Project title:	Solutions to the loss of active ingredients for weed control in vegetable crops (Continuation)
Project number:	FV 256b
Project leaders:	Cathy Knott, (private consultant) 55 Church St, Werrington Peterborough PE4 6QU Tel: 01733 575001 Charlie Woods, Kirton Science Manager Warwick HRI Kirton Research Centre Kirton Boston PE20 1NN
Report:	Final report, September 2008
Previous reports:	Final reports FV 256 2004, 2005, 2006; FV 256a 2007
Key staff:	Cathy Knott, Herbicide Specialist Geoff Clarke, Research Assistant, Warwick HRI Kirton Roy Kitchen, Warwick HRI Kirton
Location of project:	Warwick HRI Kirton
Project coordinator:	HDC Vegetable Panel Members
Date project commenced:	01 February 2008
Date completion due:	30 September 2008
Key words:	Drilled: bulb Onion, Leek, Carrot, Parsnip, Coriander, Swede, Vining peas, Baby-leaf spinach, Dwarf French beans, Transplants: Celery, Cauliflower, Lettuce; 'Volunteer' potatoes; Crop safety, herbicides, pre-weed emergence A 12333D (prodiamine), post-weed-emergence A 12333D, pyroxulam, OS159 (pyraflufen-ethyl)

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
Independent Herbicide Private Consultant

Signature ..... Date .. 5 September 2008
.....

[Name]
[Position]
[Organisation]

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

Report authorised by:

[Name]
[Position]
[Organisation]

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

[Name]
[Position]
[Organisation]

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

CONTENTS

Grower Summary

Headline

Potential alternative herbicides for the future, which appear to be safe (non-phytotoxic) to a few crops have been identified and are worth further evaluation. Vegetable crops in trial were: drilled bulb onion, leek, carrot, parsnip. coriander, vining pea, dwarf French bean, swede, baby leaf spinach; transplanted celery, cauliflower and lettuce. No herbicide controlled the "volunteer" potatoes.

- A 12333D (prodiamine) at 2.0 L/ha applied pre-weed-emergence appeared safe to onion, leek, carrot, parsnip, coriander and safe pre-transplanting to celery and cauliflower. It may also be safe to dwarf French bean, vining pea and lettuce at 1.0 L/ha. It controlled a wide weed spectrum but not groundsel. It had little foliar activity on weeds and was safe to crops except for spinach and dwarf French bean. This herbicide appears very promising but a decision has yet to be made regarding introduction in Europe.
- Pyroxulam at a low dose rate of 50 g/ha applied post-emergence of crop and weed, has potential for use in onion, leek and carrot. It controlled several species at this dose but had a weakness on fat-hen and mayweeds.
- OS159 (pyraflufen-ethyl) at a low dose of 0.1 L/ha applied post-emergence of crop and weed was only safe to waxy-leaved onion, leek, cauliflower, swede and at 0.2 L/ha to vining pea. Weed control was poor and it was only effective on small nettle.

Background and expected deliverables

Crop Protection Companies no longer screen new herbicides on minor crops. Important herbicides for vegetable growers were lost in the 91/414/EEC Review. There were some derogations for "Essential Uses" but these expired 31 December 2007. Trifluralin cannot be used after 20 March 2009, propachlor not after September 2010. In addition, at product re-registration stage in the UK, dose rates of several herbicides included on Annex 1 have been reduced (e.g. linuron, pendimethalin). Alternatives are therefore sought and HDC project FV 256 screened "new" herbicides for crop tolerance in 2004, 2005, 2006, 2007 and 2008. The overall aim of this project is 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 all pesticides is uncertain as a result of the 91/414/EEC revision.
- Establish a screening system 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.
- 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

Herbicides were applied at 2 x Normal, Normal, ½ Normal dose rates in all crops, except onion and leek, where Normal, ½ Normal, ¼ Normal dose rates were used. In the 2008 trial pyroxulam was applied at a lower dose rate and as a different formulation from the product for winter wheat. 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 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-weed-emergence herbicides applied pre-emergence of drilled crops and pre-transplanting: √ safe; x not safe

Herbicide 'Normal' dose/ha	Onion	Leek	Carrot	Parsnip	Coriander	Celery transplants	Cauliflower transplants	Lettuce transplants	Dwarf Bean	Vining Pea	Swede	Spinach
A 12333D 2.0L	√	√	√	√	√	√	√	√ ½N	√ ½N	√ ½N	**x**	**x**

Table 2. Post-weed-emergence herbicides: √ safe; x not safe

Herbicide 'Normal' dose/ha	Onion, Bulb	Leek	Carrot	Parsnip	Coriander	Celery transplants	Cauliflower transplants	Lettuce transplants	Dwarf Bean	Vining Pea	Swede	Spinach
A 12333D 2.0L	√	√	√	√	√	√	√	√	x	√	√	x
pyroxulam N 50g	√	√	√	x	x	x	√ ½N	√ ½N	x	x	x	x
OS159 0.2L	√ ½N#	√ ½N	x	x	x	x	√ ½N	x	x	√	√ ½N	x

#√ ¼ N for salad onions; A 12333D did not control emerged weeds except for small nettle.

Weed species controlled

Appendix 1 shows Common and Latin weed names.

There were extremely high populations of small nettle, shepherd's purse and redshank on this trial site. Other predominant weed species were chickweed, mayweeds, and groundsel. There were a few fat-hen, smooth sow-thistle and black bindweed and numbers were variable.

Pre- and post-emergence herbicides gave no suppression of 'volunteer' potatoes. An extra treatment, Nirvana (pendimethalin/imazamox) at Normal and twice N dose rates, did not suppress potatoes or prevent potato berry formation in this trial.

Table 3. Pre-weed-emergence herbicides: √ weed species controlled; x poor control or not controlled at various dose rates

Pre-weed-emergence Herbicide dose rate/ha	Small nettle	Shepherd's purse	Redshank	Groundsel	Chickweed	Smooth sow-thistle	Mayweeds#	Fat-hen	Black-bindweed
A 12333D 4.0L	√	√	√	x	√	√	√	√	√
A 12333D 2.0L	√	√	√	x	√	x	√	√	√
A 12333D 1.0L	√	√	√	x	√	x	√	√	√
A 12333D 0.5L	x	x	x	x	x	x	x	x	x

scentless mayweed and 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	Redshank	Pale persicaria	Groundsel	Chickweed	Smooth sow-thistle	Mayweeds#	Fat-hen	(Annual meadow-grass)	(Field speedwell)	Black-bindweed	(Field pennycress)
A 12333D 4.0L	√	x	x	x	x	√	x	x	x	-	-	x	-
A 12333D 2.0L	√	x	x	x	x	x	x	x	x	-	-	x	x
A 12333D 1.0L	√	x	x	x	x	x	x	x	x	-	-	x	x
A 12333D 0.5L	x	x	x	x	x	x	x	x	x	-	-	x	x
pyroxulam 100g	√	√	√	√	√	√	x	x	x	-	-	x	-
pyroxulam 50g	√	√	√	√	√	√	x	x	x	-	-	x	-
pyroxulam 25g	√	√	x	x	x	√	x	x	x	-	-	x	-
pyroxulam 12.5g	x	x	x	x	x	x	x	x	x	-	-	x	-
OS159 0.4L	√	x	x	x	x	x	x	x	x	x	x	x	-
OS159 0.2L	√	x	x	x	x	x	x	x	x	x	x	x	-
OS159 0.1L	√	x	x	x	x	x	x	x	x	x	x	x	-
OS159 0.05L	√	x	x	x	x	x	x	x	x	x	x	x	-

scentless mayweed and pineappleweed; pyroxulam 50g/ha suppressed creeping thistle

