

Project title: Solutions to the loss of active ingredients for weed control in vegetable crops (Continuation)

Project number: FV 256c

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Report: Final report, September 2010

Previous reports: Final reports FV 256 2004, 2005, 2006; FV 256a 2007; FV 256b 2008

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Location of project: Elsoms Trial Ground, Spalding, Lincs.

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Date project commenced: 01 February 2010

Date completion due: 30 September 2010

Key words: Drilled: bulb Onion, Leek, Carrot, Parsnip, Coriander, Mizuna, Swede, Vining peas, Baby-leaf spinach, Dwarf French beans; Transplants: Celery, Cauliflower, Lettuce; Asparagus crowns; 'Volunteer' potatoes; Crop safety, herbicides, Pre-sowing/planting and soil incorporated HDC H3; after sowing pre-emergence/before planting HDC H1, post-sowing/post planting after weed emergence HDC H4

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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.

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Grower Summary

Headline

Potential alternative herbicides for the future, which appear to be safe (non-phytotoxic) to several vegetable crops have been identified and are worth further evaluation. The herbicides are confidential at the moment.

Background and expected deliverables

All conventionally grown outdoor field vegetables are dependent on herbicides to control weeds that cause loss of quality, yield and harvesting difficulties. Herbicides are used to avoid contamination of produce with weedy parts (some toxic) that could result in crop rejection thus incurring considerable financial loss. Without a range of herbicides to control a wide weed spectrum, growing UK vegetables could become uneconomic.

Growers have lost key herbicides that were not supported by Crop Protection Companies in the EC pesticide review (e.g. metoxuron). Some that were supported failed to achieve Annex 1 status - for example trifluralin (Treflan), in 2008 propachlor (Ramrod), in 2009 chlorthal-dimethyl (Dacthal). Use of trifluralin and propachlor is no longer permitted and this will have a great impact on brassicas, lettuce and onions. Herbicide uses of chlorpropham (Comrade etc.) have also been revoked and it must not be used after 31 July 2010. The 'voluntarily withdrawn' List 3 actives are still to be assessed.

At product re-registration stage in the UK, dose rates of several herbicides included on Annex 1 were reduced (e.g. linuron, pendimethalin). In addition, (Butisan S etc.) metazachlor to 1000g a.i./ha to be applied only one year in three and this will have an impact on leaf and flower-head Brassica production.

The new EU regulation (EC1107/2009) may mean the loss of other key herbicide actives such as linuron, ioxynil in future.

Alternatives are therefore urgently needed.

A simple screening of new herbicides not previously tested in the UK, was done each year from 2004-2008 at Warwick HRI Kirton. The screen was at Elsoms Seeds site in 2010. The aim was:

- To identify candidate herbicides after consultation with crop protection companies, a search of literature, discussions with vegetable sectors in other European Member States and the USA IR-4 Project. Only herbicides on Annex 1 or supported in the Review are selected, but the future of many pesticides is uncertain as a result of the new EU regulation (1107/2009) and the Water Framework Directive.
- To test a range of vegetables for crop tolerance to new herbicides available for major crops or vegetables in other European Member States but whose development cannot be justified by the manufacturers for UK minor crop use.
- To find new solutions for weed control as rapidly as possible by further development, and obtain Specific Off-Label Approvals (SOLAs) through HDC.

Summary of the project and main conclusions

Main conclusions:

Vegetable crops in trial were: drilled bulb onion, leek, carrot, parsnip, coriander, vining pea, dwarf French bean, swede, mizuna, baby-leaf spinach; transplanted celery, cauliflower, lettuce, and planted asparagus crowns. No herbicide killed the "volunteer" potatoes but HDC H3 4.0 Kg/ha delayed emergence of shoots.

- HDC H3 at 2.0 Kg/ha (1200 g a.i./ha) applied before sowing or planting and soil-incorporated appeared safe to all crops except mizuna where it was safe at 1.0 Kg/ha, but it was not safe to onion, leek or spinach. It could be a replacement for trifluralin in

brassicas. It would be effective in dry soil conditions. HDC H3 controlled several species, importantly Polygonums and fat-hen, but not groundsel, shepherd's purse or mayweeds.

- HDC H1 at of 2.0L/ha applied pre-emergence of drilled crop and weed, and before transplanting has potential for use in carrot, parsnip, coriander, vining pea, dwarf French bean, baby leaf spinach and planted asparagus crowns. Weeds controlled included fat-hen, small nettle, shepherd's purse and mayweeds but it was less effective on groundsel and had weaknesses on Polygonums.
- HDC H4 at 25g/ha applied post-weed-emergence and post-emergence of drilled crops and post transplanting was only safe to onion and leek, dwarf French bean and possibly at 12.5g/ha to lettuce. Most weed species at this site were not susceptible and only shepherd's purse and a low population of mayweeds were controlled.

General Summary:

HDC H3, a residual herbicide, was applied before sowing or planting and soil-incorporated with the exception of asparagus where it was applied after planting but before spear emergence. HDC H1 another residual herbicide was applied pre-emergence of drilled crops but before transplanting of celery, cauliflower and lettuce. HDC H4, a sulfonylurea, was applied post-weed emergence and post planting.

Herbicides were applied at 2 x Normal (N), Normal, ½ Normal dose rates in all crops, except onion and leek, where Normal, ½ Normal, ¼ Normal dose rates were used. Assessments were made for any crop damage (phytotoxicity). Weed control was monitored to identify the potential of each product to control the target weeds.

Crop Safety

The following information is based on only one trial, on an irrigated, light, silt loam soil. For crop safety there should no, or negligible/transient damage at a recommended dose rate and no, or acceptable, effects at the overlap dose.

Table 1. Pre-sowing soil incorporated herbicide HDC H3; pre-weed-emergence herbicide HDC H1 applied pre-emergence of drilled crops and pre-transplanting: √ safe; X not safe, N normal

Herbicide 'Normal' dose/ha	Onion	Leek	Carrot	Parsnip	Coriander	Celery transplants	Cauliflower transplants	Lettuce transplants	Dwarf Bean	Vining Pea	Swede	Mizuna	Spinach	Asparagus
HDC H3	√ ¼ N	√ ¼ N	√	√	√	√	√	√	√	√	√	√ ½ N	X	√
HDC H1	√ ½ N	√ ½ N	√	√	√	√ ½ N	√	X	√	√	X	X	√	√

Table 2. Post-weed-emergence herbicide: ✓ safe; x not safe, N normal

Herbicide 'Normal' dose/ha	Onion	Leek	Carrot	Parsnip	Coriander	Celery transplants	Cauliflower transplants	Lettuce transplants	Dwarf Bean	Vining Pea	Swede	Mizuna	Spinach	Asparagus
HDC H4	✓	✓	X	X	X	X	X	✓ ½N	✓	X	X	X	X	X

Weed species controlled

Appendix 1 shows Common and Latin weed names.

The main weed species were fat-hen, fig-leaved goosefoot, red dead-nettle, small nettle, shepherd's purse, chickweed and groundsel on this trial site. There were also some mayweeds, speedwells, annual meadow-grass, redshank, knotgrass and a few black bindweed.

HDC H3 applied pre-planting and incorporated at 4.0 Kg/ha delayed emergence of 'volunteer' potato shoots and reduced vigour. HDC H1 and HDCH4 had no effect on potatoes.

Table 3. Pre-sowing soil incorporated herbicide HDC H3; pre-weed-emergence herbicide HDC H1 applied pre-emergence of drilled crops and pre-transplanting: ✓ weed species controlled; x poor control or not controlled at various dose rates; x✓ variable, () low populations

Pre-weed- emergence Herbicide dose rate/ha	Small nettle	Shepherd's purse	Red dead-nettle	Groundsel	Chickweed	Mayweeds#	Fig-leaved goosefoot	Fat-hen	Black-bindweed	Knotgrass	Ivy-leaved speedwell	Field speedwell	Annual meadow- grass
HDC H3 4.0kg	✓	x	✓	x	✓	✓	✓	✓	✓	✓	✓	✓	✓
HDC H3 2.0kg	✓	x	✓	x	✓	x	✓	✓	✓	✓	✓	✓	✓
HDC H3 1.0kg	x	x	✓	x	x	x	✓	✓	(x)	x	(x)	(x)	(✓)
HDC H3 0.5kg	x	x	x	x	x	x	x	x	x	x	x	x	x
HDC H1 4.0L	✓	✓	✓	✓	✓	✓	✓	✓	x	x	x	x	✓
HDC H1 2.0L	✓	✓	x	x✓	✓	✓	✓	✓	x	x	x	x	✓
HDC H1 1.0L	x	✓	x	x	✓	✓	x✓	x✓	x	x	x	x	✓
HDC H1 0.5L	x	x	x	x	x	x	x	x	x	x	x	x	x

mainly pineappleweed

Table 4. Post-weed-emergence herbicides: √ weed species controlled; x poor control or not controlled at various dose rates; (low population limited data)

Post-weed-emergence Herbicide dose rate/ha	Small nettle	Shepherd's purse	Red dead-nettle	Groundsel	Chickweed	(Mayweeds)#	Fig-leaved goosefoot	Fat-hen	(Redshank)	Knotgrass	Ivy-leaved speedwell	Field speedwell	Annual meadow-grass
HDC H4 50g	√ st	√	√ st	x	x	(√)	x	x	x	x	x	x	x
HDC H4 25g	x	√	√ st	x	x	(√)	x	x	x	x	x	x	x
HDC H4 12.5g	x	√	x	x	x	(x)	x	x	x	x	x	x	x

scented and scentless mayweed; st stunted

HDC H3 at 2.0 Kg/ha (1200 g a.i./ha), a residual herbicide, applied before sowing or planting and soil-incorporated, has potential for use in several crops and is effective in dry soil conditions. It appeared safe to drilled carrot, parsnip, coriander, vining pea (possibly), dwarf French bean, swede; transplanted celery, cauliflower and lettuce. It was also safe to mizuna at 1.0 Kg/ha. HDC H3 was not safe to onion and leek and caused severe damage to baby-leaf spinach. Efficacy was poor where it was not soil-incorporated - when applied post-planting of asparagus crowns. It controlled several species at 1200 g a.i./ha - importantly Polygonums, fat-hen and annual meadow-grass, but not groundsel, shepherd's purse or mayweeds.

HDC H1 at of 2.0 L/ha, a residual herbicide, also appeared very promising. It was applied pre-emergence of drilled crop and weed, and before transplanting and has potential for use in carrot, parsnip, coriander, vining pea, dwarf French bean, baby-leaf spinach and planted asparagus crowns. It may also be safe at 1.0 L/ha to transplanted celery, drilled onion and leek. HDC H1 killed lettuce, swede and mizuna, but surprisingly it appeared safe to transplanted cauliflower. HDC H1 gives good control of volunteer oilseed rape (data from other trials). Weeds controlled included fat-hen, small nettle, shepherd's purse, annual meadow-grass and a low population of mayweeds but it was less effective on groundsel and had weaknesses on Polygonums, red dead-nettle, and speedwells.

