (spears and fern not removed)		
6. Callisto	mesotrione	1.5 l
7. Sumimax	flumioxazin	0.1 l
8. BUK 9900H	confidential	4.0 l
9. Stomp Aqua + Goltix 90 + HDCH1	pendimethalin + metamitron + confidential	3.3 l + 2.2 kg + 2.0 l
Full fern (not removed)		
10. Goltix 90 + Activator oil	metamitron + oil	2.2 kg + 0.2 l

At site 1 in the first year of planting, the crop was not harvested and the fern was not removed before application of treatments 6-9 to see the effect of herbicides on the fern and developing buds below the soil surface. A safe treatment might mean that removal of fern was unnecessary unless glyphosate was added.

At **Site 2** a pre-emergence herbicide Flexidor + Sencorex (1.75 l + 0.9 kg)/ha was applied overall before post-harvest treatments.

Herbicide Product	*Active Ingredient*	*Dose product l/ha*
1. untreated	-	
1a. Roundup Biactive	*glyphosate*	*4.0 l*
Pre-emergence		
2. Callisto	mesotrione	1.5 l
3. Sumimax	flumioxazin	0.1 l
4. BUK 9900H	confidential	4.0 l
5. Stomp Aqua + Goltix 90 + HDC H1	pendimethalin + metamitron + confidential	3.3 l + 2.2 kg + 2.0 l
11. Dual Gold	s-metolachlor	1.4 l
12. Goltix 90	metamitron	2.2 kg
13. Flexidor + Sencorex	isoxaben + metribuzin	1.75 l + 0.9 kg
14. HDC H1	confidential	2.0 l
Post-harvest (spears and fern removed)		
6. Callisto	mesotrione	1.5 l
6a. Callisto + Roundup Biactive	mesotrione + glyphosate	1.5 l + 4.0 l
7. Sumimax	flumioxazin	0.1 l
7a. Sumimax + Roundup Biactive	flumioxazin+ glyphosate	0.1l + 4.0 l
8. BUK 9900H	confidential	4.0 l
8a. BUK 9900H + Roundup Biactive	confidential+ glyphosate	4.0 l + 4.0 l
9. Stomp Aqua + Goltix 90 + HDC H1	pendimethalin + metamitron + confidential	3.3 l + 2.2 kg + 2.0 l
9a. Stomp Aqua + Goltix 90 + HDC H1 + Roundup Biactive	pendimethalin + metamitron + confidential+ glyphosate	3.3 l + 2.2 kg + 2.0 l+ 4.0 l
Full fern (not removed)		
10. Goltix 90 + oil	metamitron + oil	2.2 kg + 0.2 l

At site 2 additional treatments 11 - 14 were applied pre-emergence of spears.

In the established crop in its 6th year the fern and remaining spears were removed before application of post-harvest herbicides 6-9. At site 2 post-harvest plots were split so that treatments 6 - 9 were applied without glyphosate, for 6a – 9a glyphosate as Roundup Biactive 4.0 l/ha were added. The untreated plot was also split and Roundup Biactive 4.0

l/ha was also applied as treatment 1a at post-harvest stage. In a commercial situation in a weedy crop, glyphosate would be added to a tank-mix of residual herbicide(s).

Treatment 10 was applied when full fern had developed.

Records/Assessments

Appendix 1 shows Common and Latin weed names.
The following records and assessments were undertaken following application of the various experimental treatments.

- Crop and weed growth stage were recorded at the times of application and crop assessment
- Crop emergence (pre-emergence herbicides only)
- Weather data at, and following, application
- Weed counts for species/m^2 present on untreated control plots and species remaining on herbicide treated plots
- Weed control scores (0 no control – 10 no weeds) and % weed cover /plot.
- Crop damage (phytoxicity) scores (0=complete kill, 7=acceptable damage, 10=no damage) at appropriate intervals after applications.

Crop score	*% Phytotoxicity*
0	Complete kill
1	80 – 95% damage
2	70 – 80% damage
3	60 – 70% damage
4	50 – 60% damage
5	40 – 50% damage
6	25 – 40% damage
7	20 – 25% damage (considered unlikely to cause loss in yield or quality at harvest)
8	10 – 20% damage
9	5 – 10% damage
10	No damage (as untreated controls)

- Observations on any phytotoxicity symptoms and effects such as delayed emergence, distortion of spears etc. recorded.
- Number of live buds/plant fern stage (Site 1).

Application Details

Treatments were applied: at Site 1 using an Azo precision plot sprayer with a 2 m boom, delivering 200 l/ha water volume through four Lurmark flat fan nozzles 02F110 at 1.9 bar pressure; at Site 2 using an Azo compressed air, precision plot sprayer with a 2 m boom delivering 200 l/ha water volume through four 02 bubble jet nozzles at 3 bar pressure. At site 2, Flexidor + Sencorex (1.75 l + 0.9 kg)/ha was applied pre-emergence on 7 April overall to post-harvest plots 6-10.

Date applied	***Weather***	***Weeds Growth Stages***
Site 1. Spalding planted 16 April 2010		
18 April pre-spear-emergence Treatments 2 – 5	15ºC; RH 31%; sunny cloud cover 0%; soil surface dry fine seedbed, moisture below; no rain after application; irrigation 21 April 13mm	none
12 June post-harvest most fern expanded some flowering Treatments 6, 7, 8, 9	19ºC; RH 48%; cloud cover 50%; soil surface dry, wet below; fern dry; no rain after application.	fat-hen, fig-leaved goosefoot, annual meadow-grass, knotgrass, red dead-nettle, shepherd's purse, mustard, small nettle, groundsel all very large plants; fat-hen ½ fern ht
17 June full fern 40-60cm tall, flowering, some flower drop Treatment 10	20ºC (22 ºC later); RH 47%; cloud cover 70% (0% later); soil surface dry, wet below; fern dry; no rain after application.	Weeds as above
Site 2. Salford Priors 6th year crop		
7 April pre-spear-emergence. Treatments 2 – 5	12ºC; soil surface capped, moist drying, wet below.	groundsel beginning to emerge, cotyledon
11 June post-harvest Treatments 1a, 6 – 9, 6a – 9a	18ºC; soil surface capped, moist drying, wet below. End of harvest 10 June crop cut back a few spears remained.	groundsel 15-25cm, buds; black nightshade 2-5 true leaves
15 July full fern Treatment 10	20ºC; soil surface capped, dry, moist below. Fern and weeds dry.	groundsel senescing; black nightshade 2 true leaf to 20cm tall

Results and Discussion

Crop Tolerance

Pre-emergence of spears - Site 1

Table 1. Site 1: Crop tolerance to pre-emergence herbicides.