All herbicides caused severe damage to baby-leaf spinach. Only A12333D was safe to coriander,

A12333D (prodiamine), a residual herbicide appears very promising but a decision has yet to be made regarding introduction in Europe. A12333D at 2.0 L/ha applied pre-weed-emergence appeared safe to onion, leek, carrot, parsnip, coriander and safe pre--transplanting to celery and cauliflower. It may possibly be safe to dwarf French bean, vining pea and lettuce at 1.0 L/ha. It caused severe damage to spinach and swede.
Efficacy was excellent for high populations of a range of important weeds: small nettle, shepherd's purse, redshank, black-bindweed, chickweed, mayweeds and fat-hen but groundsel was not controlled. Other work (in the US) shows that it also controls knotgrass, amaranthus and annual meadow-grass. However, A 12333D was less effective in the earlier-sown onion and leek, possibly because conditions were cooler and a little drier after application than for later timings.

A12333D had little foliar activity post-emergence and appeared to be safe to all crops except spinach and dwarf French bean when applied at 2.0 L/ha. In wet conditions there was some soil residual activity and control of small nettle. At 4.0 L/ha it affected the stem base of bean and caused breakage.

Pyroxulam at a low dose rate of 50 g/ha applied post-emergence of crop and weed, has potential for use in onion, leek and carrot. It controlled several species including small nettle, shepherd's purse, redshank and pale persicaria and groundsel at this dose but had weaknesses on fat-hen, black-bindweed and mayweeds.

OS159 (pyraflufen-ethyl) at a low dose of 0.1 L/ha applied post-emergence of crop and weed was only safe to waxy-leaved onion, leek, cauliflower, swede and at 0.2 L/ha to vining pea. At 0.2 and 0.1 L/ha OS159 caused a kink in the onion leaves that were present at the time of application and could be unsuitable for salad onions. Weed control was poor and it was only effective on small nettle. It did not kill volunteer potatoes at the doses used.

A potential alternative herbicide, which appears to be safe (non-phytotoxic) to several crops was identified and is worth further evaluation if the company plan to proceed with development in the EU. Further work would be needed on: A12333D (prodiamine) applied pre-emergence pre-and post-transplanting of the tolerant crops (Table 1) particularly carrots and parsnips, parsley and transplanted brassicas.

Herbicides: Current Approval Status (August 2008)

Herbicide Product	**Company**	**active substance and formulation**	**'N' rate/ha**	**EC Review status**	**Registered now *or in future?***
Pre-weed-emergence					
A 12333D Pre-transplants	Syngenta	prodiamine 480 g/l SC	2.0 L		*cereals, grass?*
Post-weed-emergence (2+ weeks after transplanting)					
A 12333D	Syngenta	prodiamine 480 g/l SC	2.0 L		*cereals, grass?*
	Dow	pyroxulam 75% wg	50 g	New not on Annex 1 yet	Submitted different dose and formulation UK registration cereals
OS159	Nihon-Nohyaku	pyraflufen-ethyl # 20 g/L SC	0.2 L	Annex 1	UK potato desiccant at 0.8 L/ha dose rate,

Financial benefits

The safety of a range of vegetable crops to some alternative herbicides and the potential for SOLAs has been identified in this early stage screening trial. However, some 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 salad onions or leaf crops coriander and baby-leaf spinach unmarketable.

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.

As a result of the 91/414/EEC pesticide review programme, growers have lost key herbicides. In addition, at product re-registration stage, dose rates of several herbicides included on Annex 1 have been reduced in the UK (e.g. linuron, pendimethalin). **The future of nearly all herbicides is now uncertain as a result of the 91/414/EEC revision.**

Action points for growers

- Establish an 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.
- A potential alternative residual herbicide for the future that appears to be safe (non-phytotoxic) to several crops has been identified in 2008 and further work is needed to assess crop safety efficacy and programmes. However this depends on a company decision.
- 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.

The overall aim of this project is to create a system for preliminary herbicide screening on a range of horticultural 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 through the SOLA programme).

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. However, the future of all pesticides is uncertain under the proposals for the new regulation 91/414/EEC.

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: Warwick HRI Kirton

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

Crop details: Crops were sown with a Stanhay Singulaire drill, on a 1.83 m bed of 4 rows/plot on 40 cm row width at high populations, except for peas and beans, which were sown with a Planet push drill in double rows. Press wheels on drills ensured a fine, firm seedbed therefore plots were not rolled. Transplants were planted with a machine –a Michigan planter with 3 rows/plot, except for lettuce - 4 rows/plot.

Trial Design: Plot size 2 m long x 1 bed width (1.83 m), 2 replicates each treatment (total 416 plots).

Sowing dates and herbicide application dates 2008

Pre-weed-emergence			
Crop (Variety)	***Sowing/transplant date***	***Crop Growth stage***	***Date applied***
Onion (Wellington)	17 April	Pre-emergence	18 April
Leek ((Roxton)	17 April	Pre-emergence	18 April
Dwarf French Bean (Parker)	16 May	Pre-emergence	16 May
Pea (Cabree)	16 May	Pre-emergence	16 May
Celery transplant (Victoria)	15 May	after transplanting	15 May
Cauliflower transplant (Fremont)	15 May	after transplanting	15 May
Lettuce iceberg transplant (Challenge)	15 May	after transplanting	15 May
Coriander (Santos)	16 May	Pre-emergence	16 May
Swede (Magres)	16 May	Pre-emergence	16 May
Spinach baby-leaf (Whale)	16 May	Pre-emergence	16 May
Carrot (Nairobi)	2 May	Pre-emergence	2 May
Parsnip (Javelin)	2 May	Pre-emergence	2 May

Post-emergence plots: a standard 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.