No adverse effects were observed on carrot or parsnip roots from HDC H3 or HDC H1. HDC H4, 25 g/ha a sulfonylurea, applied post-weed-emergence and post-emergence of drilled crops and post transplanting was safe to onion and leek at the N (normal) dose of 25g/ha, (and at 50 g/ha 2xN), at 25g/ha to dwarf French bean and possibly at 12.5g/ha to lettuce. Other crops were severely damaged, exhibiting symptoms of yellowing, severe stunting and production of multiple shoots. Most weed species at this site were not susceptible including Polygonums, fat-hen, fig-leaved goosefoot, groundsel and annual meadow-grass therefore weed control was poor. Here it was only effective on shepherd's purse and a low population of mayweeds, but it would control volunteer oilseed rape. It could be useful post-emergence for onion and leek where shepherd's purse and mayweeds are a problem.

HDC H3 and HDC H1 are potential alternative residual herbicides. HDC H3 could be a direct replacement for trifluralin in brassicas and in crops where pre-emergence weed control is a problem under dry soil conditions. A follow-up with another herbicide will be needed for species that escape control. HDC H1 pre-emergence controls mayweeds – a problem in carrots and parsnips and it would be an alternative to linuron. However, tank-mix partners will be needed - possibly pendimethalin to control Polygonums and clomazone for groundsel. Further work on HDC H1 in spinach is worth investigation.

Herbicides: Current Approval Status (August 2010)

Herbicide Product & timing	Company	active substance (a.i. formulation)	EC Review status	N rate product/ha	Registered now or in future?
HDC H3 pre-sowing/pre-transplant soil incorporated	Confidential	Confidential	Annex 1	2.0 kg/ha (1200 g a.i./ha)	No UK registration yet.
HDC1 pre-emergence, pre-transplant	Confidential	Confidential	Not yet on Annex 1	2.0 L/ha	No EU registration yet
HDC H4 post-plant, early post-weed-em	Confidential	Confidential	Annex 1	25 g/ha	No UK registration yet

Financial benefits

As a result of the 91/414/EEC pesticide review programme, vegetable growers have lost key herbicides. Weeds cause yield loss, harvesting difficulties and, importantly, contamination of produce with weedy parts (some toxic) that could result in crop rejection thus incurring considerable financial loss. All conventionally grown outdoor field vegetables are dependent on herbicides and without a range of herbicides to control a wide weed spectrum, vegetable growing could become uneconomic in the EU.

Herbicides that appear to be safe (non-phytotoxic) to several vegetable crops and the potential for SOLAs have been identified in this early stage screening trial in 2010. However, the herbicides are not yet registered in the UK and it will take time before they are available to the grower. The study also identified herbicides that are too damaging in certain crops, and the type of symptoms that would render them unmarketable.

Action points for growers

- Continue this early stage screening system to evaluate new herbicides when available.
- Need to be aware that there may be further losses if important actives in List 3 of the 91/414/EEC review fail to achieve Annex 1 listing. For active ingredients included on Annex 1 there may be restrictions on timings and dose rates at product re-registration stage. The future of many herbicides is now uncertain as a result of the new EU Regulation (EC1107/2009) and the Water Framework Directive.
- Potential alternative residual herbicides for the future that appears to be safe (non-phytotoxic) to several crops has been identified in 2010 and further work may be needed to assess crop safety, efficacy and programmes.
- Where no data are available, two years residues trials may be required for a SOLA (Specific Off-Label Approval) application.

Science Section

Introduction

Herbicide screening trials on a range of vegetable crops were funded by the Agrochemical Industry and carried out at NVRS/HRI until 1990. Information on crop tolerance, made available to relevant crop sectors for further development, was extremely useful. Crop Protection Companies no longer screen new herbicides on minor crops.

Important herbicides for vegetable growers have been lost because they were not supported in the EC Review, or failed to achieve Annex 1 status. The derogations for their “Essential Uses” expired 31 December 2007 and alternatives are therefore sought. The future of many pesticides is uncertain as a result of the new EU regulation (EC1107/2009) and the Water Framework Directive.

The overall aim of this project is to create a system for herbicide screening on a range of crops chosen by the HDC Vegetable Panels. The first HDC screening trial began in 2004. New active substances for arable crops or used in vegetables in other Member States are selected a) if they are already on Annex 1 or supported in the EC Review although they may not be registered yet in the UK; b) after consultations with researchers in Crop Protection Companies, vegetable sectors in other European Member States and USA IR-4 Project. The screening trial provides information on crop phytotoxicity to active substances so that they can be evaluated further in commercial crops or in residue trials to support on-label or SOLA use (by the HDC)

Objectives were to:

- assess crop safety ('phytotoxicity') to herbicides tested
- assess where possible, efficacy against weeds that are common problems in vegetables
- identify suitable candidates for further development and for SOLAs

Materials and methods

Site: Elsoms Trial Ground, near Spalding

Soil type (ADAS scale): Silt Loam (light)

Crop details: Drilled crops were sown at high plant populations in 4 rows/ plot on 40 cm row width in 1.83 m beds with a Monosem Air Drill, except for peas and beans, which were sown in double rows with a Planet Push Drill. Press wheels on drills ensured a fine, firm seedbed therefore plots were not rolled. Transplants were planted with a Ferrari Module Planter on 4 rows/ plot for celery, 3 rows/ plot for cauliflower. Lettuce was hand-planted in 4 rows/ plot.

Trial Design: Plot size 2 m long x 1 bed width (1.83 m), 2 replicates each treatment (total 360 plots).

Weather at Spalding

April was a very sunny month with higher than average temperatures but May was cooler than average. April and May were very dry months with much lower rainfall than the long-term average (less than 50%), and there was negligible rainfall until 29 April. Temperatures were below average during the first half of May and there was a severe frost (the last one) on the night of 12 May. Temperatures were high in the third week. There was no rain until 29 May when there was 18mm, and 1 June was also wet. The first few days of June were hot but cooler weather followed with periods of heavy rain from 5th to the 10th June and showers until the 14th June. The rest of the month was very dry and there was no rainfall

until 29 June and none in July until 12 July. Temperatures were higher than average during the last half of June and the first half of July.

Irrigation applied: with an overhead spray, 13mm on each occasion - 21 April after sowing onion leek, potatoes, asparagus; 14 May; and on 21 May and 25 May to all crops,.

Sowing dates and herbicide application dates 2010

<i>Pre-weed-emergence</i>			
<i>Crop (Variety)</i>	<i>Sowing/ transplant date</i>	<i>Herbicide application</i>	<i>Date applied</i>
'Volunteer' potatoes.	16 April	HDC H3 pre-sowing incorporated HDC H1 pre-emergence	16 April 18 April
Onion (Hystar)	16 April	HDC H3 pre-sowing incorporated HDC H1 pre-emergence	16 April 18 April
Leek ((Striker)	16 April	HDC H3 pre-sowing incorporated HDC H1 pre-emergence	16 April 18 April
Carrot (Nairobi)	26 April	HDC H3 pre-sowing incorporated HDC H1 pre-emergence	26 April 29 April
Parsnip (Palace)	26 April	HDC H3 pre-sowing incorporated HDC H1 pre-emergence	26 April 29 April
Coriander (Filtro)	12 May	HDC H3 pre-sowing incorporated HDC H1 pre-emergence	12 May 13 May
Celery transplant (Tango)	13 May	HDC H3 pre-plant incorporated HDC H1 pre-planting	12 May 13 May
Cauliflower transplant (Fargo)	13 May	HDC H3 pre-plant incorporated HDC H1 pre-planting	12 May 13 May
Lettuce iceberg transplant (Challenge)	13 May	HDC H3 pre-plant incorporated HDC H1 pre-planting	12 May 13 May
Pea (Cabree)	12 May	HDC H3 pre-sowing incorporated HDC H1 pre-emergence	12 May 13 May
Dwarf French Bean (Parker)	12 May	HDC H3 pre-sowing incorporated HDC H1 pre-emergence	12 May 13 May
Swede (Magres)	12 May	HDC H3 pre-sowing incorporated HDC H1 pre-emergence	12 May 13 May
Mizuna (Early)	12 May	HDC H3 pre-sowing incorporated HDC H1 pre-emergence	12 May 13 May
Spinach baby-leaf (Renegade)	12 May	HDC H3 pre-sowing incorporated HDC H1 pre-emergence	12 May 13 May
Asparagus crowns (Gijnlim)	16 April	HDC H3 post-planting pre-emergence HDC H1 pre-emergence	18 April 18 April

Post weed-emergence HDC H4			
<i>Crop (Variety)</i>	<i>Sowing/transplant date</i>	<i>Crop Growth stage</i>	<i>Herbicide & date applied</i>
'Volunteer' potatoes.	16 April	1-3 shoots	HDC H4 26 May
Onion (Hystar)	16 April	1 Leaf	HDC H4 26 May
Leek ((Striker)	16 April	1 Leaf	HDC H4 26 May
Carrot (Nairobi)	26 April	2 True Leaves	HDC H4 4 June
Parsnip (Palace)	26 April	1-2 True Leaves	HDC H4 11 June
Coriander (Filtro)	12 May	2 True Leaves	HDC H4 11 June
Celery transplant (Tango)	13 May	established	HDC H4 4 June
Cauliflower transplant (Fargo)	13 May	established	HDC H4 4 June
Lettuce iceberg transplant (Challenge)	13 May	established	HDC H4 4 June
Pea (Cabree)	12 May	2-3 node	HDC H4 4 June
Dwarf French Bean (Parker)	12 May	Simple Leaf	HDC H4 4 June
Swede (Magres)	12 May	2 True Leaves	HDC H4 4 June
Mizuna (Early)	12 May	2 True Leaves	HDC H4 4 June
Spinach baby-leaf (Renegade)	12 May	2 True Leaves	HDC H4 4 June
Post-harvest HDC H4			
Asparagus crowns (Gijnlim)	16 April	90% fern 20% spears	HDC H4 4 June

Post-emergence plots: a pre-emergence herbicide was applied Ramrod + Stomp (9.0 +1.5) L/ha to onion, leek on 18 April; Stomp + Linuron (500 g/L formulation) (1.6 + 1.0) L/ha to carrot, parsnip on 11 May.

Herbicides

Herbicides were screened for crop tolerance. Herbicides were applied at 2x 'Normal', Normal, ½ Normal dose rates in all crops, except onion and leek where dose rates were Normal, ½ Normal, ¼ Normal. 'Normal' dose rates were appropriate for the light soil type.

Herbicide and application timing	Herbicide Product	Company	active substance and formulation	'N' Normal dose rate product/ha
<i>Pre-weed-emergence</i>				
HDC H3 pre-sowing incorporated	Confidential	Confidential	Confidential	2.0 Kg (1200 g a.i.)
HDC H1 pre-emergence	Confidential	Confidential	Confidential	2.0 L
<i>Post-weed-emergence (2+ weeks after transplanting)</i>				
HDC H4	Confidential	Confidential	Confidential	25g

Application Data

Sprays were applied using an Azo plot precision sprayer with a 2 m boom with four Lurmark 110^o flat fan nozzles 02F110 (BCPC code F110/0.80/3) delivering 200 L/ha water volume at 1.9 bar pressure.

Plots were irrigated soon after application of pre-emergence residual herbicide HDC H1.