Herbicide Product	*Dose product/ha*	*19/5 spears emerged*	*30/5 spears emerged*	*17/6 fern flower*	*25/6 flower drop*	*14/7 fern*
1. untreated	-	10	10	10	10	10
Pre-emergence 18 April						
2. Callisto	1.5 l	10	10	10	10	10
3. Sumimax	0.1 l	10	10	10	10	10
4. BUK 9900H	4.0 l	10	10	10	10	10
5. Stomp Aqua+Goltix +HDC H1	3.3 l + 2.2 kg + 2.0 l	10	10	10	10	10

Score (0 = plant death, 7 = acceptable damage, 10 = no damage/untreated); means of three replicates assessed at several dates and growth stages (of untreated crop).

Asparagus began to emerge on 5 May and full emergence had taken place by 19 May. Emergence was uneven on all plots including the untreated. The crop was irrigated after herbicides were applied. There was no damage at any growth stage from any pre-emergence herbicide (Table 1).

Post-harvest stage - Site 1

In order to evaluate tolerance of asparagus fern to herbicides, the fern was not removed before the application of post-harvest sprays.

Table 2. Site 1: Crop tolerance to post-harvest herbicides applied on 12 June to asparagus when most fern expanded and 17 June full fern

Herbicide Product	*Dose product l/ha*	*17/6 fern flower*	*21/6*	*25/6 flower drop*	*14/7*	*20/7*
Post-harvest 12 June (fern not removed)						
6. Callisto	1.5 l	9 bl tips	7 bl	3.3 bl 70%	1d	0
7. Sumimax	0.1 l	10	8 b tips	7 b sc 30%	5	5
8. BUK 9900H	4.0 l	10	10	9.3 k	10	10
9. Stomp Aqua + Goltix 90 + HDC H1	3.3 l + 2.2 kg + 2.0 l	10	10	9 k	10	10
Full fern (not removed) 17 June						
10. Goltix 90 +oil	2.2 kg + 2ml	-	10	10	10	10

Score (0 = plant death, 7 = acceptable damage, 10 = no damage/untreated); means of three replicates assessed at several dates and growth stages (of untreated crop).

bl bleaching; b brown; sc scorch; d main fern dead; k kink in stem

Bleaching of fern tips was observed within 5 days of application of Callisto (Table 2). Bleaching increased until 70% of the plant was affected by 25 June; growth above ground died. Sumimax (treatment 7) was slower to affect the fern and caused brown scorch on average 30% of the plant by 20 July. Rain probably increased the effect of Sumimax. BUK 9900H and the tank-mix Stomp Aqua + Goltix 90 + HDC H1 had very little effect on the asparagus fern although a slight kink on the stems of occasional asparagus plants developed, possibly caused by pendimethalin. However, similar effects were seen earlier on all plots – possibly an effect from wind.
Treatments 8 and 9 appear to be safe to spray at fern stage. Goltix 90 + oil also had no effect on asparagus fern.

Samples of 10 asparagus plants (one row) in their first year were taken from each plot and the number of new spears and live buds just below ground were counted. Table 3 shows that the numbers on plots treated with pre-emergence herbicides treatments 1-5 (all crop-safe) were related to efficacy and removal of weed competition, and % weed cover, and the lowest number was on untreated plots. The greatest number of spears and new buds were for plots treated with tank-mix Stomp Aqua + Goltix 90 + HDC H1, where plots were almost weed-free, and BUK 9900H which also performed well. Asparagus on plots treated with Callisto were overwhelmed with knotgrass and/or covered with annual meadow-grass later, and numbers of new buds were low.

Table 3. Site 1 the mean number of live new spears and buds/10 plants on 19 July, 37 days after treatment with post-harvest treatments; % weed cover on 9 June (means of 3 replicates).

Herbicide Product	*Dose product l/ha*	*No live buds/ 10 plants*	*% weed cover*
1. untreated	-	12	83
Pre-emergence 18 April			
2. Callisto	1.5 l	17	25
3. Sumimax	0.1 l	20	9
4. BUK 9900H	4.0 l	24.3	11
5. Stomp Aqua + Goltix 90 + HDC H1	3.3 l + 2.2 kg + 2.0 l	27.3	3
Post-harvest 12 June			
6. Callisto	1.5 l	1.33#	86
7. Sumimax	0.1 l	2.7##	95
8. BUK 9900H	4.0 l	11.7	96
9. Stomp Aqua + Goltix 90 + HDC H1	3.3 l + 2.2 kg + 2.0 l	11.33	93
Full fern 17 June			
10. Goltix 90 + Activator oil	2.2 kg + 2ml	11.7	83

#All 10 primary stems dead; ## all 10 primary stems damaged

Plots treated (6-9, 10) at post-harvest stage had suffered severe weed competition until 12 June and % weed cover was similar to the untreated plots. Treatments 8, 9 and 10 had little effect on the large weeds (Table 10) and were safe to the fern (Table 2) thus the numbers of spears and new buds were similar to the untreated. Callisto (treatment 6) was very effective on the large weeds (Table 5), but caused severe bleaching damage to the fern on the primary stem, which died. Buds below soil surface also died leaving only a mean 1.33 new live buds per 10 plants sampled. Sumimax (treatment 7) was slower to affect asparagus, but fern became brown and some primary stems had died at the time of sampling and there were only a mean of 2.7 new buds per 10 plants.