Post-weed-emergence			
Crop (Variety)	*Sowing/ plant date*	*Crop Growth stage*	*Date applied*
Onion (Wellington)	17 April	2 Leaves	10 June B D, 11 June C
Leek ((Roxton)	17 April	2 Leaves	10 June B D, 11 June C
Dwarf French Bean (Parker)	16 May	Simple Leaf	10 June B D, 11 June C
Pea (Cabree)	16 May	2-3 node	10 June B D, 11 June C
Celery transplant (Victoria)	15 May	established	10 June B D, 11 June C
Cauliflower transplant (Fremont)	15 May	established	10 June B D, 11 June C
Lettuce Iceberg transplant (Challenge)	15 May	established	10 June B D, 11 June C
Coriander (Santos)	16 May	2 True Leaves	17 June B C D
Swede (Magres)	16 May	2 True Leaves	10 June B D, 11 June C
Spinach baby leaf (Whale)	16 May	2 True Leaves	10 June B D, 11 June C
Carrot (Nairobi)	2 May	2 True Leaves	10 June B D, 11 June C
Parsnip (Javelin)	2 May	1-2 True Leaves	17 June B C D
Potatoes	17 April	Large, flower buds	10 June B D, 11 June C

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. Pre-emergence dose rates were appropriate for the light soil type.

Code	**Herbicide Product**	**Company**	**active substance and formulation**	**'N' rate/ ha**
Pre-weed-emergence				
A	A 12333D 2d post transplants	Syngenta	prodiamine 480 g/l SC	2.0 L
Post-weed-emergence (2+ weeks after transplanting)				
B	A 12333D early 2d post transplants	Syngenta	prodiamine 480 g/l SC	2.0 L
C	post transplants	Dow	pyroxulam 75% wg	50 g
D	OS159 post transplants	Nihon-Nohyaku	pyraflufen-ethyl # 20 g/L SC	0.2 L

tested in formulation with bifenox FV 256 in 2004, not tested alone

Application Data

Sprays were applied using an Oxford precision sprayer with a 2 m boom and four 110º flat fan nozzles (BCPC code F110/0.80/3) delivering 200 L/ha water volume at 2 bar pressure to give fine spray quality. Rainfall and irrigation data are shown in Appendix 2.

Pre-weed-emergence Herbicide Trial

Date	Weather	GS Crop; Soil
Pre-emergence Onion & Leek (sown 17 April)		
18 April A	7.4ºC; 80% RH; cloud cover 8; rain after application trace.	Sowing depth 1 cm; fine seedbed, surface damp
Pre-emergence Carrot & Parsnip (sown 2 May)		
2 May A	11.3ºC; 76% RH; cloud cover 1; rain after application trace	Sowing depth 1 cm; fine seedbed, surface dry
Pre -transplant pre-weed-emergence Celery, Lettuce & Cauliflower (planted 15 May)		
15 May A	13.5ºC; 83% RH; cloud cover 4; no rain after application, irrigation 16 May 13mm	fine seedbed, surface dry
Peas, Dwarf Beans, Swede, Spinach, Coriander (sown16 May)		
16 May A	12.8ºC; 63% RH; cloud cover 8; no rain after application, irrigation 16 May 13mm	Sowing depth 1 cm, peas 2cm; fine seedbed, surface dry

Post-weed-emergence Herbicide Trial

Standard pre-emergence herbicide Normal dose was applied: on 19 April onions and leeks Ramrod + Stomp (9.0 + 1.5) L/ha; on 11 May 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)
Post-weed-emergence Onion, Leek, Carrot, Swede, Spinach, Celery, Lettuce & Cauliflower, Peas, Beans, Potatoes			
10 June B & D	16.9ºC; 73% RH; cloud cover 7; no rain after application until 11 June 2.5mm	Onion 2 L, Leek 2 L, Carrot 2 TL Swede, Spinach 2-4TL; pea 2-3 node, bean simple leaf; transplants established; potatoes 50 cm tall, buds.	Large redshank, nettle, black-bindweed Large fat-hen, redshank small nettle cotyledon-2 - 4TL, redshank 1 -2TL; groundsel, chickweed 6 TL, black-bindweed 1 TL,
Post-weed-emergence Onion, Leek, Carrot, Swede, Spinach, Celery, Lettuce & Cauliflower, Peas, Beans, Potatoes			
11 June C	17.0ºC; 73% RH; cloud cover 2; rain later 2.5mm	As above	As above
Post-weed-emergence Coriander, Parsnip			
17 June B, C & D	13.8ºC (20ºC later); 81% RH; cloud cover 6; no rain after application until 18 June 0.3mm	coriander 2 TL, Parsnip 1-2 TL	small nettle chickweed 4-6TL, redshank 2TL, groundsel, black-bindweed 1-2 TL Large fat-hen, redshank

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.
- 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).

Weather and Irrigation at Kirton (Appendix 2)
April was cooler than in previous years at Kirton. Temperatures were above average in May, but there was negligible rainfall until 24 May and irrigation was therefore applied (Appendix 2). The last week in May until 4 June was very wet. June was cooler and cloudier than in recent years with frequent rainfall that maintained vigorous growth of crops and weeds. July was very windy, with above average temperatures in the latter part of the month and rainfall was also higher than average.

Results and Discussion

Crop tolerance

No adverse effects were observed on carrot or parsnip roots from any herbicide.

Phytotoxicity symptoms pre-weed-emergence herbicide (Tables 5-9)
A12333D
A12333D at 2.0 L/ha applied pre-weed-emergence appeared safe to drilled onion, leek, carrot, parsnip, coriander and safe pre--transplanting to celery and cauliflower. It may possibly be safe to dwarf French bean, vining pea and lettuce at 1.0 L/ha. However, at early stages (1-2 nodes) vining peas suffered severe leaf-crinkling and distortion from all doses although subsequent growth was normal, and a similar effect was noted at a later growth stage in dwarf French beans. At 4.0 L/ha it caused slight stunting in several crops and delayed and appeared to reduce emergence of coriander.
The most sensitive crops were baby-leaf spinach and swede – they were chlorotic at cotyledon stage and died soon after emergence.

Phytotoxicity symptoms post-weed-emergence herbicides (Tables 10-14)
A12333D
A12333D is a residual soil-acting herbicide with little foliar activity and applied post-weed-emergence it was safe at 2.0 L/ha to drilled onion, leek, carrot, parsnip, coriander, swede and safe to celery, cauliflower and lettuce, transplants. A12333D at 4.0 L/ha dose rate caused stunting in most of these crops, particularly swede. A12333D, at all dose rates tested, caused very severe damage observed soon after application to spinach and dwarf French beans in the form of leaf crinkling and distortion. The 4.0 L/ha dose damaged the stem base of beans and caused breakage.