Pre-weed-emergence herbicides

Date	Weather	GS Crop; Soil conditions
<i>Pre-sow Onion & Leek pre-plant asparagus, potatoes incorporated (sown 16 April)</i>		
16 April HDC H3	10°C; 40% RH; cloud cover 10%; irrigation 13 mm on 20 April	Dry seed; Sowing depth 1 cm; fine seedbed but a few small clods 5cm, surface dry
<i>Pre-emergence Onion, Leek & Asparagus (planted 16 April)</i>		
18 April HDC H1	7°C; 40% RH; cloud cover 0%; irrigation 13mm on 20 April	Dry seed; Sowing depth 1 cm; fine seedbed but a few small clods 5cm diameter, surface dry
<i>Pre-sow incorporated Carrots & Parsnip (sown 26 April)</i>		
26 April HDC H3	15°C; 38% RH; cloud cover 80%; rain 29 April	fine seedbed, surface dry
<i>Pre-emergence Carrot & Parsnip (sown 2 May)</i>		
29 April HDC H1	18°C; 38% RH; cloud cover 90%; rain after application 29, 30 April & 1 May;	Dry seed; Sowing depth 1 cm; fine seedbed, surface dry
<i>Pre-plant incorporated Celery, Lettuce & Cauliflower (planted 13 May)</i>		
12 May HDC H3	12°C; 42% RH; cloud cover 50%; no rain after application, irrigation 14 May 13 mm	fine seedbed, surface dry
<i>Pre-plant pre-weed-emergence Celery, Lettuce & Cauliflower (planted 13 May)</i>		
13 May HDC H3	Frost previous night 3°C; 43% RH; cloud cover 0%; no rain after application, irrigation 14 May 13 mm	fine seedbed, surface dry
<i>Pre-sow incorporated Peas, Dwarf Beans, Swede, Mizuna, Spinach, Coriander (sown 12 May)</i>		
12 May HDC H3	12°C; 42% RH; cloud cover 50%; no rain after application, irrigation 14 May 13 mm	fine seedbed, surface dry
<i>Pre-emergence Peas, Dwarf Beans, Swede, Mizuna, Spinach, Coriander (sown 12 May)</i>		
13 May HDC H1	Frost previous night , 3°C; 43% RH; cloud cover 0%; no rain after application, irrigation 14 May 13 mm	Dry seed; fine seedbed, surface dry

Post-weed-emergence herbicide

Pre-emergence herbicide Normal dose was applied: on 18 April to onions and leeks Ramrod + Stomp (9.0 + 1.5) L/ha; on 29 April to carrots and parsnips, Stomp + Linuron (500 g/L formulation) (1.6 + 1.0) L/ha.

Date	Weather	GS crop (number leaves L, true leaves TL)	GS weeds (number of True Leaves TL)
<i>Post-weed-emergence Onion, Leek, Potatoes</i>			
26 May HDC H4	12°C; 73% RH; cloud cover 90%; no rain after application until 29 May	Onion 1 L, Leek 1 L, Potatoes 1-3 shoots 100 cm tall	No weeds Fat-hen large plant, red dead- nettle 4TL – large plant small nettle 4 -6TL, groundsel, mayweeds 4TL, chickweed 6 TL- small plant, black-bindweed 1 TL
<i>Post-weed-emergence Carrot, Swede, Mizuna, Spinach, Celery, Lettuce, Cauliflower, Peas, Beans, Asparagus</i>			
4 June HDC H4	20°C; 73% RH; cloud cover 0%; no rain after application until 5/6 June	Carrot 2-2 ½ TL, Swede 2TL, Mizuna 3-4TL, Spinach 2-2 ½ TL, pea 3 node, dwarf bean simple leaf, asparagus 90% fern 10% spear, transplants	No weeds on carrots; Fat-hen 2-5TL, fig-leaved goosefoot 2-4TL red dead-nettle 2TL, small nettle 2-4TL, groundsel, black-bindweed 2 TL, Annual meadow-grass several

Date	Weather	GS crop (number leaves L, true leaves TL)	GS weeds (number of True Leaves TL)
		established	GS, shepherd's purse 2-4TL-small plant
<i>Post-weed-emergence Coriander, Parsnip</i>			
11 June HDC H4	17°C; 37% RH; cloud cover 70%; no rain after application until 13/14 June	Coriander 2 TL, Parsnip 1-2 TL	On coriander, large plant fat-hen, small nettle, shepherd's purse

Records/Assessments

The following records and assessments were undertaken at, or following application of the various experimental treatments:

- Crop and weed growth stage recorded at times of application and crop assessment.
- Weather during and after application.
- Estimates of reduction in crop emergence or delay after pre-emergence applications.
- Observations of phytotoxicity symptoms, crop scores for damage (0=complete kill; 7=acceptable damage depending on the market; 10=no damage) at appropriate intervals.
- Numbers of weed species present on untreated control plots.
- Weed species present on herbicide treated plots and overall weed control scores (0=no control; 7= acceptable control; 10=complete control).

Results and Discussion

Crop tolerance

Phytotoxicity symptoms pre-weed-emergence herbicide (Tables 5 - 10)

HDC H3 at 2.0 Kg/ha (1200 g a.i./ha), a residual herbicide, applied before sowing or planting and soil-incorporated appeared safe to drilled carrot, parsnip, coriander, vining pea, dwarf French bean, swede; transplanted celery, cauliflower and lettuce. It was also safe to mizuna at 1.0 Kg/ha. HDC H3 was not safe to onion and leek and reduced and delayed emergence. It caused severe damage to baby-leaf spinach. HDC H3 was safe to asparagus, where it was applied before spear emergence but not soil-incorporated, but weed control was poor. No adverse effects from HDC H3 were observed on carrot or parsnip roots.

HDC H1 at of 2.0L/ha, a residual herbicide, was applied pre-emergence of drilled crop and weed, and before transplanting and was safe to carrot, parsnip, coriander, vining pea, dwarf French bean, asparagus crowns and baby-leaf spinach. It may also be safe at 1.0 L/ha to transplanted celery, drilled onion and leek. The most sensitive crop was lettuce and many plants had died within 10 days after planting. Swede and mizuna were also very sensitive - they were chlorotic at cotyledon stage and died soon after emergence. Surprisingly, HDC H1 appeared safe to transplanted cauliflower.

No adverse effects from HDC H1 were observed on carrot or parsnip roots.

Phytotoxicity symptoms post-weed-emergence herbicides (Tables 11 - 16)

HDC H4, a sulfonyleurea herbicide, was applied post-emergence of drilled crops and post transplanting to emerged weeds. It was safe to onion and leek at the N (normal) dose of 25g/ha and at 50 g/ha (2xN), at 25g/ha to dwarf French bean and possibly at 12.5g/ha to lettuce. The highest dose rate in lettuce caused slight reduction in lettuce frame (stunting), occasional plants were loose and open not characteristic of iceberg type. Other crops were severely damaged at all dose rates, exhibiting symptoms of yellowing, severe stunting and production of multiple shoots at the base of the crop plants. Celery leaves were curled and

distorted. Carrot and parsnip roots were abnormal, constricted and thinner than untreated roots.

Crop Safety (summary)

The following information is based on only one trial, on an irrigated, light soil. For crop safety there should be no, or negligible/transient, damage at a recommended dose rate and no, or acceptable, effects at the 'overlap' dose.

Table 1. Pre-sowing soil incorporated herbicide HDC H3; pre-weed-emergence herbicide HDC H1 applied pre-emergence of drilled crops and pre-transplanting: ✓ safe; x not safe, N normal

Herbicide 'Normal' dose/ha	Onion	Leek	Carrot	Parsnip	Coriander	Celery transplants	Cauliflower transplants	Lettuce transplants	Dwarf Bean	Vining Pea	Swede	Mizuna	Spinach	Asparagus
HDC H3	✓ ¼ N	✓ ¼ N	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓ ½ N	X	✓
HDC H1	✓ ½ N	✓ ½ N	✓	✓	✓	✓ ½ N	✓	X	✓	✓	X	X	✓	✓

Table 2. Post-weed-emergence herbicide: ✓ safe; x not safe, N normal

Herbicide 'Normal' dose/ha	Onion	Leek	Carrot	Parsnip	Coriander	Celery transplants	Cauliflower transplants	Lettuce transplants	Dwarf Bean	Vining Pea	Swede	Mizuna	Spinach	Asparagus
HDC H4	✓	✓	X	X	X	X	X	✓ ½N	✓	X	X	X	X	X

Crop Tolerance Scores (mean of two replicates) pre-weed-emergence herbicides

Table 5. Onion and leek sown 16 April, HDC H3 incorporated pre-sowing 16 April, HDC H1 applied 18 April, onion and leek emerged 5 May. Assessment date, growth stage L leaf, crop damage score (0 total kill; 7 acceptable; 10 no damage)

Herbicide Assessment Date: Untreated GS:	Rate	Onion				Leek			
		5/5 loop	19/5 crook-½ L	30/5 1 L	23/6 3½ L	5/5 loop	19/5 ½ L	30/5 1 L	23/6 3 ½ L
HDC H3 2.0kg	N	9	7	6 red st	4	9	7	6 red st	4
HDC H3 1.0kg	½ N	10	9	8st	8	10	8	8st	8
HDC H3 0.5kg	¼ N	10	10	10	10	10	10	10	10
HDC H1 2.0L	N	7del	7st	6st	6	7del	7delst	6del	6
HDC H1 1.0L	½ N	9del	10	10	10	9del	9	10	10
HDC H1 0.5L	¼ N	10	10	10	10	10	10	10	10

st stunting; red reduced emergence; del delay

Table 6. Carrot and parsnip sown 26 April, HDC H3 incorporated pre-sowing 26 April, HDC H1 applied 29 April pre-emergence. Carrot emerged 14 May, parsnip late, uneven emergence 2 June. Coriander sown 12 May, HDC H3 incorporated 12 May pre-sowing, HDC H1 applied pre-emergence on 13 May, coriander emerged 30 May. Assessment date, untreated growth stage (cot cotyledon, TL true leaf), crop damage score (0 total kill; 7 acceptable; 10 no damage)

Herbicide Assessment date: Untreated GS:	Rate	Carrot			Parsnip		Coriander		
		24/5 cot-½ TL	4/6 2½ T L	23/6 6 TL	4/6 cot -1 TL	23/6 2-3½ TL	30/5 cot	4/6 1 TL	23/6 5 TL
HDC H3 4.0kg	2N	10	10	10	10	10	10	10	10
HDC H3 2.0kg	N	10	10	10	10	10	10	10	10
HDC H3 1.0kg	½ N	10	10	10	10	10	10	10	10
HDC H1 4.0L	2N	8 red	7st thin*1½TL	6 thin	10	10	10	10	7
HDC H1 2.0L	N	10	10	10	10	10	10	10	9
HDC H1 1.0L	½ N	10	10	10	10	10	10	10	10

red reduced emergence; st stunting; thin thinning on 4 June * GS 1 ½ TL

Table 7. Celery, cauliflower and lettuce transplanted 13 May: HDC H3 incorporated pre-planting 12 May, HDC H1 applied 13 May pre-transplanting. Assessment date, growth stage, crop damage score (0 total kill; 7 acceptable; 10 no damage)