Pre-emergence of spears - Site 2

Table 4. Site 2: Crop tolerance to pre-emergence herbicides

Herbicide Product	*Dose product l/ha*	*16/4*	*22/4*	*28/4*	*21/5*
1. untreated		10	10	10	10
Pre-emergence 7 April					
2. Callisto	1.5 l	10	10	10	10
3. Sumimax	0.1 l	10	10	10	10
4. BUK 9900H	4.0 l	10	10	10	10
5. Stomp Aqua + Goltix 90 + HDC H1	3.3 l + 2.2 kg + 2.0 l	10	10	10	10
11. Dual Gold	1.4 l	10	10	10	10
12. Goltix 90	2.2 kg	10	10	10	10
13. Flexidor + Sencorex	1.75 l + 0.9 kg	10	10	10	10
14. HDC H1	2.0 l	10	10	10	10

Score (0 = plant death, 7 = acceptable damage, 10 = no damage/untreated); means of three replicates.

As at Site 1, assessments on several dates showed no effect on spear emergence and no crop damage at any stage (Table 4).

Post-harvest Stage- Site 2

At site 2 post-harvest plots were split so that treatments 6-9 were applied without glyphosate, for 6a–9a glyphosate as Roundup Biactive 4.0 l/ha were added. The untreated plot was also split and Roundup Biactive 4.0 l/ha was also applied at post-harvest stage as treatment 1a. At Site 2 the fern and spears were removed before application of post-harvest herbicides 6-9. Although most spears were cut back, a small number, 2-6 cm high, remained. On 18 June damage to the remaining spears was assessed (Table 5): there were negligible effects from 1a Roundup Biactive alone; Callisto (treatment 6) caused bleaching and distortion; Sumimax (treatment 7) caused some stunting and some spear distortion was observed from BUK9900H (treatment 8). There was no damage from the Stomp Aqua + HDC H1 + Goltix tank-mix (treatment 9). Any effects had grown out by 23 July assessment but fern growth was variable which made it difficult to assess any small differences if present.

Table 5. Site 2 most spears cut back, a small number remained when post-harvest treatments were applied.

Herbicide Product	*Dose product l/ha*	*18/6 Crop 10-40cm*	*23/7 Fern*
1. untreated		10	10
1a. R Biactive	4.0 l	9.7	10
Post-harvest 11 June			
6. Callisto	1.5 l	6 bl dis	10
6a. Callisto + R Biactive	1.5 l + 4.0 l	6 bl dis	10
7. Sumimax	0.1 l	7 st	10
7a. Sumimax + R Biactive	0.1 l+ 4.0 l	7 st	10
8. BUK 9900H	4.0 l	9 dis	10
8a. BUK 9900H + R Biactive	4.0 l + 4.0 l	8 dis	10
9. Stomp Aqua + Goltix 90 + HDCH1	3.3 l + 2.2 kg + 2.0 l	10	10
9a. Stomp Aqua + Goltix 90 + HDCH1 + R Biactive	3.3 l + 2.2 kg + 2.0 l+ 4.0 l	9	10

Crop tolerance of remaining asparagus spears: crop damage score (0 = plant death, 7 = acceptable damage, 10 = no damage/untreated) mean of three replicates assessed on 18 June and 23 July; growth stage of untreated crop

bl bleaching; dis distortion; st stunting

Table 6. Site 2: Crop tolerance to herbicides applied to asparagus at fern stage

Herbicide Product	*Dose product l/ha*	*14/8 Full Fern stage*
1. untreated		10
Full fern 15 July		
10. Goltix 90 + oil	2.2 kg + 2 ml	10

Crop damage score (0 = plant death, 7 = acceptable damage, 10 = no damage/ untreated) mean of three replicates assessed on 14 August; growth stage of untreated crop

Table 6 shows that Goltix + oil applied in asparagus at fern stage appeared very safe but fern growth was uneven and it was difficult to assess any small differences.

Weed Control

Pre-emergence of spears - Site 1

The weed species were unevenly distributed at Site 1, with high populations of knotgrass and *Chenopodium* spp. in replicate 1 and red dead-nettle in replicate 3 of untreated plots. There was a patch of cultivated mustard that escaped control on plots treated with BUK 9900H in replicate 1.

Table 7. Site 1, pre-emergence herbicides

Herbicide	*Dose product /ha*	*Fig-leaved goosefoot*	*Fat-hen*	*Knotgrass*	*Mustard*	*Annual meadow-grass*	*Shepherds purse*	*Red dead-nettle*	*Small nettle*	*Chickweed*	*Groundsel*	*Ivy-leaved speedwell*	TOTAL
1. untreated	-	25	10	35#	1	5	4	49	10	3	0	7	149
		25	*10*	*40#*	*1*	*38*	*4*	*49*	*10*	*3*	*1*	*9*	*190*
Pre-emergence 18 April													
2. Callisto	1.5 l	0	0	5#	0	0	0	0	0	0	0	0	5
		0	*0*	*10#*	*0*	*107*	*0*	*0*	*0*	*0*	*0*	*5*	*122*
3. Sumimax	0.1 l	0	0	3	0	0	0	0	0	0	0	0.7	4
		0	*0*	*4*	*0*	*30*	*0.3*	*0*	*0*	*0*	*0*	*3.7*	*38*
4. BUK 9900H	4.0 l	0	0	0	4	0	0	0	0	0	0	0	4
		0	*0*	*0*	*6*	*5*	*0.7*	*0*	*0*	*0*	*3*	*0*	*15*
5. tank-mix	3.3 l+ 2.2 kg +2.0 l	0	0	0	0.6	0	0	0	0	0	0	0	1
		0	*1.3*	*0*	*5st*	*0*	*0*	*0*	*0*	*0*	*0*	*0.7*	*7st*

Numbers of weed species/m^2 (mean of 3 counts in 0.33m^2 quadrats for 3 replicates) and total on 19 May, 31 days after treatment (DAT) and 9 June, 52 DAT (in italics) fern flowering but before flower drop

 # mainly on replicate 1

Weed counts made 31 days after treatment (Table 7) showed that all pre-emergence herbicides were effective on high populations of red dead-nettle, fat-hen, fig-leaved goosefoot and chickweed. Some knotgrass escaped control with Callisto and Sumimax, and

BUK 9900H did not control the vigorous mustard cultivar. The tank-mix with Stomp Aqua + Goltix 90 + HDC H1 gave complete control of all species.