Pyroxulam

Pyroxulam is a foliar acting, translocated herbicide. A lower dose and different formulation from that authorised for cereals was used in this trial, but it caused severe damage to several crops. Initial effects were chlorosis and wilting followed by stunting. Swede and spinach were the most sensitive crops to all dose rates, dying within days of application. All dose rates also killed parsnip and coriander and caused very severe stunting in celery. Peas became very stunted and produced multiple shoots, and in dwarf French beans there was no further growth after application. Onion, leek and possibly carrot were safe to pyroxulam at 50 g/ha. Pyroxulam applied at 25 g/ha was marginally safe to cauliflower and surprisingly, lettuce.

OS 159 (pyraflufen-ethyl)

Pyraflufen-ethyl is a contact-acting desiccant. Damage symptoms were scorch, occurring in several vegetables. It was only safe to some waxy-leaved crops – vining peas were tolerant of 0.2 L/ha, 0.2 L/ha was safe to leek and 0.1 L/ha to bulb onion, At 0.2 and 0.1 L/ha pyraflufen-ethyl caused a kink in those onion leaves present at the time of application and may therefore only be suitable for salad onions at 0.05 L/ha. Pyraflufen-ethyl caused scorch and white leaf spotting in cauliflower, but the new growth was not affected and the 0.1 L/ha dose rate was safe. Swede recovered from initial scorch and 0.1 L/ha appeared safe. In dwarf French beans pyraflufen-ethyl at all dose rates killed the first simple leaves and caused distortion of trifoliate leaves. The beans recovered to some extent but the harvest delays would be unacceptable. Lettuce and spinach were the most sensitive crops, both suffering distortion and spinach leaves also became narrowed, plant death followed.

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-weed-emergence herbicides applied pre-emergence of drilled crops and pre-transplanting: √ safe; x not safe

Herbicide 'Normal' dose/ha	Onion	Leek	Carrot	Parsnip	Coriander	Celery transplants	Cauliflower transplants	Lettuce transplants	Dwarf Bean	Vining Pea	Swede	Spinach
A 12333D 2.0L	√	√	√	√	√	√	√	√ ½N	√ ½N	√ ½N	x	x

Table 2. Post-weed-emergence herbicides: √ safe; x not safe

Herbicide 'Normal' dose/ha	Onion, Bulb	Leek	Carrot	Parsnip	Coriander	Celery transplants	Cauliflower transplants	Lettuce transplants	Dwarf Bean	Vining Pea	Swede	Spinach
A 12333D 2.0L	√	√	√	√	√	√	√	√	x	√	√	x
pyroxulam N 50g	√	√	√	x	x	x	√ ½N	√ ½N	x	x	x	x
OS159 0.2L	√ ½N #	√ ½N	x	x	x	x	√ ½N	x	x	√	√ ½N	x

#√ ¼N for salad onions; A 12333D did not control emerged weeds except for small nettle.

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

Table 5. Onion and leek sown 17 April, pre-emergence herbicides applied 18 April, onion and leek emerged 6 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** **8/5** **loop**	**15/5** **1 L**	**2/6** **1 ½ -2L**	**8/6** **2-3 L**	**10/7** **4 ½ L**	**Leek** **8/5** **loop**	**15/5** **½ L**	**2/6** **1 ½ L**	**8/6** **2 ½ L**	**2/7** **4 L**
A 12333D 2.0 L	N	10	10	10	9st	9	10	10	10	8st	8
A 12333D 1.0L	½ N	10	10	10	10	10	10	10	10	10	10
A 12333D 0.5L	¼ N	10	10	10	10	10	10	10	10	10	10

st stunting

Table 6. Carrot and parsnip sown 2 May, pre-emergence herbicides applied 2 May, carrot emerged 27 May, parsnip 2 June. Coriander sown 16 May, pre-emergence herbicides applied on 16 May, coriander emerged on 2 June. 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**	**Carrot** **27/5** **cot**	**2/6** **1-2 TL**	**8/6** **3 TL**	**2/7** **6 TL**	**Parsnip** **2/6** **cot**	**8/6** **cot -1 TL**	**2/7** **4 TL**	**Coriander** **2/6** **cot**	**8/6** **cot-1 TL**	**2/7** **5 TL**
A 12333D 4.0 L	2N	10	10	8 1TL st	9 st	10	6st	9 st	9del	8cot del red	8 st
A 12333D 2.0L	N	10	10	9	10	10	8	10	10	10	10
A 12333D 1.0L	½ N	10	10	10	10	10	9	10	10	10	10

red reduced emergence; del delayed emergence; st stunting

Table 7. Celery, cauliflower and lettuce transplanted 15 May: pre-weed-emergence herbicide applied 15 May pre-transplanting. Assessment date, growth stage, crop damage score (0 total kill; 7 acceptable; 10 no damage)

Herbicide ***Assessment date:*** ***Untreated GS:***	**Rate**	**Celery** **27/5**	**2/6** **2 ½ new L**	**8/6** **3 ½ L**	**2/7**	**Cauliflower** **27/5**	**2/6**	**8/6**	**2/7**	**Lettuce** **27/5**	**2/6**	**8/6**	**2/7** **harvest**
A 12333D 4.0 L	2N	10	10	7 st	8	10	10	8 st	9	10	9 st	5 cl st	4 st
A 12333D 2.0L	N	10	10	10	10	10	10	9	10	10	10	7	6
A 12333D 1.0L	½ N	10	10	10	10	10	10	10	10	10	10	9	10

cl chlorosis; st stunting

Table 8. Vining peas, dwarf French beans sown 16 May, pre-emergence herbicides applied 16 May. Peas emerged 27 May, dwarf bean emerged 31 May. Assessment date, growth stage, crop damage score (0 total kill; 7 acceptable; 10 no damage)

Herbicide ***Assessment date:*** ***Untreated GS:***	**Rate**	**Pea** **27/5**	**2/6** **1-2 node**	**8/6** **2-3 node**	**2/7** **1st flower open**	**Dwarf beans** **2/6** **em-simple L**	**8/6** **simple L**	**2/7** **2 trifoliate L**
A 12333D 4.0 L	2N	10	4severe cr 100% pl	8 st	9	10	8 st	6 dist
A 12333D 2.0L	N	10	6 cr 80% pl	10	10	10	10	8 dist
A 12333D 1.0L	½ N	10	7 cr 60-70% pl	10	10	10	10	9

em emergence; st stunting; dist distortion; cr crinkling and distortion of leaves on % of plants pl