Herbicide Assessed : Untreated GS:	Rate	Celery			Cauliflower			Lettuce		
		24/5	4/6 2 ½ new L	23/6 6½ new L	24/5	4/6	23/6	24/5	4/6	23/6
HDC H3 4.0kg	2N	8nec	10	10	10	10	10	10	10	10
HDC H3 2.0kg	N	9.5	10	10	10	10	10	10	10	
HDC H3 1.0kg	½ N	10	10	10	10	10	10	10	10	
HDC H1 4.0L	2N	6 nec	6.5 st	5nec st	9st	8st	10	2 sev nec	0	0
HDC H1 2.0L	N	9	9	8 nec st	10	10	10	5	2	1
HDC H1 1.0L	½ N	10	10	10	10	10	10	7	5	4

sev nec severe necrosis leaf and some plants dead; nec necrosis from root uptake on 23/6; st stunting

Table 8. Vining peas, dwarf French beans sown 12 May, HDC H3 incorporated 12 May pre-sowing, HDC H1 applied pre-emergence on 13 May. Peas and dwarf beans emerged 21 May. Assessment date, growth stage, crop damage score (0 total kill; 7 acceptable; 10 no damage)

Herbicide Assessment date: Untreated GS:	Rate	Pea			Dwarf beans		
		24/5 Plumule	4/6 2-3 node	23/6 1 st flower open	24/5 emergence - simple L	8/6 simple L	23/6 2 trifoliolate L
HDC H3 4.0kg	2N	9 del st	9	10	10	9st	8 slight st
HDC H3 2.0kg	N	10	10	10	10	10	10
HDC H3 1.0kg	½ N	10	10	10	10	10	10
HDC H1 4.0L	2N	10	9 cl	10	10	10	10
HDC H1 2.0L	N	10	10	10	10	10	10
HDC H1 1.0L	½ N	10	10	10	10	10	10

st stunting; cl slight chlorosis lower leaves

Table 9. Swede, mizuna and spinach sown 12 May, HDC H3 incorporated 12 May pre-sowing, HDC H1 applied pre-emergence on 13 May. All emerged 24 May. Assessment date, growth stage (cot cotyledon, TL true leaf), crop damage score (0 total kill; 7 acceptable; 10 no damage)

Herbicide Assessment Date: Untreated GS:	Rate	Swe de			Mizun a			Spinach		
		24/5 cot	4/6 2TL	23/6 5½ TL	24/5 cot- 1TL	4/6 3-4TL	23/6 # 8TL	24/5 cot	4/6 2½ TL	23/6# 10TL
HDC H3 4.0kg	2N	10	10	10	10	6st 1TL	6	4 del cl red	2 st nec	2
HDC H3 2.0kg	N	10	10	10	10	9	9.5	6 red	4	4
HDC H3 1.0kg	½ N	10	10	10	10	10	10	8 del cl	6	6
HDC H1 4.0L	2N	4cl st	0	0	2 nec	0	0	7cl st	6 st nec	8 del
HDC H1 2.0L	N	6cl	0	0	5 cl nec	1	1	10	9.5	10
HDC H1 1.0L	½ N	8cl	2	2	8	3	3	10	10	10

cl chlorosis; st stunting; red reduced emergence; del delayed emergence or maturity; nec necrosis swede and spinach emerged then died; # past harvest stage

Table 10. Asparagus crowns planted 16 April, HDC H3 **not incorporated**, both HDC H3 and HDC H1 applied pre-emergence on 18 April. Uneven spear emergence on all plots 14 – 19 May. Assessment date, growth stage, crop damage score (0 total kill; 7 acceptable; 10 no damage)

Herbicide Assessment Date: Untreated GS:	Rate	Asparagu s			
		19/5 spears	24/5 fern	4/6 fern flowers	23/6 Flower drop
HDC H3 4.0kg	2N	10	10	10	10
HDC H3 2.0kg	N	10	10	10	10
HDC H3 1.0kg	½ N	10	10	10	10
HDC H1 4.0L	2N	10	10	10	10
HDC H1 2.0L	N	10	10	10	10
HDC H1 1.0L	½ N	10	10	10	10

Crop Tolerance Scores (mean of two replicates) post-weed-emergence herbicide

Table 11. Bulb onion and leek sown 16 April, HDC H4 post-emergence herbicide applied 26 May. Assessment date, growth stage (L leaf), crop damage score (0 total kill; 7 acceptable; 10 no damage)

Herbicide Assessment Date: Untreated GS:	Rate	Onion			Leek		
		4/6 1 ½ L	16/6 2 ½ L	7/7 5L	4/6 1 1/2 L	16/6 2 ½ L	7/7 5L
HDC H4 25g	N	7 dis cl	9.5 st 2L	10	9 dis	10	10
HDC H4 12.5g	½ N	9	10	10	10	10	10
HDC H4 6.25g	¼ N	10	10	10	10	10	10

dis distortion (less on leek); cl chlorosis;

Table 12. Carrots, parsnips sown 26 April, carrots emerged 14 May, parsnips uneven emergence 2 June; coriander sown 12 May emerged 30 May. Post-emergence herbicide HDC H4 applied 4 June carrot, 11 June coriander, parsnip. Assessment date, growth stage (TL true leaf), crop damage score (0 total kill; 7 acceptable; 10 no damage)

Herbicide Assessment date: Untreated GS:	Rate	Carrot		Parsnip		Coriander	
		16/6 3-4 TL	7/7 6-7 TL root pencil	16/6 1 - 2 TL	8/7 5 TL pencil	16/6 3 TL	7/7 bolting
HDC H4 50g	2N	2 sev cl st	0	1sev cl st	0 dead	2 sev cl	0
HDC H4 25g	N	3 sev cl st	0	2 sev cl st	0 dead	4 cl	0
HDC H4 12.5g	½ N	5cl st	0	4 cl st	1 sev st	6 cl	2 sev st

sev severe; st stunting; cl chlorosis (noted 1DAT on carrot)

carrots 7/7 not dead but unmarketable multiple shoots at crown 9 -11 tiny TL and tiny constricted roots at all dose rates; coriander 7/7 severe stunting multiple shoots stunted plants.

Table 13. Celery, cauliflower, iceberg lettuce transplanted 13 May. Post-emergence herbicide HDC H4 applied 4 June. Assessment date, growth stage, crop damage score (0 total kill; 7 acceptable; 10 no damage)

Herbicide Assessment date: Untreated:	Rate	celery		cauliflower		lettuce	
		16/6 5 new L	7/7	16/6	7/7 Curd 2cm	16/6 90% ground cover	7/7 harvest
HDC H4 50g	2N	3 cl st dis 2L	0 st dis	3 sev dis	2 sev st	6 60%cover	4
HDC H4 25g	N	6 st dis 3L	0	5 dis	3st	8 80% cover	6
HDC H4 12.5g	½ N	8 3-4 L	2	8 slight dis	5	10 90% cover	9

cl chlorosis; sev severe; st stunting; dist distortion growing point unmarketable;

celery 7/7 unmarketable, leaves still green but curled over and distorted, tillers beginning at base of plants;

cauliflower 16/6 severe distortion of the growing point , on 7/7 no curd at 2N, only tiny curd at N and ½ N;

lettuce 16/ 6 smaller frame, 7/7 at 2N and N lettuce a few loose poor hearts, side shoots at base of some plants

Table 14. Peas and dwarf French beans sown 16 May, emerged 27 May and 31 May respectively. Post-emergence herbicide HDC H4 applied 4 June. Assessment date, growth stage untreated (TL true leaf, trif L trifoliolate leaf), crop damage score (0 total kill; 7 acceptable; 10 no damage).

Herbicide <i>Assessment date:</i> <i>Untreated GS:</i>	Rate	peas 16/6 6 node enclosed bud	7/7 canning stage	dwarf beans 16/6 1 ¼ trif L	7/7 1 st open flower
HDC H4 50g	2N	4 4 ½ node no bud	0	6 st	8 slight st
HDC H4 25g	N	6 4 ½ node	0	8 st 1 trif	9
HDC H4 12.5g	½ N	8 5 ½ node encl bud	0	10	10

peas 16/6 cl growing point and st, chlorotic multiple tillers at 2N, N, all dose rates delayed maturity; 7/7 dwarf plants not harvestable by machine; dwarf Beans st stunting but no disruption or multiple shoots.

Table 15. Swede, mizuna and spinach sown 12 May, emerged 24 May. Post-emergence herbicide HDC H4 applied 4 June. Assessment date, growth stage (TL true leaf), crop damage score (0 total kill; 7 acceptable; 10 no damage)

Herbicide <i>Assessment date:</i> <i>Untreated GS:</i>	Rate	swede 16/6 5 TL	7/7 7TL	mizuna 16/6 10 ½ TL	7/7 past harvest stage	spinach 16/6 7full 2 half TL	7/7 bolting
HDC H4 50g	2N	2 w d	0	1 d	0 d	2 w	1d
HDC H4 25g	N	4	0	3	2	4	3
HDC H4 12.5g	½ N	6	0	4	3	6	5

d plant death; w leaves wilting;

swedes 7/7 unmarketable all dose rates severe stunting and multi-tillering from the root crown, similar effects in mizuna at the base of the plant, spinach a lesser effect and plants still green

Table 16. Asparagus planted 16 April. Post-emergence herbicide HDC H4 applied at fern stage 4 June. Assessment date, growth stage, crop damage score (0 total kill; 7 acceptable; 10 no damage)

Herbicide <i>Assessment date:</i> <i>Untreated GS:</i>	Rate	asparagus 16/6 Fern flowering	7/7 Flower drop
HDC H4 50g	2N	3 sc kink	3 sc st
HDC H4 25g	N	9*	5 sc st
HDC H4 12.5g	½ N	9*	8

sc scorched; st stunted; kink in stem; *leaves closed up

Weed Control

The Latin names for weeds are given in Appendix 1.

Summaries for control of weed species are shown in Tables 3 and 4.

On untreated areas for the earlier drilled plots there were high populations of red dead-nettle, small nettle, shepherd's purse, chickweed, pineappleweed (in onion and leek) and annual meadow-grass. Other weed species were fat-hen, fig-leaved goosefoot, groundsel and speedwells. In the later drilled/transplanted crops (May 12/13) weed populations on untreated areas were lower - predominantly fat-hen, fig-leaved goosefoot, with fewer red dead-nettle, small nettle and shepherd's purse. There were a few knotgrass and redshank in some plots, and mayweeds (scented and scentless).

Swede, mizuna, spinach and lettuce smothered weeds except where the crop suffered herbicide damage, but asparagus, onion and leek were uncompetitive. These effects are reflected in weed control scores, for example see Table 30.

Pre-weed-emergence herbicides (Tables 17-31)

HDC H3, a residual herbicide, affects seed germination and inhibits growth of shoots and roots. It is applied before sowing or planting and soil-incorporated and is effective in dry soil conditions. Efficacy was poor where it was not soil-incorporated - when applied post-planting of asparagus crowns in this trial. It controlled several species at 2.0 Kg/ha (1200 g a.i./ha) - importantly Polygonums, fat-hen and annual meadow-grass, but not groundsel, shepherd's purse or mayweeds.