On 9 June, more than 7 weeks after application and near the end of the potential harvest period, late flushes of annual meadow-grass and speedwell were recorded on plots treated with Callisto, Sumimax and BUK 9900H. The late weed emergence was not a result of soil disturbance in the harvest operation because the spears were not harvested. After 7 weeks the herbicides had not persisted, with the exception of treatment 5, the Stomp Aqua + Goltix 90 + HDC H1 tank-mix, where mustard emerged late on one plot but were stunted.

Table 8. Site 1 pre-emergence herbicides applied 18 April

Herbicide Product	*Dose product /ha*	*14/5*	*19/5*	*9/6*	*25/6*	*15/7*
1. untreated		0	0	0	0	0
Pre-emergence 18 April						
2. Callisto	1.5 l	9	9.3	6	4	3
3. Sumimax	0.1 l	9.7	9.6	7	5.3	4.3
4. BUK 9900H	4.0 l	9	9.3	8	6	6
5. Stomp Aqua+Goltix+HDC H1	3.3 l + 2.2 kg + 2.0 l	10	10	8.7	8.3	8.3

Weed control scores (0 = no control, 7 = acceptable control, 10 = complete control); mean of 3 replicates assessed on several dates

Weed control (Table 8) was good for all treatments initially, up to 19 May, but the asparagus was uncompetitive and in replicate 1 the few knotgrass that escaped control with Callisto and Sumimax, and the mustard with BUK 9900H grew vigorously (scores 9 June), the late flush of annual meadow-grass on all Callisto and Sumimax plots resulted in poor weed control at later assessments (25 June). Weed control with the tank-mix (treatment 5) was excellent throughout with the exception of small stunted mustard that emerged late.

Table 9. Site 1 pre-emergence herbicides applied 18 April

Herbicide Product	*Dose product /ha*	*Fig-leaved goosefoot*	*Fat-hen*	*Knotgrass*	*Mustard*	*Annual meadow-grass*	*Shepherds purse*	*Red dead-nettle*	*Small nettle*	*Chickweed*	*Groundsel*	*Ivy-leaved speedwell*	*TOTAL*
1. untreated		12	25	7	0.3	1	5	19	11	1	0.3	1	83
													100
2. Callisto	1.5 l	0	0	20	0	4	0	0	0	0	0	1	25
		0	*0*	*33*	*0*	*41*	*0*	*0*	*0*	*0*	*0*	*2*	*76*
3. Sumimax	0.1 l	0	0	7	0	1.3	0	0	0	0	0	1	9
		0	*0*	*13*	*0*	*9*	*0.3*	*0*	*0*	*0*	*0*	*1*	*23*
4. BUK 9900H	4.0 l	0	0	0	10	0	0	0	0	0	1	0	11
		0	*0*	*0*	*27*	*0*	*0*	*0*	*0*	*0*	*3*	*0*	*30*
5. tank-mix	3.3 l+2.2 kg+2.0 l	0	0	0	3st	0	0	0	0	0	0.3	0	3.3
		0	*0*	*0*	*17*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*17*

Percentage plot cover for the main weed species and total on 9 June at asparagus fern stage and 25 June, in italics, (except for untreated on this date) mean of three replicates

st stunted

Table 9 shows percentage plot cover of the main weed species on 9 June, and 25 June. This was not recorded for untreated plots on 25 June when because by this time the tallest predominant species had covered the plots (total cover 100%) competing with the low-growing weeds. Knotgrass completely covered plots treated with Callisto on replicate 1, and annual meadow grass on the other two replicates. The most effective treatments were with the tank-mix and also BUK 9900H, where only the mustard cultivar covered the plots.

Post-harvest stage - Site 1

In practice in a commercial asparagus crop fern and any remaining spears would be removed post-harvest and glyphosate added to a residual herbicide but at Site 1 the safety of herbicides on fern was evaluated to see whether removal would be necessary, and efficacy without glyphosate was assessed.

No pre-emergence herbicides were applied to the plots and weeds were very large, with fat-hen at half the height of fern on 12 June. Percentage of the plot covered by each weed

species was assessed before application of herbicides at the post-harvest stage and on two occasions afterwards (Table 10). There was natural senescence of some species: shepherd's purse, groundsel, red dead-nettle from mid-July.

Callisto (treatment 6) achieved a slow kill of *Chenopodium* species. Some knotgrass remained and annual meadow-grass was bleached and scorched but did not die. This was the most effective treatment and most species were killed leaving only 10% plot covered by weeds - a reduction from the total cover of 86% before treatment.

The tank-mix Stomp Aqua + Goltix 90 + HDC H1 (treatment 9) initially caused scorch and stunting of fat-hen and fig-leaved goosefoot but the stems remained green and plants did not die. Red dead-nettle, small nettle, chickweed and shepherd's purse suffered severe scorch and died as did the low numbers of annual meadow-grass. Sumimax (treatment 7) is more effective in wet conditions and there was rain the following day; it initially caused severe damage to fat-hen and fig-leaved goosefoot but there was re-growth at the base of the main stem. Sumimax did not control knotgrass and annual meadow-grass. BUK 9900H (treatment 8) had little contact activity and control of emerged weeds was poor. Weeds were too advanced for control with Goltix 2.2 kg/ha + oil (treatment 10) applied on 17 June.