Table 9. Swede and spinach sown 16 May, pre-emergence herbicides applied 16 May, emerged 25 and 27 May respectively. 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**	**Swede** **2/6 cot**	**8/6** **2 TL**	**2/7** **5 - 6 TL**	**Spinach** **27/5** **cot**	**2/6** **cot**	**8/6** **2TL**	**2/7** **8 TL**
A 12333D 4.0 L	2N	10	3 cot, cl, dying	0	10	10	3 cot, cl, dying	0
A 12333D 2.0L	N	10	4	0	10	10	4	0
A 12333D 1.0L	½ N	10	5	0	10	10	5	0

cl chlorosis; swede and spinach emerged then died

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

Table 10. Bulb onion and leek sown 18 April, post-emergence herbicides applied 4 June. Assessment date, growth stage (L leaf), crop damage score (0 total kill; 7 acceptable; 10 no damage)

Herbicide ***Assessment Date:*** ***Untreated GS:***	**Rate**	**Onion** **19/6** **3 ½ L**	 **30/6** **4 ½ L**	 **8/7** **5-6L**	**Leek** **19/6** **3 L**	 **30/6** **4 ½ L**	 **8/7** **5-6L**
A 12333D 2.0L	N	10	10	10	10	10	10
A 12333D 1.0L	½ N	10	10	10	10	10	10
A 12333D 0.5L	¼ N	10	10	10	10	10	10
pyroxulam 50g	N	10	9 cl	10	10	8.5 cl	10
pyroxulam 25g	½ N	10	10	10	10	10	10
pyroxulam 12.5g	¼ N	10	10	10	10	10	10
OS159 0.2L	N	9	9	9 (7 k 80%)	10	10	10
OS159 0.1L	½ N	10	10	10 (8 k 50%)	10	10	10
OS159 0.05L	¼ N	10	10	10 (9)	10	10	10

cl chlorosis; potential scores in brackets for salad onions k kink in upper leaves in % plants reduce marketability

Table 11. Carrots, parsnips sown 2 May, carrots emerged 27 May, parsnips 2 June; coriander sown 16 May emerged 2 June. Post-emergence herbicides applied 10/11 June carrot, 17 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** **19/6** **3-4 TL**	**30/6** **6L**	**8/7** **7-8TL**	**Parsnip** **19/6** **2 TL**	**30/6** **4TL**	**8/7** **5 TL**	**Coriander** **19/6** **2 ½ TL**	**30/6** **5 TL**	**8/7** **bolting**
A 12333D 4.0L	2N	10	10	10	10	10	10	10	10	10
A 12333D 2.0L	N	10	10	10	10	10	10	10	10	10
A 12333D 1.0L	½ N	10	10	10	10	10	10	10	10	10
pyroxulam 100g	2N	6 st cl	6 cl st	7st	9 cl	2cl d	1d	5 cl st	1cl st d	0 d
pyroxulam 50g	N	8 cl	9 cl	9st	10	3 cl d	2d	7 cl st	2.5	1
pyroxulam 25g	½ N	10	10	10	10	4	3.5cl st	9 cl	3.5	3
OS159 0.4L	2N	3 sc lf loss	3 sc thin	4st 5TL	0d	0	0	2 sc	2 sc	3
OS159 0.2L	N	5 sc lf loss	5	6	1	1sc	1	4	3	4
OS159 0.1L	½ N	6	6	9	2	2sc	3	6	5	5

st stunting; cl chlorosis; sc scorch, lf loss leaf loss thin thinning d some plant death

Table 12. Celery, cauliflower, iceberg lettuce transplanted 15 May, post-weed-emergence herbicides applied 10/11 June. Assessment date, growth stage, crop damage score (0 total kill; 7 acceptable; 10 no damage). Cauliflower harvest date 5 August

Herbicide ***Assessment date:***	**Rate**	**celery** **19/6** **4-5 new L**	**30/6** **7 new L**	**8/7**	**cauliflower** **19/6**	**30/6**	**8/7**	**lettuce** **19/6**	**30/6**	**8/7** **harvest**
A 12333D 4.0L	2N	10	6 st	10	10	9 st	8 st	8 st	9 st	8
A 12333D 2.0L	N	10	9	10	10	10	10	10	10	9
A 12333D 1.0L	½ N	10	10	10	10	10	10	10	10	10
pyroxulam 100g	2N	5 cl st	2.5 severe st	2	8 st dist	6 st	4 st	6 st	6 st	4
pyroxulam 50g	N	7 cl st	4.5 cl	3	10	8 st	7 st	9	9	6
pyroxulam 25g	½ N	10	6.5	5	10	10	10	10	10	9
OS159 0.4L	2N	6 sc	3 sc st	4sc dist	5 sc sp	6 sp	10	2 severe sc	0 dist 100%	0
OS159 0.2L	N	7 sc	4	5	6 sc	6.5	10	3	1 dist 90%	2
OS159 0.1L	½ N	9	6	6	8	8	10	4	2 dist 70%	4

sc scorch; cl chlorosis; st stunting; dist distortion unmarketable; sp white spotting

Table 13. Peas and dwarf French beans sown 16 May, emerged 27 May and 31 May respectively. Post -weed-emergence herbicides applied 10/11 June. Assessment date, growth stage untreated (TL true leaf, trif L trifoliate leaf), crop damage score (0 total kill; 7 acceptable; 10 no damage). Pea harvest date 29 July, beans 12 August

Herbicide ***Assessment date:*** ***Untreated GS:***	**Rate**	**peas 19/6 enclosed bud**	**30/6 emerged bud - open flower**	**8/7 flat pod**	**Dwarf beans 19/6 ½ trif L**	**30/6 2 trif L**	**8/7 green bud**
A 12333D 4.0L	2N	10	10	8st	5 st dist	3 dist	4 ##
A 12333D 2.0L	N	10	10	10	6 st dist	4 dist	6 dist
A 12333D 1.0L	½ N	10	10	10	9 st	6 dist	10
pyroxulam 100g	2N	5 cl	3 severe cl st	2	4 cl st wilt	2 cl #	1
pyroxulam 50g	N	7.5 cl	5 cl st	4	5	3 cl st#	2
pyroxulam 25g	½ N	9	6 st	6	6	4 st #	3
OS159 0.4L	2N	7 st	7 st	6 st	2 st sc	3 sc, dist	4*
OS159 0.2L	N	10	10	10	4st sc	4	6*
OS159 0.1L	½ N	10	10	10	6	6 dist	8

cl chlorosis; st stunting; sc scorch; dist trifoliate; # simple leaf stage no further growth; ##base stem breakage; *loss simple leaf, new growth normal

Table 14. Swede and spinach sown 16 May, emerged 25 May and 27 May respectively. Post -weed-emergence herbicides applied 10/11 June. Assessment date, growth stage (TL true leaf), crop damage score (0 total kill; 7 acceptable; 10 no damage)