HDC H1, a residual herbicide, was applied pre-emergence of drilled crop and weed, and before transplanting. HDC H1 gives good control of volunteer oilseed rape (data from other trials). Weeds controlled included fat-hen, small nettle, shepherd's purse, annual meadow-grass and a low population of mayweeds but it was less effective on groundsel and had weaknesses on Polygonums, red dead-nettle, and speedwells.

Post-weed-emergence herbicides (Tables 31-41)

Uncompetitive crops were sprayed with standard pre-emergence herbicides so that plots were not overgrown by weeds and crop safety could be assessed. Onions and leeks were sprayed with the Stomp + Ramrod (1.5 + 9.0) L/ha; carrots and parsnips with Stomp + Linuron (500 g/L formulation) (1.6 + 1.0) L/ha. No weeds remained in onion and leek plots but there were a few redshank, fat-hen, fig-leaved goosefoot and groundsel in plots of carrots and parsnips.

HDC H4, a sulfonylurea, was applied post-weed-emergence, post-emergence of drilled crops and post transplanting. Most weed species at this site were not susceptible to N (normal) dose of 25g/ha including Polygonums, fat-hen, fig-leaved goosefoot, groundsel and annual meadow-grass therefore weed control was poor. Here it was only effective on shepherd's purse and a low population of mayweeds, but it would control volunteer oilseed rape.

Weed species controlled (summary)

Table 3. Pre-sowing soil incorporated herbicide HDC H3; pre-weed-emergence herbicide HDC H1 applied pre-emergence of drilled crops and pre-transplanting: √ weed species controlled; x poor control or not controlled at various dose rates; x√ variable; (low population limited data)

Pre-weed-emergence Herbicide dose rate/ha	Small nettle	Shepherd's purse	Red dead-nettle	Groundsel	Chickweed	Mayweeds#	Fig-leaved goosefoot	Fat-hen	Black-bindweed	Knotgrass	Ivy-leaved speedwell	Field speedwell	Annual meadow-grass
HDC H3 4.0kg	√	x	√	x	√	√	√	√	√	√	√	√	√
HDC H3 2.0kg	√	x	√	x	√	x	√	√	√	√	√	√	√
HDC H3 1.0kg	x	x	√	x	x	x	x	x	(x)	x	(x)	(x)	(√)
HDC H3 0.5kg	x	x	x	x	x	x	x	x	x	x	x	x	x
HDC H1 4.0L	√	√	√	√	√	√	√	√	x	x	x	x	√
HDC H1 2.0L	√	√	x	x√	√	√	√	√	x	x	x	x	√
HDC H1 1.0L	x	√	x	x	√	√	x√	x√	x	x	x	x	√
HDC H1 0.5L	x	x	x	x	x	x	x	x	x	x	x	x	x

mainly pineappleweed

Table 4. Post-weed-emergence herbicides: √ weed species controlled; x poor control or not controlled at various dose rates; - weeds not present on untreated plots; (low population limited data)

Post-weed-emergence Herbicide dose rate/ha	Small nettle	Shepherd's purse	Red dead-nettle	Groundsel	Chickweed	(Mayweeds)#	Fig-leaved goosefoot	Fat-hen	(Redshank)	Knotgrass	Ivy-leaved speedwell	Field speedwell	Annual meadow-grass
HDC H4 50g	√ st	√	√ st	x	x	(√)	x	x	x	x	x	x	x
HDC H4 25g	x	√	√ st	x	x	(√)	x	x	x	x	x	x	x
HDC H4 12.5g	x	√	x	x	x	(x)	x	x	x	x	x	x	x

scented and scentless mayweed

Volunteer potato control pre- and post-emergence (Table 42)

Potatoes are a frequent problem in vegetable crops. Volunteer potatoes were planted on 16 April, with four tubers on each plot.

HDC H3 at 4.0 Kg/ha (2400 ga.i./ha) applied pre-planting and soil incorporated delayed potato emergence by 16 days compared to untreated potatoes and reduced the number of shoots/plant. The 2.0 Kg/ha dose had less effect.

HDC H1 had no effect on emergence of potato and did not suppress growth.

HDC H4 applied post-emergence of the potatoes on 26 May caused negligible effect except for slight temporary yellowing of the growing points.

No treatment prevented formation of potato apples, but HDC H3 at the 4.0 Kg/ha dose rate reduced numbers.

Weed species controlled

Appendix 1 shows Common and Latin weed names.

Pre-weed-emergence treatments (predominant species in bold type)

Table 17. Pre-weed-emergence herbicides: weed species remaining after treatment, weed species controlled, weed species on untreated plots of **onion** and **leek** drilled early on 17 April assessed on 19 May and 5 June. Related weed counts see below

Herbicide	Weed species not controlled	Weed species controlled
HDC H3 2.0kg	shepherd's purse mayweed groundsel	red dead-nettle annual meadow-grass chickweed fat-hen knotgrass small nettle
HDC H3 1.0kg	shepherd's purse small nettle mayweed groundsel chickweed red dead-nettle	annual meadow-grass fat-hen knotgrass
HDC H3 0.5kg	shepherd's purse groundsel small nettle red dead-nettle mayweed fat-hen annual meadow-grass chickweed knotgrass	
Untreated: red dead-nettle small nettle annual meadow-grass chickweed fat-hen groundsel shepherd's purse mayweed knotgrass		
HDC H1 2.0L	red dead-nettle ivy-leaved speedwell field speedwell knotgrass	small nettle annual meadow-grass fat-hen shepherd's purse mayweed chickweed groundsel
HDC H1 1.0L	red dead-nettle ivy-leaved speedwell field speedwell knotgrass annual meadow-grass groundsel	small nettle fat-hen shepherd's purse mayweed chickweed
HDC H1 0.5L	red dead-nettle small nettle mayweed ivy-leaved speedwell field speedwell knotgrass chickweed groundsel fat-hen shepherd's purse annual meadow- grass	
Untreated: red dead-nettle small nettle annual meadow-grass chickweed fat-hen groundsel shepherd's purse mayweed ivy-leaved speedwell knotgrass		

Numbers of weed species/m² on 19 May on untreated plots for each herbicide area (mean 12 counts in 0.33 m² quadrat) in 2 replicates **onion** and **leek**

	Fat-hen	Red dead-nettle	Small nettle	Knotgrass	Annual meadow-grass	Shepherd's purse	Chickweed	Groundsel	Mayweeds#	Ivy-leaved speedwell	Field speedwell	TOTAL
Untreated (HDC H3)	4	52	21	2	8	2	7	2	1	1	0	51
Untreated (HDC H1)	4	96	30	1	20	2	23	2	10	2	6	191

mainly pineappleweed

Table 18. Pre-weed-emergence herbicides: weed species remaining after treatment, weed species controlled, weed species on untreated plots of **carrot** and **parsnip** assessed 24 May and 14 June. Related weed counts see below

Herbicide	Weed species not controlled	Weed species controlled
HDC H3 4.0kg	shepherd's purse groundsel	small nettle red dead-nettle annual meadow-grass chickweed mayweed fat-hen fig-leaved goosefoot field speedwell
HDC H3 2.0kg	shepherd's purse groundsel mayweed	small nettle red dead-nettle annual meadow-grass chickweed fat-hen fig-leaved goosefoot field speedwell
HDC H3 1.0kg	shepherd's purse small nettle mayweed groundsel	annual meadow-grass chickweed fat-hen fig-leaved goosefoot red dead-nettle field speedwell
Untreated: small nettle red dead-nettle annual meadow-grass shepherd's purse chickweed mayweed fat-hen fig-leaved goosefoot groundsel field speedwell		
HDC H1 4.0L	field speedwell	small nettle red dead-nettle annual meadow-grass shepherd's purse chickweed mayweed fat-hen fig-leaved goosefoot groundsel
HDC H1 2.0L	red dead-nettle field speedwell groundsel	small nettle annual meadow-grass shepherd's purse chickweed mayweed fat-hen fig-leaved goosefoot
HDC H1 1.0L	red dead-nettle field speedwell groundsel fat-hen fig-leaved goosefoot	small nettle annual meadow-grass shepherd's purse chickweed mayweed
Untreated: small nettle red dead-nettle annual meadow-grass shepherd's purse chickweed mayweed fat-hen fig-leaved goosefoot groundsel field speedwell		

Number of weed species/m² on 24 May on untreated for each herbicide area (mean 12 counts in 0.33 m² quadrat) for 2 replicates of **carrot** and **parsnip**.

	Red dead-nettle	Small nettle	Fat-hen	Fig-leaved goosefoot	Annual meadow-grass	Shepherd's purse	Chickweed	Groundsel	Mayweeds#	Field speedwell	TOTAL
Untreated (HDC H3)	25	102	5	6	18	29	11	4	9	4	213
Untreated (HDC H1)	91	103	20	13	39	15	16	6	9	3	315

pineappleweed and scentless mayweed

Table 19. Pre-weed-emergence herbicides applied 12 or 13 May: weed species remaining after treatment, weed species controlled, weed species on untreated plots of **coriander** assessed 5 and 23 June. Related weed counts see below

Herbicide	Weed species not controlled	Weed species controlled
HDC 4.0kg H3	shepherd's purse	red dead-nettle small nettle fat-hen groundsel
HDC 2.0kg H3	shepherd's purse groundsel	small nettle fat-hen red dead-nettle
HDC 1.0kg H3	shepherd's purse groundsel red dead-nettle small nettle fat-hen	
Untreated: red dead-nettle small nettle fat-hen shepherd's purse groundsel		
HDC H1 4.0L		fat-hen fig-leaved goosefoot red dead-nettle small nettle shepherd's purse annual meadow-grass
HDC H1 2.0L	red dead-nettle	fat-hen fig-leaved goosefoot small nettle shepherd's purse annual meadow-grass
HDC H1 1.0L	red dead-nettle	fat-hen fig-leaved goosefoot small nettle shepherd's purse annual meadow-grass
Untreated: fat-hen fig-leaved goosefoot red dead-nettle small nettle shepherd's purse annual meadow-grass		

Number of weed species / m² on 5 June on untreated for each herbicide area (mean 6 counts in 0.33 m² quadrat) for 2 replicates of **coriander**

	Red dead-nettle	Small nettle	Fat-hen	Fig-leaved goosefoot	Annual meadow-grass	Shepherd's purse	Groundsel	TOTAL
Untreated (HDC H3)	13	6	4	1	1	3	2	30
Untreated (HDC H1)	11	6	17	16	4	11	1	66

Table 21 . Pre-weed-emergence herbicides applied 12 or 13 May: weed species remaining after treatment, weed species controlled, weed species on untreated plots of **lettuce, cauliflower** and **celery** assessed 5 and 23 June. Related weed counts see below

Herbicide	Weed species not controlled	Weed species controlled
HDC H3 4.0kg	shepherd's purse	red dead-nettle fat-hen fig-leaved goosefoot small nettle knotgrass black-bindweed
HDC H3 2.0kg	shepherd's purse small nettle	red dead-nettle fat-hen fig-leaved goosefoot knotgrass black-bindweed
HDC H3 1.0kg	shepherd's purse small nettle fat-hen fig-leaved goosefoot knotgrass	red dead-nettle black-bindweed
Untreated: red dead-nettle fat-hen shepherd's purse fig-leaved goosefoot small nettle knotgrass black-bindweed		
HDC H1 4.0L	red dead-nettle	fat-hen fig-leaved goosefoot shepherd's purse small nettle annual meadow-grass black-bindweed
HDC H1 2.0L	red dead-nettle black-bindweed	fig-leaved goosefoot fat-hen shepherd's purse small nettle annual meadow-grass
HDC H1 1.0L	red dead-nettle fat-hen fig-leaved goosefoot black-bindweed	shepherd's purse small nettle annual meadow-grass
Untreated: red dead-nettle fat-hen fig-leaved goosefoot shepherd's purse small nettle annual meadow-grass black-bindweed		

Number s of weed species / m² on 5 June on untreated for the herbicide area (mean 18 counts in 0.33m² quadrat) for 2 replicates weed species on untreated plots of **cauliflower, lettuce** and **celery**.