Table 10. Site 1 post-harvest stage herbicides

Herbicide Product	*Dose product /ha*	*Fig-leaved goosefoot*	*Fat-hen*	*Knotgrass*	*Mustard*	*Annual meadow-grass*	*Shepherds purse*	*Red dead-nettle*	*Small nettle*	*Chickweed*	*Groundsel*	*Ivy-leaved speedwell*	*TOTAl*
1. Untreated		*12*	*25*	*7*	*0.3*	*1*	*5*	*19*	*11*	*1*	*0.3*	*1*	*83*
													100
Post-harvest 12 June													
6. Callisto	1.5 l	*4*	*45*	*1*	*0.3*	*3*	*2.3*	*13.3*	*7.3*	*11.3*	*0*	*0.7*	*86*
		0.7	**15**	**1**	**0**	**2.3**	**0**	**0**	**0**	**0**	**0**	**0.7**	**20**
		0	0	5	0	4	0	0	0	0	0	1	10
7. Sumimax	0.1 l	*2*	*33*	*1*	*0*	*2*	*6*	*21.7*	*10*	*4.3*	*0*	*2.3*	*95*
		0.3	**20st**	**1**	**0**	**15**	**1.7**	**0**	**0**	**0**	**0**	**0**	**37**
		2	20	8	0	27	0	0	0	0	0	0	57
8. BUK 9900	4.0 l	*3.3*	*30.3*	*0*	*1.7*	*1*	*1.3*	*36.7*	*13.3*	*3.3*	*0.7*	*4*	*96*
		3.3	**30.3**	**0**	**1.7**	**1**	**5.7**	**36.7**	**13.3**	**3.3**	**0.7**	**4**	**100**
		3	30	0	1	1	5	35	10	3	0	4	90
9. tank-mix	3.3 l+2.2 kg +2.0 l	*11.7*	*38*	*0*	*0.3*	*0.7*	*3.3*	*21.7*	*11.7*	*3.7*	*0*	*2.3*	*93*
		5st	**24st**	**0**	**0**	**0**	**0**	**1.3**	**0**	**0**	**0.7**	**0**	**6.4**
		5st	20st	0	0	0.3	0	1.3	0	0	0.7	0	27
Full fern 17 June													
10. Goltix+oil	2.2 kg	*1.7*	*28.3*	*0*	*0*	*1.3*	*7*	*20.3*	*13.7*	*7*	*0.3*	*3*	*83*
		2	**30**	**0**	**0**	**1.3**	**8.7**	**20.3**	**13.7**	**7**	**0.3**	**3**	**88**
		2	30	0	0	1.3	8.7	20.3	13.7	7	0.3	3	88

Percentage weed plot cover for weed species on 9 June (before herbicide applications) (italics) and after, on 25 June (bold) and 15 July (red text) - means of 3 replicates

st stunted

Table 11. Site 1 post-harvest and fern stage herbicides

Herbicide Product	*Dose product /ha*	*25/6*	*15/7*
1. untreated		0	0
Post-harvest 12 June			
6. Callisto	1.5 l	6.3	8
7. Sumimax	0.1 l	4.3	4
8. BUK 9900H	4.0 l	0	0
9. Stomp Aqua + Goltix 90 + HDC H1	3.3 l + 2.2 kg + 2.0 l	6	6
Full fern 17 June			
10. Goltix 90 +oil	2.2 kg	0	0

Weed control scores (0 = no control, 7 = acceptable control, 10 = complete control) mean of 3 replicates on two dates.

Weed control scores are shown in Table 11. Callisto gave good control of some very large weeds and was the most effective post-harvest treatment. The tank-mix of Stomp Aqua + Goltix 90 + HDC H1 was also effective on some species. Overall weed control for Sumimax was unacceptable. BUK 9900H had little contact activity and Goltix + oil did not control the large weeds.

Pre-emergence of spears - Site 2

There were high populations of target species black nightshade (260 plants/ m^2) and groundsel (41 plants/ m^2) in the established crop (Table 12). Callisto 1.5 l/ha (treatment 2) and BUK 9900H 4.0 l/ha (treatment 4) provided the best control of these two weeds. Groundsel was susceptible to pre-emergence Sumimax 0.1 l/ha (treatment 3) and Goltix 90 2.2 kg/ha (treatment 12) but black nightshade was not. Efficacy of HDC H1 2 l/ha on both weeds was poor but the combination Stomp Aqua + Goltix 90 + HDC H1 (3.3 l + 2.2 kg + 2.0 l)/ha gave good control. Dual Gold 1.4 l/ha (treatment 11) and the tank-mix of Flexidor + Sencorex (1.75 l + 0.9 kg)/ha (treatment 13) were effective on black nightshade in this trial, but inadequate on groundsel. All treatments gave excellent control of populations of fat-hen (46 plants/ m^2) with the exception of Dual Gold, which was poor.

Table 12. Site 2, pre-emergence herbicides

Herbicide Product	*Dose product l/ha*	*Black nightshade*		*Fat-hen*		*Groundsel*	
		No./m^2	%	No./m^2	%	No./m^2	%
1. untreated	-	260		46		41	
Pre-emergence 11 April							
2. Callisto	1.5 l	9	97	0	100	0	100
3. Sumimax	0.1 l	128	51	7	86	7	84
4. BUK 9900H	4.0 l	2	99	0	100	3	92
5. Stomp Aqua + Goltix 90 + HDC H1	3.3 l + 2.2 kg + 2.0 l	50	81	2	95	4	89
11. Dual Gold	1.4 l	30	88	17	64	20	51
12. Goltix 90	2.2 kg	80	69	3	93	4	89
13. Flexidor + Sencorex	1.75 l + 0.9 kg	31	88	0	100	10	76
14. HDC H1	2.0 l	190	27	3	93	24	40

Numbers of main weed species/m^2 (mean of 3 counts in 0.1m^2 quadrat, 3 replicates); % control at early fern stage on 21 May, 44 days after treatment.