Herbicide ***Assessment date:*** ***Untreated GS:***	**Rate**	**swede 19/6 3-4 TL**	**30/6 5 TL**	**8/7 7TL**	**spinach 19/6 4 exp TL**	**30/6 8 TL**	**8/7 bolting**
A 12333D 4.0L	2N	10	5 st	6 st	4 cr dist	2 dist	2
A 12333D 2.0L	N	10	9	9	6 dist	4 dist	4
A 12333D 1.0L	½ N	10	10	10	10	6 dist	6
pyroxulam 100g	2N	3 cl nec w	1 cl d	0	2 cl nec st	1 dist cl d	0
pyroxulam 50g	N	5 cl nec w	3 cl d	0	4	3 dist cl d	2
pyroxulam 25g	½ N	7	5	1	5	5 dist cl d	3
OS159 0.4L	2N	5.5 sc	7	8 st	1 sc dist	2 narr L dist	2
OS159 0.2L	N	7.5 sc	9	10	3 sc	4 narr L dist	4
OS159 0.1L	½ N	9.5	10	10	4	5 narr L	5

cl chlorosis; st stunting; sc scorch; nec necrosis; d plant death; dist leaves distorted; narr L narrowed leaves; w leaves wilting

Weed Control (Latin names for weeds are given in Appendix 1)

Pre-weed-emergence herbicide (Tables 15-24)

There were very high populations of small nettle, up to 231/m^2 on this area of the trial and there were two flushes in carrots and parsnips, sown 2 May. Other predominant weed species were shepherd's purse, redshank and chickweed. Numbers of groundsel, mayweeds, fat-hen and smooth sow-thistle were variable, low to high. Mayweed species were mainly pineappleweed in onion and leek, scentless in other crops. There were a few black-bindweed in some plots.

A12333D (prodiamine)

A12333D inhibits growth of shoots and roots. Several weeds emerged but they died later. A12333D at dose rates of 4.0, 2.0 and 1.0 L/ha controlled a wide spectrum (Table 3) of important weeds, including Polygonums that affect vegetable crops: shepherd's purse, redshank, black-bindweed, chickweed, mayweeds and it was particularly effective on the very high population of small nettle. It was less reliable at the lower dose rates on smooth sow-thistle. Groundsel appeared to be resistant. A12333D applied pre-emergence to the earlier sown onion and leek at dose rates of 2.0 L/ha (N normal), and below gave poor control possibly because conditions were cooler and drier in April. At 2.0 L/ha only redshank and chickweed were controlled.

Post-weed-emergence herbicides (Tables 25-34)

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. Some redshank and small nettle remained in plots of the four crops. In the other crops on untreated plots there were extremely high populations of small nettle, high populations of shepherd's purse and several chickweed; other predominant weed species were redshank in transplanted crops, peas, beans, swede and spinach. The numbers of groundsel, fat-hen, mayweeds, pale persicaria and black-bindweed were variable.

A12333D
A12333D applied post-weed-emergence had little activity on emerged weeds (Table 4). Irrigation was applied on three occasions in May and A12333D at the 4.0, 2.0 and 1.0 L/ha dose rate had good residual soil activity on nettle except where they were large on the onion, leek, carrot and parsnip areas.

Pyroxulam
Pyroxulam applied at 50 or 100 g/ha (a lower dose than that authorised for wheat), controlled several weed species (Table 4). Pyroxulam did not control fat-hen, scentless mayweed or smooth sow-thistle even at the 100 g/ha dose. It was very effective on small nettle, shepherd's purse and chickweed even at 25 g/ha, and at 50 g/ha it killed redshank, pale persicaria and groundsel.

OS 159
At the low dose rates applied in this trial 0.4, 0.2, 0.1 and 0.05 L/ha, efficacy of OS 159 was poor and it failed to control the species present with the exception of small nettle, which was well controlled.

Volunteer potato control pre- and post-emergence (Table 30)
Potatoes are a frequent problem in vegetable crops. Volunteer potatoes were chitted and planted at the same time as onions and leeks (17 April).
This year pre-emergence herbicides were evaluated: A12333D, and, following reports of control also Nirvana (imazamox/pendimethalin). Neither suppressed potatoes or prevented potato berry formation in this trial.

At the time of post-emergence applications on 10 and 11 June potato growth was very advanced, flower buds had formed and there were several shoots 50 cm tall. No herbicide suppressed potatoes or prevented berry formation and scores are shown in Table 30. OS 159 (pyraflufen-ethyl) is used as a potato desiccant at 0.8 L/ha and at 0.4 L/ha scorched c. 10% of the leaf area of the potato plants, but otherwise herbicides had negligible effect.

Weed species controlled (summary)

Pre- and post-emergence herbicides gave no suppression of 'volunteer' potatoes. An extra treatment, Nirvana (pendimethalin/imazamox) at Normal and twice N dose rates, did not suppress potatoes or prevent potato berry formation in this trial.

Table 3. Pre-weed-emergence herbicides: √ weed species controlled; x poor control or not controlled at various dose rates

Pre-weed-emergence Herbicide dose rate/ha	Small nettle	Shepherd's purse	Redshank	Groundsel	Chickweed	Smooth sow-thistle	Mayweeds#	Fat-hen	Black bindweed
A 12333D 4.0L	√	√	√	x	√	√	√	√	√
A 12333D 2.0L	√	√	√	x	√	x	√	√	√
A 12333D 1.0L	√	√	√	x	√	x	√	√	√
A 12333D 0.5L	x	x	x	x	x	x	x	x	x

scentless mayweed and 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 populations limited data)

Post-weed-emergence Herbicide dose rate/ha	Small nettle	Shepherd's purse	Redshank	Pale persicaria	Groundsel	Chickweed	Smooth sow-thistle	Mayweeds#	Fat-hen	(Annual meadow-grass)	(Field speedwell)	Black bindweed	(Field pennycress)
A 12333D 4.0L	√	x	x	x	x	√	x	x	x	-	-	x	-
A 12333D 2.0L	√	x	x	x	x	x	x	x	x	-	-	x	x
A 12333D 1.0L	√	x	x	x	x	x	x	x	x	-	-	x	x
A 12333D 0.5L	x	x	x	x	x	x	x	x	x	-	-	x	x
pyroxulam 100g	√	√	√	√	√	√	x	x	x	-	-	x	-
pyroxulam 50g	√	√	√	√	√	√	x	x	x	-	-	x	-
pyroxulam 25g	√	√	x	x	x	√	x	x	x	-	-	x	-
pyroxulam 12.5g	x	x	x	x	x		x	x	x	-	-	x	-
OS 159 0.4L	√	x	x	x	x	x	x	x	x	x	x	x	-
OS 159 0.2L	√	x	x	x	x	x	x	x	x	x	x	x	-
OS 159 0.1L	√	x	x	x	x	x	x	x	x	x	x	x	-
OS 159 0.05L	√	x	x	x	x	x	x	x	x	x	x	x	-

scentless mayweed and pineappleweed; pyroxulam 50g/ha suppressed creeping thistle

Weed species controlled

Appendix 1 shows Common and Latin weed names.