	Red dead-nettle	Small nettle	Fat-hen	Fig-leaved goosefoot	Annual meadow-grass	Shepherd's purse	Chickweed	Groundsel	Knotgrass	Black-bindweed	TOTAL
Untreated (HDC H3)	17	4	14	4	1	7	1	1	2	2	53
Untreated (HDC H1)	23	5	20	9	4	6	1	1	0	2	71

Table 22. Pre-weed-emergence herbicide applied 12 and 13 May: weed species remaining after treatment, weed species controlled, weed species on untreated plots of **pea** and **dwarf bean** assessed 5 and 23 June. Related weed counts see below

Herbicide	Weed species not controlled	Weed species controlled
HDC H3 4.0kg	shepherd's purse groundsel	red dead-nettle fig-leaved goosefoot knotgrass small nettle annual meadow-grass field speedwell black-bindweed
HDC H3 2.0kg	shepherd's purse groundsel	red dead-nettle fat-hen fig-leaved goosefoot knotgrass small nettle annual meadow-grass field speedwell black-bindweed
HDC H3 1.0kg	shepherd's purse fig-leaved goosefoot fat-hen knotgrass groundsel small nettle	red dead-nettle annual meadow-grass field speedwell black-bindweed
Untreated: red dead-nettle fig-leaved goosefoot shepherd's purse knotgrass fat-hen small nettle annual meadow-grass field speedwell black-bindweed		
HDC H1 4.0L	knotgrass black-bindweed field speedwell	red dead-nettle fig-leaved goosefoot shepherd's purse annual meadow-grass small nettle fat-hen groundsel mayweeds
HDC H1 2.0L	knotgrass black-bindweed red dead-nettle field speedwell	fig-leaved goosefoot shepherd's purse annual meadow-grass small nettle fat-hen groundsel mayweeds
HDC H1 1.0L	red dead-nettle fat-hen knotgrass fig-leaved goosefoot black-bindweed field speedwell groundsel	shepherd's purse annual meadow-grass small nettle mayweeds
Untreated: red dead-nettle fig-leaved goosefoot shepherd's purse annual meadow-grass small nettle fat-hen knotgrass black-bindweed field speedwell groundsel mayweeds		

Number of weed species / m² on 5 June on untreated (pre-weed-emergence) for the herbicide area (mean 12 counts in 0.33 m² quadrat) for 2 replicates of **pea** and **dwarf bean**.

	Red dead-nettle	Small nettle	Fat-hen	Fig-leaved goosefoot	Annual meadow-grass	Shepherd's purse	Groundsel	Mayweeds#	Knotgrass	Black-bindweed	Field speedwell	Ivy-leaved speedwell	TOTAL
Untreated (HDC H3)	11	4	5	11	2	6	3	0	8	2	2	0	54
Untreated (HDC H1)	23	6	3	6	5	7	3	2	2	2	2	1	62

#scented and scentless

Table 23. Pre-weed-emergence herbicides applied 12 and 13 May: weed species remaining after treatment, weed species controlled, weed species on untreated plots of **mizuna**, **spinach** and **swede** assessed 5 and 23 June. Related weed counts see below

Herbicide		Weed species not controlled	Weed species controlled
HDC 4.0kg	H3	shepherd's purse	fat-hen fig-leaved goosefoot knotgrass red dead-nettle small nettle
HDC 2.0kg	H3	shepherd's purse	fat-hen fig-leaved goosefoot knotgrass red dead-nettle small nettle
HDC 1.0kg	H3	shepherd's purse fat-hen fig-leaved goosefoot knotgrass small nettle	red dead-nettle
Untreated: fat-hen fig-leaved goosefoot shepherd's purse knotgrass red dead-nettle small nettle			
HDC 4.0L	H1	knotgrass field speedwell	fat-hen fig-leaved goosefoot shepherd's purse red dead-nettle small nettle annual meadow-grass
HDC 2.0L	H1	knotgrass field speedwell red dead-nettle	fig-leaved goosefoot fat-hen shepherd's purse small nettle annual meadow-grass
HDC 1.0L	H1	knotgrass fat-hen fig-leaved goosefoot red dead-nettle field speedwell small nettle	shepherd's purse annual meadow-grass
Untreated: fat-hen fig-leaved goosefoot shepherd's purse red dead-nettle small nettle annual meadow-grass field speedwell knotgrass			

Number of weed species / m² on 5 June on untreated (pre-weed-emergence) for the herbicide area (mean of 18 counts in 0.33 m² quadrat) for 2 replicates of **mizuna**, **spinach** and **swede**

	Red dead-nettle	Small nettle	Fat-hen	Fig-leaved goosefoot	Annual meadow-grass	Shepherd's purse	Chickweed	Knotgrass	Mayweeds#	Field speedwell	TOTAL
Untreated (HDC H3)	3	3	20	17	1	6	1	7	1	1	61
Untreated (HDC H1)	5	6	19	10	5	7	1	3	1	3	61

#scented and scentless

Table 24. Pre-weed-emergence herbicide applied 18 April: weed species remaining after treatment, weed species controlled, weed species on untreated plots of **asparagus** assessed 19 May and 4 June. Related weed counts see below

Herbicide		Weed species not controlled	Weed species controlled
HDC 4.0kg	H3	shepherd's purse fat-hen fig-leaved goosefoot mustard stunted black-bindweed knotgrass	red dead-nettle small nettle chickweed annual meadow-grass ivy-leaved speedwell
HDC 2.0kg	H3	shepherd's purse fat-hen fig-leaved goosefoot mustard ivy-leaved speedwell stunted knotgrass	red dead-nettle small nettle chickweed annual meadow-grass
HDC 1.0kg	H3	shepherd's purse mustard fat-hen fig-leaved goosefoot knotgrass ivy-leaved speedwell red dead-nettle small nettle	chickweed annual meadow-grass
Untreated: fig-leaved goosefoot fat-hen red dead-nettle small nettle knotgrass chickweed mustard annual meadow-grass shepherd's purse ivy-leaved speedwell			
HDC 4.0L	H1	A few stunted ivy-leaved speedwell	fig-leaved goosefoot fat-hen red dead-nettle small nettle chickweed annual meadow-grass mustard
HDC 2.0L	H1	mustard (stunted) ivy-leaved speedwell red dead-nettle	fat-hen fig-leaved goosefoot small nettle chickweed annual meadow-grass
HDC 1.0L	H1	mustard fat-hen fig-leaved goosefoot ivy-leaved speedwell field speedwell red dead-nettle	small nettle chickweed annual meadow-grass
Untreated: fig-leaved goosefoot fat-hen red dead-nettle small nettle chickweed annual meadow-grass mustard ivy-leaved speedwell			

Number of weed species / m² on 19 May on untreated (pre-weed-emergence) for the herbicide area (mean 6 counts in 0.33m² quadrat) in 2 replicates weed species on untreated plots of **asparagus**

	Fat-hen	Fig-leaved goosefoot	Red dead-nettle	Small nettle	Knotgrass	Black-bindweed	Annual meadow-grass	Shepherd's purse	Chickweed	Mustard #	Ivy-leaved speedwell	Field speedwell	TOTAL
Untreated (HDC H3)	9	30	18	6	7	1	3	2	7	6	3	0	91
Untreated (HDC H1)	31	31	18	8	2	0	8	2	8	6	5	2	121

mustard cultivated variety

Weed Control Scores pre-weed-emergence herbicides (mean of two replicates)

Table 25. Pre-weed-emergence HDC H3 applied 16 April, **onion, leek** sown 16 April, HDC H1 applied 18 April. Weed control score (0 no control; 7 acceptable; 10 complete control); assessment date, GS growth stage untreated (L leaf)

Herbicide	Onio				Leek				
	<i>Untreated GS:</i> <i>Assessed:</i>	n	1 L	1 ½	3 ½	½ L	1 L	1 ½ L	3 ½ L
		½ L 19/5	30/ 5	L 5/6	L 24/6	19/5	30/5	5/6	24/6
HDC H3 2.0kg		9	8	7	5	9	8	7	5
HDC H3 1.0kg		8	6	5	3	8	6	5	3
HDC H3 0.5kg		4	4	2	1	4	4	2	1
HDC H1 2.0L		8	7	5	3	8	7	5	3
HDC H1 1.0L		4.5	4	3	2	4.5	4	3	2
HDC H1 0.5L		3	2	1	1	3	2	1	1

Low scores for HDC1 poor control of high population of red dead-nettle, HDC H3 poor control of shepherd's purse

Table 26. Pre-weed-emergence HDC H3 applied 26 April, **carrot, parsnip** sown 26 April, HDC H1 applied 29 April. Weed control score (0 no control; 7 acceptable; 10 complete control); assessment date, GS growth stage untreated (TL true leaf)

Herbicide	Carrot		Parsnip		
	<i>Untreated GS:</i> <i>Assessed:</i>	2-2 ½ TL 5/6	6 ½ TL 24/6	cot-1 TL 5/6	2-3 ½ TL 24/6
HDC H3 4.0kg		8	6.5	8	6.5
HDC H3 2.0kg		6	5	5	5
HDC H3 1.0kg		4	3	3	3
HDC H1 4.0L		9.5	8.5	9.5	8.5
HDC H1 2.0L		8	6	8	6
HDC H1 1.0L		5	3	6	4

Table 27. Pre-weed-emergence HDC H3 applied 12 May, **coriander** sown 12 May, HDC H1 applied 13 May; weed control score (0 no control; 7 acceptable; 10 complete control); assessment date; GS growth stage untreated (TL true leaf)

Herbicide	Coriander		
	<i>Untreated GS:</i> <i>Assessed:</i>	1 TL 5/6	5 ½ TL 24/6
HDC H3 4.0kg		10	9.5
HDC H3 2.0kg		9	8.5
HDC H3 1.0kg		6	6
HDC H1 4.0L		10	10
HDC H1 2.0L		9.5	8.5
HDC H1 1.0L		6	5

Table 28. Pre-weed-emergence HDC H3 applied 12 May, HDC H1 applied pre-transplanting 13 May, **lettuce, cauliflower, celery** transplanted 13 May. Weed control score (0 no control; 7 acceptable; 10 complete control); assessment date