Table 13. Site 2, pre-emergence herbicides applied 11 April

Herbicide Product	*Dose product L/ha*	% weed control
1. untreated	-	0 (37)
Pre-emergence 11 April		
2. Callisto	1.5 L	90
3. Sumimax	0.1 L	57
4. BUK 9900H	4.0 L	92
5. Stomp Aqua + Goltix 90 + HDC H1	3.3 L + 2.2 Kg + 2.0 L	83
11. Dual Gold	1.4 L	67
12. Goltix 90	2.2 Kg	87
13. Flexidor + Sencorex	1.75 L + 0.9 Kg	72
14. HDC H1	2.0 L	60

Percentage control fat-hen and black nightshade (groundsel had senesced by this time) on 3 August, asparagus at full fern stage (mean of three replicates) total weed plot cover on untreated in brackets

Percentage weed control assessed for the pre-emergence treatments at Site 2 on 3 August (Table 14) reflected earlier assessments. As at site 1, the crop was not harvested and the soil was not disturbed but on some plots weeds were well controlled 16 weeks after application. Here Callisto and BUK9900H were the best treatments.

Post-harvest - Site 2

A pre-emergence treatment of Flexidor + Sencorex (1.75 l + 0.9 kg)/ha was applied overall, but prior to post-harvest applications the main weed species, groundsel were 15-25 cm tall, with flower buds and black nightshade was at 2-5 true leaf stage.
On the 18 June weed cover on untreated plots was 10% for groundsel and 3.3% for black nightshade (Table 13). At the second assessment on 23 July the groundsel had senesced naturally on untreated and treated plots, but the black nightshade growth stages were from 2 true leaves to large plants 30 cm tall.

Roundup Biactive alone (treatment 1a), and in tank-mixes (6a-9a), controlled the large groundsel and black nightshade that were present at the time of application.
Callisto, and Sumimax had good contact and residual activity: the quickest effect was delivered by Callisto on groundsel and by Sumimax on black nightshade. On 23 July, 42 days after treatment control of black nightshade was excellent for Callisto and Sumimax, good for BUK 9900H and just acceptable for the tank-mix treatment 9.

Table 14. Site 2, post-harvest herbicides

Herbicide Product	*Dose product l/ha*	*Groundsel*	*Black nightshade*	
		18/6	18/6	23/7
1. untreated		0 (10)	0 (3.3)	0 (4.3)
1a. Roundup Biactive	4.0 l	9.5	9.6	10
Post-harvest 11 June				
6. Callisto	1.5 l	4.7	6.3	10
6a. Callisto + Roundup Biactive	1.5 l + 4.0 l	9.7	9.9	10
7. Sumimax	0.1 l	3.7	10	9.8
7a. Sumimax + Roundup Biactive	0.1 l+ 4.0 l	9.7	10	9.7
8. BUK 9900H	4.0 l	1.7	2.7	9.6
8a. BUK 9900H + Roundup Biactive	4.0 l + 4.0 l	9.6	9.8	9.3
9. Stomp Aqua + Goltix 90 + HDC H1	3.3 l + 2.2 kg + 2.0 l	2.7	3.7	7.7
9a. Stomp Aqua + Goltix 90 + HDC H1 + Roundup Biactive	3.3 l + 2.2 kg + 2.0 l + 4.0 l	9.3	9.7	9.8

Weed control scores (0 = no control, 10 = no weed); mean of three replicates, on 18 June, (7 days after treatment (DAT)) for the main weed species groundsel and black nightshade on 18 June, black nightshade on 23 July (42 DAT). Percentage green weed ground cover on untreated plots shown in brackets.

The groundsel had begun to senesce when treatment 10 was applied, black nightshade was from 2 true leaf stage to large plant 20 cm tall and the weed (as at Site 1) was too large for control with Goltix 90 + oil (Table 15). On 14 August some black nightshade plants were large 10- 30cm tall.

Table 15 Site 2, fern stage herbicide

Herbicide Product	*Dose product l/ha*	*Black nightshade 14/8*
1. untreated		0 (5.7)
Post full fern 15 July		
10. Goltix 90 + oil	2.2 kg + 2 ml	0

Weed control scores (0 = no control, 7 = acceptable control, 10 = complete control); mean of 3 replicates, assessed on 14 August. Percentage green weed ground cover on untreated plots in brackets.

Conclusions

Appendix 2 gives some indications of weed susceptibility based on this project and other work but this data should be treated with caution.

Herbicides pre-emergence of spears

All herbicides tested were safe to newly planted crowns of asparagus at Site 1 – there was no effect on spear emergence or the number of new buds formed by mid-July. Counts for numbers of new spears and live buds just below ground (10 asparagus plants per plot) were related to herbicide efficacy and % weed cover competing with and shading the crop. All herbicides were also safe to the 6-year established crop at Site 2.

At Site 1 all herbicides gave excellent control of a wide range of weeds including *Chenopodium* spp. and nettle. Knotgrass escaped control with Callisto 1.5 l/ha and Sumimax 0.1 l/ha and neither herbicide controlled a late flush of annual meadow-grass. BUK 9900H 4.0 l/ha was more effective on these species. The best control at Site 1 was with the tank-mix Stomp Aqua + Goltix 90 + HDC H1. Seven weeks after application a few weeds began to emerge on treated plots, so even in the absence of soil disturbance during harvesting in this first year crop, herbicides may not persist until post-harvest treatments could be applied.

At Site 2 there were high populations of important target species black nightshade and groundsel in the established crop. Callisto 1.5 l/ha and BUK 9900H 4.0 l/ha performed best on these two weeds. Sumimax 0.1 l/ha and Goltix 90 2.2 kg/ha pre-emergence controlled groundsel but were not effective on black nightshade. Efficacy of HDC H1 2 l/ha did not control either. Dual Gold 1.4 L/ha (treatment 11) and the tank-mix of Flexidor + Sencorex (1.75 L + 0.9 Kg)/ha (treatment 13) were effective on black nightshade in this trial, but inadequate on groundsel. The poor control of groundsel supported observations that groundsel may have become resistant to Sencorex (metribuzin) at this site. All treatments gave excellent control of fat-hen with the exception of Dual Gold, which was poor.