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

Table 15. Pre-weed-emergence herbicide applied 18 April: weed species remaining after treatment, weed species controlled, weed species on untreated plots of **onion** and **leek** drilled early on 17 April. Assessed 8 May and 8 June. Related weed counts see below

Herbicide	Weed species not controlled	Weed species controlled
A 12333D 2.0L	**black-bindweed small nettle fat-hen** mayweed groundsel (field pennycress) shepherd's purse	chickweed redshank
A 12333D 1.0L	**black-bindweed small nettle fat-hen** redshank mayweed groundsel shepherd's purse (field pennycress)	
A 12333D 0.5L	**black-bindweed small nettle fat-hen** redshank mayweed groundsel shepherd's purse (field pennycress)	
Untreated: **small nettle redshank chickweed fat-hen black-bindweed** groundsel shepherd's purse mayweed		

Number of weed species/m^2 on 3 June on untreated (pre-weed-emergence) for each herbicide area (mean 8 counts in 0.33 m^2 quadrat) in 2 replicates **onion** and **leek**

	Small nettle	Shepherd's purse	Redshank	Groundsel	Chickweed	Fat-hen	Mayweeds#	Black-bindweed	TOTAL
Untreated (A 12333D)	217	4	15	2	9	9	1	6	263

mainly pineappleweed

Table 16. Pre-weed-emergence herbicide applied 2 May: weed species remaining after treatment, weed species controlled, weed species on untreated plots of **carrot** and **parsnip**. Two flushes Another flush mainly nettle at cotyledon stage on carrots noted 8 June Assessed 8 June and 2 July. Related weed counts see below

Herbicide	**Weed species not controlled**	**Weed species controlled**
A 12333D 4.0L	groundsel smooth sow-thistle	shepherd's purse small nettle black-bindweed redshank black-bindweed chickweed fat-hen mayweeds
A 12333D 2.0L	groundsel shepherd's purse smooth sow-thistle	redshank black-bindweed small nettle chickweed fat-hen mayweeds
A 12333D 1.0L	groundsel **shepherd's purse** smooth sow-thistle **redshank small nettle** black-bindweed mayweeds	chickweed fat-hen
Untreated: **small nettle shepherd's purse redshank chickweed fat-hen groundsel mayweeds** smooth sow-thistle black-bindweed		

Number of weed species/m^2 on 13 June on untreated (pre-weed-emergence) for each herbicide area (mean 8 counts in 0.33 m^2 quadrat) in 2 replicates of **carrot** and **parsnip.**

	Small nettle	Shepherd's purse	Redshank	Sow-thistle, smooth	Groundsel	Chickweed	Fat-hen	Mayweeds#	Black-bindweed	TOTAL
Untreated (A 12333D)	152	13	35	4	8	8	16	7	1	245

some pineappleweed and scentless mayweed

Table 17. Pre-weed-emergence herbicide applied 16 May: weed species remaining after treatment, weed species controlled, weed species on untreated plots of **coriander**. Assessed 8 June and 2 July. Related weed counts see below

Herbicide	**Weed species not controlled**	**Weed species controlled**

A 12333D 4.0L	**groundsel**	small nettle shepherd's purse redshank chickweed mayweed smooth sow-thistle groundsel fat-hen
A 12333D 2.0L	**groundsel**	small nettle shepherd's purse redshank chickweed mayweed fat-hen smooth sow-thistle
A 12333D 1.0L	**groundsel** smooth sow-thistle	redshank chickweed mayweed small nettle shepherd's purse fat-hen
Untreated: **small nettle shepherd's purse redshank chickweed mayweed smooth sow-thistle** groundsel		

Number of weed species / m^2 on 14 June on untreated (pre-weed-emergence) for each herbicide area (mean 2 counts in 0.33 m^2 quadrat) in 2 replicates of **coriander**

	Small nettle	Shepherd's purse	Redshank	Sow-thistle, smooth	Groundsel	Chickweed	Mayweeds#	Fat-hen	TOTAL
Untreated (A 12333D)	186	45	53	9	6	12	16	3	330

scentless mayweed

Table 18. Pre-weed-emergence herbicide applied pre-transplanting 15 May; weed species remaining after treatment, weed species controlled, weed species on untreated plots of **lettuce, cauliflower** and **celery.** Assessed 8 June and 2 July. Related weed counts see below

Herbicide	**Weed species not controlled**	**Weed species controlled**
A 12333D 4.0L	**groundsel**	small nettle shepherd's purse redshank chickweed mayweed smooth sow-thistle black-bindweed fat-hen
A 12333D 2.0L	**groundsel** smooth sow-thistle	small nettle shepherd's purse redshank chickweed mayweed black-bindweed fat-hen
A 12333D 1.0L	**groundsel** smooth sow-thistle	small nettle shepherd's purse redshank chickweed mayweed black-bindweed fat-hen
Untreated: **small nettle shepherd's purse redshank chickweed groundsel mayweed** smooth sow-thistle black-bindweed fat-hen		

Number of weed species / m^2 on 13 June on untreated (pre-weed-emergence) for the herbicide area (mean 6 counts in 0.33m^2 quadrat) in 2 replicates weed species on untreated plots of **lettuce, cauliflower** and **celery**.

	Small nettle	Shepherd's purse	Redshank	Sow-thistle, smooth	Groundsel	Chickweed	Fat-hen	Mayweeds#	Black-bindweed	TOTAL
Untreated (A 12333D)	231	38	45	4	7	15	3	7	2	352

scentless mayweed

Table 19. Pre-weed-emergence herbicide applied 16 May: weed species remaining after treatment, weed species controlled, weed species on untreated plots of **pea, dwarf bean, spinach** and **swede.** Assessed 8 June and 2 July. Related weed counts see below

Herbicide	**Weed species not controlled**	**Weed species controlled**
A 12333D 4.0L	**groundsel**	small nettle shepherd's purse redshank chickweed fat-hen mayweed smooth sow-thistle black-bindweed
A 12333D 2.0L	**groundsel** smooth sow-thistle	small nettle shepherd's purse redshank chickweed fat-hen mayweed black-bindweed
A 12333D 1.0L	**groundsel** smooth sow-thistle	redshank chickweed fat-hen mayweed black-bindweed small nettle shepherd's purse
Untreated: **small nettle shepherd's purse redshank chickweed fat-hen groundsel mayweed smooth sow-thistle** black-bindweed		

Number of weed species / m^2 on 13 June on untreated (pre-weed-emergence) for the herbicide area (mean 8 counts in 0.33 m^2 quadrat) in 2 replicates of **pea, dwarf bean**, **spinach** and **swede**
.