Herbicide	Celery		Cauliflower		Lettuce	
	Assessed:	5/6	24/6	5/6	24/6	5/6
HDC H3 4.0kg	9.5	9	9	9	9.5	9.5
HDC H3 2.0kg	9	8	8.5	8	9	8.5
HDC H3 1.0kg	7	6	7	6	7	6.5
HDC H1 4.0L	10	9	9*	8	10	9.5
HDC H1 2.0L	9	7	8*	6.5	9	7.5
HDC H1 1.0L	7	6	6*	5	6	4

* weeds in row after passage of planter

Table 29. Pre-weed-emergence HDC H3 applied 12 May, **peas and dwarf beans** sown 12 May, HDC H1 applied 13 May; weed control score (0 no control; 7 acceptable; 10 complete control); assessment date; GS growth stage untreated

Herbicide	peas		dwarf beans	
	Untreated GS: Assessed:	3 node 5/6	1 st open flower 24/6	simple leaf 5/6
HDC H3 4.0kg	9.5	9.5	9.5	9
HDC H3 2.0kg	9	9	9	8
HDC H3 1.0kg	7	6	5	5
HDC H1 4.0L	10	9.5	10	10
HDC H1 2.0L	9.5	9.5	10	9
HDC H1 1.0L	6	6	6	6

Table 30. Pre-weed-emergence HDC H3 applied 12 May, **swede, mizuna, spinach** sown 12 May, HDC H1 applied 13 May; weed control score (0 no control; 7 acceptable; 10 complete control); assessment; GS growth stage untreated (TL true leaf)

Herbicide	swede		mizuna		spinach	
	Untreated GS: Assessed:	2TL 5/6	5 ½ TL 24/6	3-4TL 5/6	8-9TL# 24/6	2-2 ½ TL 5/6
HDC H3 4.0kg	10	9.5	10	10	10	9
HDC H3 2.0kg	9	9	10	9	9.5	8
HDC H3 1.0kg	7.5	7	8.5	8	7	5
HDC H1 4.0L	10	9	10	9	10	10
HDC H1 2.0L	10	8	9	7	9.5	9.5
HDC H1 1.0L	8	6	7	5	7	7

Crops suppressed weeds; # past harvest stage

Table 31. Pre-weed-emergence herbicides HDC H3 (not incorporated for asparagus) and HDC H1 both applied 18 April, **asparagus** planted 16 April; weed control score (0 no control; 7 acceptable; 10 complete control); assessment date

Herbicide <i>Untreated GS:</i> <i>Assessed:</i>	asparagus spear emergence 19/5	fern flowers 4/6	fern/flower drop 24/6
HDC H3 2.0kg	9	6	5
HDC H3 1.0kg	7	4	3
HDC H3 0.5kg	3	2	1
HDC H1 4.0L	10	9	6
HDC H1 2.0L	9	7.5	4
HDC H1 1.0L	5	5	2

Post-weed-emergence treatments (predominant species in bold type)

Standard pre-emergence herbicides were applied to the less competitive crops.

No weeds remained on 19 May after pre-emergence Stomp + Ramrod (1.5 + 9.0) L/ha was applied in **onion** and **leek**

Stomp + linuron (1.6 + 1.0) L/ha was applied to **carrot and parsnip** and only a few weeds remained: redshank and small nettle.

Weed species controlled and weed control scores were therefore not recorded for these four crops.

Table 32. Post-weed-emergence herbicide applied 11 June to **coriander** (weeds larger at this later timing). Weed species controlled, weed species on untreated assessed 25 June and 7 July. Related weed counts see below

Herbicide		Weed species not controlled	Weed species controlled
HDC 50g	H4	fat-hen fig-leaved goosefoot chickweed all only slight stunting redshank annual meadow-grass groundsel field speedwell	red dead-nettle and small nettle stunted shepherd's purse
HDC 25g	H4	fat-hen fig-leaved goosefoot red dead-nettle small nettle chickweed annual meadow-grass groundsel field speedwell redshank	shepherd's purse
HDC 12.5g	H4	fat-hen fig-leaved goosefoot red dead-nettle small nettle chickweed annual meadow-grass groundsel field speedwell redshank	shepherd's purse
Untreated: red dead-nettle shepherd's purse fig-leaved goosefoot fat-hen small nettle annual meadow-grass chickweeds groundsel redshank			

Number of weed species/m² on 5 June on untreated (post-weed-emergence) for each herbicide area (mean 6 counts in 0.33 m² quadrat for 2 replicates of **coriander**)

	Fat-hen	Fig-leaved goosefoot	Red dead-nettle	Small nettle	Annual meadow-grass	Shepherd's purse	Chickweed	Redshank	Field speedwell	Groundsel	TOTAL
Untreated (HDC H4)	23	10	19	11	4	8	3	2	2	2	84

Table 33. Post-weed-emergence herbicides applied 4 June to **celery, cauliflower, lettuce**, weed species controlled, weed species on untreated assessed 16 June and 7 July. Related weed counts see below

Herbicide	Weed species not controlled	Weed species controlled
HDC H4 50g	fat-hen fig-leaved goosefoot stunted annual meadow-grass field speedwell knotgrass	red dead-nettle and small nettle stunted shepherd's purse mayweeds
HDC H4 25g	fat-hen fig-leaved goosefoot small nettle annual meadow-grass knotgrass field speedwell	red dead-nettle (stunted) shepherd's purse mayweeds
HDC H4 12.5g	fat-hen fig-leaved goosefoot small nettle annual meadow-grass red dead-nettle knotgrass field speedwell mayweeds	shepherd's purse
Untreated: red dead-nettle shepherd's purse fig-leaved goosefoot fat-hen small nettle annual meadow-grass mayweeds knotgrass		

Number of weed species / m² on 4 June on untreated (pre-weed-emergence) for the herbicide area (mean 18 counts in 0.33m² quadrat) for 2 replicates weed species on untreated plots of **celery, cauliflower, lettuce**

	Fat-hen	Fig-leaved goosefoot	Red dead-nettle	Small nettle	Knotgrass	Annual meadow-grass	Shepherd's purse	Chickweed	Mayweeds #	Field speedwells	TOTAL
Untreated (HDC H4)	21	18	25	7	2	5	25	1	3	2	109

#scented and scentless

Table 34. Post-weed-emergence herbicide applied 4 June to **peas and dwarf green beans**, weed species controlled, weed species on untreated assessed 16 June and 7 July. Related weed counts see below

Herbicide	Weed species not controlled	Weed species controlled
HDC H4 50g	fig-leaved goosefoot fat-hen annual meadow-grass knotgrass speedwells	red dead-nettle and small nettle stunted shepherd's purse mayweeds
HDC H4 25g	fig-leaved goosefoot fat-hen annual meadow-grass small nettle speedwells knotgrass	red dead-nettle stunted shepherd's purse mayweeds
HDC H4 12.5g	red dead-nettle fig-leaved goosefoot fat-hen annual meadow-grass small nettle mayweeds speedwells knotgrass	shepherd's purse
Untreated: red dead-nettle shepherd's purse fig-leaved goosefoot fat-hen annual meadow-grass small nettle mayweeds field speedwell ivy-leaved speedwell		

Number of weed species / m² on 4 June on untreated (pre-weed-emergence) for the herbicide area (mean 12 counts in 0.33m² quadrat) for 2 replicates weed species on untreated plots of **peas and dwarf green beans**

	Fat-hen	Fig-leaved goosefoot	Red dead-nettle	Small nettle	Knotgrass	Black-bindweed	Annual meadow-grass	Shepherd's purse	Chickweed	Mayweeds #	Field speedwell	Ivy-leaved speedwell	TOTAL
Untreated (HDC H4)	3	4	17	3	1	1	4	11	1	2	1	1	49

scented and scentless

Table 35. Post-weed-emergence herbicides applied 4 June to **swede, mizuna, spinach**, weed species controlled, weed species on untreated assessed 16 June and 7 July. Related weed counts see below

Herbicide	Weed species not controlled	Weed species controlled
HDC H4 50g	fig-leaved goosefoot fat-hen knotgrass chickweed	shepherd's purse red dead-nettle and small nettle stunted
HDC H4 25g	fig-leaved goosefoot fat-hen small nettle knotgrass chickweed red dead-nettle	shepherd's purse
HDC H4 12.5g	red dead-nettle fig-leaved goosefoot fat-hen small nettle knotgrass chickweed	shepherd's purse
Untreated: shepherd's purse red dead-nettle fig-leaved goosefoot fat-hen small nettle chickweed knotgrass		

Number of weed species / m² on 4 June on untreated (pre-weed-emergence) for the herbicide area (mean 18 counts in 0.33m² quadrat) for 2 replicates weed species on untreated plots of **swede, mizuna, spinach**

	Fat-hen	Fig-leaved goosefoot	Red dead-nettle	Small nettle	Shepherd's purse	Chickweed	Mayweeds	Groundsel	Knotgrass	TOTAL
Untreated (HDC H4)	2	3	5	3	9	1	1	1	2	25

Table 36 . Post-weed-emergence herbicide applied 4 June at fern stage when weeds were very large: weed species remaining after treatment, weed species controlled, weed species on untreated plots of **asparagus** assessed 4 and 25 June. Related weed counts see below

Herbicide	Weed species not controlled	Weed species controlled
HDC H4 50g	fat-hen fig-leaved goosefoot small nettle chickweed annual meadow-grass ivy-leaved speedwell field speedwell knotgrass	red dead-nettle stunted shepherd's purse
HDC H4 25g	fat-hen fig-leaved goosefoot red dead-nettle small nettle annual meadow-grass chickweed knotgrass ivy-leaved speedwell field speedwell	shepherd's purse
HDC H4 12.5g	fat-hen fig-leaved goosefoot red dead-nettle small nettle annual meadow-grass chickweed ivy-leaved speedwell field speedwell knotgrass	shepherd's purse
Untreated: red dead-nettle fat-hen fig-leaved goosefoot small nettle annual meadow-grass chickweed shepherd's purse ivy-leaved speedwell field speedwell knotgrass		

Number of weed species / m² on 4 June on untreated (pre-weed-emergence) for the herbicide area (mean 6 counts in 0.33m² quadrat) in 2 replicates weed species on untreated plots of **asparagus**

	Fat-hen	Fig-leaved goosefoot	Red dead-nettle	Small nettle	Knotgrass	Annual meadow-grass	Shepherd's purse	Chickweed	Ivy-leaved speedwell	Field speedwell	TOTAL
Untreated (HDC H4)	18	9	23	20	2	87	17	8	3	2	95

Weed Control Scores Post-weed-emergence herbicide (mean of two replicates)

Standard pre-emergence herbicides were applied: Stomp + Ramrod (1.5 + 9.0) L/ha to **onion and leek**, Stomp + linuron (1.6 + 1.0) L/ha to **carrot and parsnip** and only a few weeds remained: redshank and small nettle. Weed control scores were not recorded.