Post-harvest herbicides

At Site 1, fern was not removed. Callisto 1.5 l/ha caused severe damage, bleaching of fern and several primary shoots died. Only a very few buds (below soil level) survived. Sumimax, whilst slower to act, was also excessively damaging to fern and reduced bud numbers. Removal of fern and spears will be vital before these are applied. The following had very little effect on the asparagus fern and appear to be safe to spray when fern is present: BUK 9900H, the tank-mix Stomp Aqua + Goltix 90 + HDC H1, and Goltix 90 + oil.

At Site 2, fern and most spears were cut back, but the small number of spears remaining suffered only slight temporary effects from Callisto and Sumimax. If fern and spears are removed it appears to be safe to use any of these herbicides. Goltix + oil, applied later, was safe to fern.

At Site 1 Callisto 1.5 l/ha was the most effective treatment leaving only 10% plot covered by weeds - a substantial reduction from the pre-treatment level of 86%. Knotgrass, annual meadow-grass and speedwells were less well controlled. Stomp Aqua + Goltix 90 + HDC H1 (3.3 l + 2.2 kg + 2.0 l)/ha left 27% of cover. Sumimax had little effect on knotgrass or annual meadow-grass. BUK 9900H and Goltix + oil had negligible effect on weeds.

At Site 2 post-harvest treated plots were split so that treatments were applied with or without Roundup Biactive 4.0 l/ha; untreated plots were also split. In a commercial situation in a weedy crop, glyphosate would be added to a tank-mix of residual herbicide(s). Roundup Biactive alone (1a) and in tank-mixes (6a - 9a), controlled the large groundsel and black nightshade that were present at the time of application.
Herbicides Callisto, and Sumimax had good contact as well as residual activity: the quickest effect was with Callisto on groundsel, and with Sumimax on black nightshade. Control of black nightshade was excellent 42 days after treatment for Callisto and Sumimax, good for BUK 9900H and just acceptable for the tank-mix.

A wider range of herbicides for a 10-year crop will enable a weed control strategy using different herbicides at different timings and through different annual programmes. This approach could avoid build up of certain weed species and avoid herbicide resistance. Groundsel may have already developed resistance to products containing metribuzin as a result of repeated use. Currently, no other active is approved for groundsel control pre-spear emergence in an established crop. In glasshouse tests on groundsel samples collected from four commercial crops, Stephen Moss, Rothamsted Research has recently confirmed very high resistance to simazine (included as a standard) and partial resistance of groundsel to both metribuzin and metamitron, with many plants damaged but surviving field rates of both herbicides. In contrast, all plants of a susceptible standard were killed by all four rates used (0.5, 1, 2, 4 x field rate). He says this pattern is consistent with classic triazine resistance, which usually confers partial cross-resistance to triazinone herbicides.

SOLAs

Products containing mesotrione and flumioxazin are authorised for use pre-spear emergence and post-harvest use in asparagus crops in the USA. For the latter timing fern

and spears would need to be removed and **caution is advisable particularly with Callisto on newly planted crops.** There are also residues data for BUK 9900H from the EU, and a foliar-acting herbicide would be needed in tank-mix (and fern removed) for post-harvest use. SOLAs for all these would be useful, particularly Callisto. An application for a SOLA for Callisto on asparagus has been made by HDC. A SOLA for Goltix applied pre-spear emergence for groundsel control could also be helpful.

Technology transfer

HDC open day at Elsoms Seeds Trial Ground 1 July 2010 - asparagus trial demonstrated by Phil Langley and Cathy Knott. Trial visited by Crop Protection Companies and agronomists on other occasions.

An article on FV 372 trial results has been submitted for HDC News.

Appendix 1

Latin name	Common name
Capsella bursa-pastoris	Shepherd's purse
Chenopodium album	Fat-hen
Chenopodium ficifolium	Fig-leaved goosefoot
Lamium purpurium	Red dead-nettle
Poa annua	Annual meadow-grass
Polygonum aviculare	Knotgrass
Senecio vulgaris	Groundsel
Solanum nigrum	Black nightshade
Stellaria media	Chickweed, common
Urtica urens	Small nettle
Veronica hederifolia	Ivy-leaved speedwell
-	Mustard cultivated

Appendix 2 (please treat with caution)

Annual Weed Susceptibility: herbicides asparagus pre-weed-emergence;

Key: S = susceptible; MS = Moderately Susceptible; R = Resistant; MR = Moderately Resistant; Rates product/ha not necessarily those approved for asparagus.

Herbicides in red not available for asparagus (Goltix and Centium not authorized at this timing can be used post-harvest, diuron product not re-registered for herbicide use at present)

	Stomp	Sencorex	Flexidor	Centium	Goltix	Callisto	Sumimax	HDC H1	BUK 9900H	Dual Gold	Diurex
	pendimethalin	metribuzin	isoxaben	clomazone	metamitron	mesotrione	flumioxazin			s-metolachlor	diuron
Common name	3.3 l	1.5 kg	2.0 l	0.2 l	2.0 kg	1.5 l	0.1 l	2.0 l	4.0 l	1.4 l	1.0 l
Amaranth, common							S	S		S	
Bindweed black	MS	MS		MR	MR	R		MS	S		MS
Bugloss		S									-
Charlock	R	S	S	R	MS	S	S	S			S
Chickweed, common	S	S	S	S	S	MS	S	S	S	MS	
Cleavers		R	MR	S	R	R		MR			MR
Corn marigold	S		S		S						-
Corn spurrey		S	S		S						S
Crane's-bill, cut-leaved											-
Deadnettle, henbit	S	S			MS						-
Dead-nettle, red	S	S	S	S	MS	S	S/MS	MS	S	S	MR
Dock, broad-leaved					S						R
Fat-hen	S	S	S	MS	S	S	S	S	S	MS	S
Fool's parsley	R			S	S			MR			S
Forget-me-not, field	S	S	S		S						-
Fumitory, common	MS	S	S	R	MS			MS			R
Gallant -soldier			S			S		S			S
Groundsel	R	S	MR	S	S	S	S	MS	S	S/ MR	MS
Hemp-nettle, common	S	S	S								-
Knotgrass	S	S	S	MR	S	MR	R	MS	S	R	MS
Mayweed, scented	MS	S	S	R	S	MS	S	S	S	S	S
Mayweed, scentless	MS	S	S	R	S	MS	S	S	S	S	S
Nettle, small	S	S	S	MR	S	S	S		S	S	S

Nightshade black	-	R	MS		MR	S	R	R	S	MS	MS
Orache, common	S	S	S		S						S
Pansy, field	S	S	S	R	S			MR			S
Parsley piert	S		S								-
Pennycress, field		S			S						S
Persicaria, pale		S		MS	MS	S			S	R	-
Pimpernel, scarlet	S	S	S		MR						S
Pineappleweed	MS	S	S	R	S			S		S	-
Poppy, common	S	S	S	R	S					S	S
Redshank		S	S	S	MS	MS	R	MS	S	R	-
Shepherd's-purse	MS	S	S	S	S		S	S	S	S	S
Sow-thistle, smooth	S	S		MS	-		S		S	S	MS
Speedwell, common, field	S	S	S		S		S	MR	S	S	R
Speedwell, ivy-leaved	S	S	S	S	MS	MR	MS	MR	S	S	R
Sun spurge		S			S	MS					-
Thistle, creeping				R	-	R					R
Wild radish		S	S		MR				R	R	S
Annual meadow grass	S	S	R	MS	S	R	MS/R	S	S	S	S
Black-grass		S	R		MR		MR	S			
Brome, barren					R						
Couch, common			R		R						
Wild-oat		R	R		R						
Vol OSR	MS	S	S	R					R		
Vol Potatoes		R									
Willowherb	-	-	MS		R						s

Appendix 2 (continued)

Annual Weed Susceptibility to herbicides (dose product/ha) for asparagus post-weed-emergence, post harvest, fern and spears removed;

*Key: S = susceptible; MS = Moderately Susceptible; R = Resistant; MR = Moderately Resistant; # cotyledon-4TL; ## weeds 1-3 leaves, add oil for fat-hen; ###early cot-1TL; * 1.0 l/ha kills large weeds. Callisto controls large weeds (e.g. at 0.75 l/ha controls fat-hen up to 12 TL, 20cm tall; black nightshade up to 10 TL, 15cm tall). Herbicides in red text unavailable for asparagus at present.*

		Goltix 90###	Lentagran#	Shield	Sencorex	Callisto	Callisto	Sumimax##
		metamitron	pyridate	clopyralid	metribuzin	mesotrione	mesotrione	flumioxazin
Common name	***Latin name***	2.0 kg	2.0 kg	0.5 l*	0.5 kg	0.75 l	1.5 l	0.1 l
Amaranth, common	*Amaranthus*					S	S	S
Bindweed black	*Fallopia convolvulus*	MR	S	MS	S		S	R
Bugloss	*Anchusa arvensis*				S		4-6L	
Charlock	*Sinapis arvensis*	MS	S		S	S	S	S
Chickweed, common	*Stellaria media*	S			S	S	S	S
Cleavers	*Galium aparine*	R	S		R		6-8whorl	MS
Corn marigold	*Chrysanthemum segetum*	S		S	MS		S	
Corn spurrey	*Spergula arvensis*	S			S			
Crane's-bill, cut-leaved	*Geranium dissectum*							
Deadnettle, henbit	*Lamium amplexicaule*	MS			S			
Dead-nettle, red	*Lamium purpureum*	MS	S		S		S	S/MS
Dock, broad-leaved	*Rumex obtusifolius*	S					MS	
Fat-hen	*Chenopodium album*	MS	S		S	S	S	
Fool's parsley	*Aethusa cynapium*	S					S	
Forget-me-not, field	*Myosotis arvensis*	S	S		S		S	
Fumitory, common	*Fumaria officinalis*	MS	S		S		S	
Gallant -soldier	*Galinsoga parviflora*							
Groundsel	*Senecio vulgaris*	MS		S	S		S	S
Hemp-nettle, common	*Galeopsis tetrahit*	S	S		S		S	
Knotgrass	*Polygonum aviculare*	MS			MS		S	R

Mayweed, scented	*Matricaria recutita*	S		S	S		S	S
Mayweed, scentless	*Tripleurospermum inodorum*	S		S	S		S	S
Nettle, small	*Urtica urens*	S	S		S		-	S
Nightshade black	*Solanum nigrum*	MR	S		R	S	S	S
Orache, common	*Atriplex patula*	S			S		S	
Pansy, field	*Viola arvensis*	MS			MS	S	S	S
Parsley piert	*Aphanes arvensis*							
Pennycress, field	*Thlaspi arvense*	S	S		S		S	
Persicaria, pale	*Persicaria lapathifolia*	MS	S	MR	S		S	R
Pimpernel, scarlet	*Anagalis arvensis*	MR			S		-	
Pineappleweed	*Matricaria discoidea*	S		S			S	S
Poppy, common	*Papaver rhoeas*	S					R	
Redshank	*Persicaria maculosa*	MS		MR	S	S	S	R
Shepherd's-purse	*Capsella bursa-pastoris*	S	S		S		S	
Sow-thistle, smooth	*Sonchus oleraceus*			S	MS		-	
Speedwell, common, field	*Veronica persica*	S			S		MS	S
Speedwell, ivy-leaved	*Veronica hederifolia*	MS			S		MS	S
Sun spurge	*Euphorbia helioscopia*	S						
Thistle, creeping	*Cirsium arvense*	S seedling		S				
Wild radish	*Raphanus raphanistrum*	MS			S		S	
Annual meadow grass	*Poa annua*	MS			S		MR	MS/R
Black-grass	*Alopecurus myosuroides*	R			MS		R	MR
Brome, barren	*Anisantha sterilis*	R						
Couch, common	*Eltrigia repens*	R			S			
Wild-oat	*Avena fatua*	R			S			
Vol OSR	*Brassica napus*	MS		R	S	S	S	S
Vol Potatoes	***Solanum tuberosum***			MS	S			suppression