Table 37. Post-weed-emergence herbicide applied 11 June to **coriander** (later timing and larger weeds than other crops). Weed control score (0 no control; 7 acceptable; 10 complete control); assessment date

Herbicide	coriander	
Assessed:	25/6	7/7bolting
HDC H4 50g	0	0
HDC H4 25g	0	0
HDC H4 12.5g	0	0

Table 38. Post-weed-emergence herbicide applied 4 June to **celery, cauliflower, lettuce** transplants. Weed control score (0 no control; 7 acceptable; 10 complete control); assessment date

Herbicide	celery		cauliflower		lettuce	
	Assessed:					
	25/6	7/7	25/6	7/7	25/6	7/7 harvest
HDC H4 50g	3.5	2	2	2	1	1
HDC H4 25g	1.5	1	1.5	1	1	1
HDC H4 12.5g	1	0.5	0	0.5	1	0.5

Table 39. Post-weed-emergence herbicide applied 4 June to **peas** and **dwarf French beans**. Weed control score (0 no control; 7 acceptable; 10 complete control); assessment date

Herbicide	peas		dwarf beans	
	Assessed:			
	25/6	7/7 harvest	25/6	7/7
HDC H4 50g	1	1	2	2
HDC H4 25g	1	1	1	1
HDC H4 12.5g	0.5	0.5	0.5	0.5

Table 40. Post-weed-emergence herbicide applied 4 June to **swede, mizuna, baby-leaf spinach**. Weed control score (0 no control; 7 acceptable; 10 complete control) ; assessment date

Herbicide	Swede		Mizuna		Spinach	
	Assessed:					
	25/6	7/7	25/6	7/7#	25/6	7/7#
HDC H4 50g	1.5	1	1	1	0.5	0
HDC H4 25g	1	1	1	1	0.5	0
HDC H4 12.5g	0.5	0.5	0.5	0.5	0.5	0

past harvest stage

Table 41. Post-weed-emergence herbicide applied 4 June to **asparagus** (larger weeds than other crops) at fern stage. Weed control score (0 no control; 7 acceptable; 10 complete control); assessment date

Herbicide	asparagus	
	Assessed:	
	25/6	7/7
HDC H4 50g	1	1
HDC H4 25g	0	0
HDC H4 12.5g	0	0

'Volunteer' potato control**Table 42. 'Volunteer' potato control;** HDC H3 applied 16 April and soil incorporated and 4 potatoes/ plot planted 16 April, HDC H1 applied 18 April. Number of emerged potato shoots on two replicates.

Herbicide/ha	Number potatoes emerged	Number potatoes emerged	Number potato shoots
<i>Assessment date:</i>	14 May	19 May	30 May
<i>Pre-plant incorporated</i>			
HDC H3 4.0kg	0	1	6 st one shoot/plant
HDC H3 2.0kg	0	4 st	7 st (2-3 shoots/plant)
HDC H3 1.0kg	4	7	8 st (2-3 shoots/plant)
Untreated	8	8	8 (2-3 shoots/plant)
<i>Pre-emergence</i>			
HDC H1 4.0L	8	8	8
HDC H1 2.0L	6	6	6
HDC H1 1.0L	8	8	8
Untreated	8	8	8

st stunted

Post-emergence herbicide HDC H4 applied on 26 May when there were 3 shoots per potato plant. Potato shoot control scores (0=no control, 10=complete kill of foliage) mean of two replicates

Herbicide/ha	Control potato shoots	
<i>Assessment date:</i>	16/6	7/7
<i>Post-weed-emergence</i>		
HDC H4 50g	0	0
HDC H4 25g	0	0
HDC H4 12.5g	0	0

HDC H4 had no effect on potatoes except for slight temporary yellowing centres of plant observed on 4 June

Conclusions

The aim of this trial was to screen herbicides for crop safety, with a view to further development and applications for SOLAs. The trial was on a light, silt loam soil. Promising herbicides also need to be tested on very light soils/sands where appropriate for the crop. Irrigation after application of residual soil-acting herbicides and heavy rainfall during the second week of June provided a stringent test of crop safety.

Crop safety (Tables 1, 2 and 5-16)

A residual herbicide is essential for slow-emerging crops, such as parsnips, or in a quick growing crop (coriander, mizuna, lettuce, baby-leaf spinach) where the time from planting/sowing to harvest is short.

This study has identified potential alternative herbicides (Tables 1 and 2) which, on limited data on a light soil, would appear to be non-phytotoxic to several vegetable crops, at the timing and dose rates suggested. The most promising safe and effective herbicides, rate product/ha were for:

Onion, leek: post-weed-emergence sulfonylurea HDC H4 at 25 g/ha where mayweeds, shepherd's purse and volunteer oilseed rape may be a problem.

Carrot, parsnip and coriander: HDC H1 at 2.0 L/ha pre-emergence controls several weed species including mayweeds but tank-mix parthers would be needed to control Polygonums (pendimethalin) and groundsel (clomazone), HDC H3 2.0 Kg/ha (1200 g a.i./ha) pre-sowing and soil incorporated would be useful where knotgrass and fat-hen are problems.

Celery transplants: HDC H3 2.0 Kg/ha (1200 g a.i./ha) pre-planting and soil incorporated.

Lettuce transplants: HDC H3 2.0 Kg/ha (1200 g a.i./ha) pre-planting and soil incorporated.

Cauliflower transplants: HDC H3 2.0 Kg/ha (1200 g a.i./ha) pre-planting and soil incorporated would be a replacement for trifluralin. It is effective under dry soil conditions and would be compatible with tractor hoeing. Efficacy on knotgrass, redshank and black-bindweed, fat-hen and annual meadow-grass is good but shepherd's purse, groundsel and mayweed will remain.

Vining peas: HDC H1 at 2.0 L/ha pre-emergence.

Dwarf French beans: HDC H1 at 2.0 L/ha pre-emergence controls volunteer oilseed rape; HDC H4 at 25 g/ha post-emergence.

Swede: HDC H3 at 2.0 Kg/ha (1200 g a.i./ha) pre-planting and soil incorporated also a replacement for trifluralin.

Mizuna: HDC H3 at 1.0 Kg/ha (600 g a.i./ha) pre-planting and soil incorporated.

Baby-leaf spinach: HDC H1 possibly at 2.0 L/ha pre-emergence, is worth investigation

Asparagus crowns: HDC H1 at 2.0 L/ha pre-emergence was included in FV 372 asparagus trials at Spalding and Salford Priors in 2010.

Weed control (Tables 3, 4 and 17-42)

Latin names for weeds are given in Appendix 1.

Summaries for control of weed species are shown in Tables 3 and 4.

On untreated areas for the earlier drilled plots there were high populations of red dead-nettle, small nettle, shepherd's purse, chickweed, pineappleweed (in onion and leek) and annual meadow-grass. Other weed species were fat-hen, fig-leaved goosefoot, groundsel and speedwells. In the later drilled/transplanted crops weed populations on untreated areas were lower - predominantly fat-hen, fig-leaved goosefoot, with fewer red dead-nettle, small nettle and shepherd's purse. Mayweed species were scented and scentless. There were a few knotgrass and redshank in some plots.

HDC H3, a residual herbicide, affects seed germination and inhibits growth of shoots and roots. It is applied before sowing or planting and soil-incorporated and is effective in dry soil conditions. Efficacy was poor where it was not soil-incorporated. It controlled several species at 2.0 Kg/ha (1200 g a.i./ha) - importantly Polygonums, fat-hen and annual meadow-grass, but not groundsel, shepherd's purse or mayweeds.

HDC H1, a residual herbicide, was applied pre-emergence of drilled crop and weed, and before transplanting. HDC H1 gives good control of volunteer oilseed rape (data from other trials). Weeds controlled included fat-hen, small nettle, shepherd's purse, annual meadow-grass and a low population of mayweeds but it was less effective on groundsel and had weaknesses on Polygonums, red dead-nettle, and speedwells.

HDC H4, a sulfonylurea, was applied post-weed-emergence, post-emergence of drilled crops and post transplanting. Most weed species at this site were not susceptible to N (normal) dose of 25 g/ha including Polygonums, fat-hen, fig-leaved goosefoot, groundsel and annual meadow-grass therefore weed control was poor. Here, it was only effective on

shepherd's purse and a low population of mayweeds, but it would control volunteer oilseed rape.

Potatoes are a frequent problem in vegetable crops.

HDC H3 at 4.0 kg/ha (2400g a.i./ha) applied pre-planting and soil incorporated delayed potato emergence by 16 days compared to untreated potatoes and reduced the number of shoots/plant and potato apple numbers. This would be of benefit in uncompetitive crops that are slow to emerge but unfortunately the 'Normal' 2.0 kg/ha dose had less effect.

HDC H1 had no effect on emergence of potato and did not suppress growth.

HDC H4 applied post-emergence of the potatoes caused negligible effect. Neither treatment prevented formation of potato apples,

Recommendations

HDC H3 and HDC H1 were identified as potentially useful for a wide range of vegetable crops. HDC H4 has potential for use in alliums and dwarf French beans. These herbicides are confidential and none have UK authorisations for a major crop. When this is achieved, residues data will be needed for the minor crops. It is recommended that:

- Residues data, are obtained if available from other countries, to support SOLA applications by HDC and to set up trials where they are not available. For a few crops authorisation will be possible through 'Mutual Recognition'.
- Evaluation of new herbicides in this early stage screening system should be continued.

Herbicides: Current Approval Status (August 2010)

Herbicide Product & timing	Company	active substance	EC Review status	N rate product	Registered now or in future?
HDC H3 pre-sowing/pre-transplant soil incorporated	Confidential	Confidential	Annex 1	2.0 kg/ha (1200g a.i./ha)	<i>No UK registration yet.</i>
HDC1 pre-emergence, pre-transplant	Confidential	Confidential	Not yet on Annex 1	2.0 L/ha	<i>No EU registration yet</i>
HDC H4 post-plant, early post-weed-emergence	Confidential	Confidential	Annex 1	25 g/ha	<i>No UK registration yet</i>

Technology Transfer

2010

Field demonstration of trial at Elsoms seeds trial ground: 1 July 2010: HDC open day, 15 July to British Carrot Growers Association and separate visits from Crop Protection Companies and agronomists.

Article FV 256c results 2010 trial to be submitted for HDC News.

Appendix 1: Weeds found on the untreated trial areas

Latin name	Common name
<i>Capsella bursa-pastoris</i>	Shepherd's purse
<i>Chenopodium album</i>	Fat-hen
<i>Chenopodium ficifolium</i>	Fig-leaved goosefoot
<i>Lamium purpureum</i>	Red dead-nettle
<i>Matricaria discoidea</i>	Pineappleweed
<i>Matricaria inodorum</i>	Scentless mayweed
<i>Matricaria recutita</i>	Scented mayweed
<i>Persicaria maculosa</i>	Redshank
<i>Poa annua</i>	Annual meadow-grass
<i>Polygonum aviculare</i>	Knotgrass
<i>Polygonum convolvulus</i>	Black-bindweed
<i>Senecio vulgaris</i>	Groundsel
<i>Stellaria media</i>	Common chickweed
<i>Urtica urens</i>	Small nettle
<i>Veronica persica</i>	Common field speedwell
<i>Veronica hederifolia</i>	Ivy-leaved speedwell