	Small nettle	Shepherd's purse	Redshank	Sow-thistle, smooth	Groundsel	Chickweed	Fat-hen	Mayweeds	Black-bindweed	TOTAL
Untreated (A 12333D)	177	34	40	15	7	13	11	5	3	305

Weed Control Scores pre-weed-emergence herbicides assessed days after treatment (DAT) mean of two replicates

Table 20. Pre-weed-emergence herbicide applied 18 April **onion, leek** sown 17 April. Assessment dates 15 May, 8 June and 2 July; weed control score (0 no control; 7 acceptable; 10 complete control); DAT; growth stage (L leaf)

Herbicide	**Onion**			**Leek**		
Untreated GS:	**1 L**	**2-3 L**	**4 ½ L**	**1 L**	**2-3 L**	4 L
DAT:	***27***	***51***	***67***	***27***	***51***	***67***
A 12333D 2.0L	4	4.5	3.5	4	4.5	3.5
A 12333D 1.0L	2.5	3	2	2.5	3	2
A 12333D 0.5L	1.5	1	0	1	1	0

Table 21. Pre-weed-emergence herbicide applied 2 May **carrot, parsnip** sown 2 May: weed control score (0 no control; 7 acceptable; 10 complete control). Assessment dates 8 June, 15 June and 2 July DAT days after treatment; growth stage (TL true leaf); weeds emerged but died later

Herbicide	**Carrot**			**Parsnip**		
Untreated GS:	**2TL**	**3 TL**	**6 TL**	**Cot-1TL**	**1 TL**	**4 TL**
DAT:	***37***	***42***	***59***	***37***	***42***	***59***
A 12333D 4.0L	9	9	9	9	9	8
A 12333D 2.0L	8	8	7	8	8	6
A 12333D 1.0L	5	5	5	5	5	4

Table 22. Pre-weed-emergence herbicides applied on 16 May **coriander** drilled 16 May**;** weed control score (0 no control; 7 acceptable; 10 complete control) assessment dates 8 June, 15 June and 2 July. DAT days after treatment; GS growth stage crop; weeds emerged but died later

Herbicide	**Coriander**		
Untreated GS:	**1 TL**	**2 TL**	**5 ½ TL**
DAT:	***23***	***30***	***47***
A 12333D 4.0L	10	10	9.5
A 12333D 2.0L	9	10	9
A 12333D 1.0L	5	10	8

Table 23. Pre-weed-emergence herbicide applied pre-transplanting 15 May, **lettuce, cauliflower, celery** transplanted 15 May**;** weed control score (0 no control; 7 acceptable; 10 complete control) assessment dates 8 June, 15 June and 2 July; DAT days after treatment; GS growth stage

Herbicide	**Celery**			**Cauliflower**			**Lettuce**		
DAT:	***24***	***31***	***48***	***24***	***31***	***48***	***24***	***31***	***48***
A 12333D 4.0L	10	10	9.5	10	10	9.5	10	10	10
A 12333D 2.0L	8	10	9	8	9	8.5	8	9	9
A 12333D 1.0L	4	9	8	4	6.5	6	4	6	6

Table 24. Pre-weed-emergence herbicides applied on 16 May drilled crops **peas, dwarf beans, swede, spinach** drilled 16 May**;**: weed control score (0 no control; 7 acceptable; 10 complete control) assessment dates 8 June, 15 June and 2 July. Baby leaf spinach was past harvest date at the last assessment; DAT days after treatment; GS growth stage crop; weeds emerged but died later

Herbicide	**Peas**			**D Beans**			**Swede**			**Spinach**		
Untreated GS:	**2-3 node**	**5 node**	**1st open flower**	**em-simple L**	**simple L**	**2 trif L**	**2 TL**	**3 TL**	**5 ½ TL**	**2 TL**	**4 TL**	**8 TL**
DAT:	***23***	***30***	***47***	***23***	***30***	***47***	***23***	***30***	***47***	***23***	***30***	***47***
A 12333D 4.0L	9	10	10	9	10	10	10	10	9	10	10	10
A 12333D 2.0L	8	10	9.5	8	10	9.5	9	9.5	8.5	9	9.5	9.5
A 12333D 1.0L	6	9	7	7	9	7	6	9	6	6	9	7

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

Table 25. Post-weed-emergence herbicides applied 10/11 June: weed species controlled, weed species on untreated plots of **onion** and **leek**. Area treated pre-weed-emergence with Stomp + propachlor (1.5 + 9.0) L/ha but several weeds escaped control. Assessed 30 June and 16 July. Related weed counts below

Herbicide	Weed species not controlled	Weed species controlled
A 12333D 2.0L	groundsel redshank (field pennycress) smooth sow-thistle	small nettle shepherd's purse
A 12333D 1.0L	groundsel redshank shepherd's purse (field pennycress) smooth sow-thistle	small nettle
A 12333D 0.5L	groundsel redshank shepherd's purse small nettle smooth sow-thistle (field pennycress)	
Untreated: redshank shepherd's purse small nettle (field pennycress) groundsel smooth sow-thistle		
pyroxulam 50g	black-bindweed	redshank small nettle shepherd's purse groundsel (creeping thistle suppressed)
pyroxulam 25g	black-bindweed redshank groundsel	small nettle shepherd's purse (creeping thistle suppressed)
pyroxulam 12.5g	black-bindweed redshank shepherd's purse groundsel	small nettle
Untreated: redshank shepherd's purse small nettle black-bindweed groundsel		
OS159 0.2L	shepherd's purse chickweed black-bindweed	small nettle groundsel
OS159 0.1L	shepherd's purse chickweed black-bindweed groundsel	small nettle
OS159 0.05L	shepherd's purse chickweed black-bindweed groundsel	small nettle
Untreated: shepherd's purse small nettle chickweed groundsel black-bindweed		

Number of weed species / m^2 remaining on 6 June after pre-emergence N dose Stomp + Ramrod (mean of 24 counts in 0.33 m^2 quadrat) on 2 replicates in **onion** and **leek**

	Black-bindweed	Redshank	Shepherd's purse	Small nettle	Chickweed	TOTAL
Untreated (Standard)	*1*	*4*	*0.5*	*2*	*1*	*8.5*

Table 26. Post-weed-emergence herbicides applied 10/11 June to carrots 17 June to parsnips: weed species controlled, weed species on untreated plots of **carrots** and **parsnips**. Area treated pre-weed-emergence with Stomp + linuron (1.6 + 1.0) L/ha but several weeds escaped control. Assessed 30 June and 16 July. Related weed counts below

Herbicide	**Weed species not controlled**	**Weed species controlled**
A 12333D 4.0L	fat-hen groundsel black-bindweed smooth sow-thistle redshank	small nettle
A 12333D 2.0L	fat-hen groundsel black-bindweed smooth sow-thistle redshank	small nettle
A 12333D 1.0L	fat-hen groundsel black-bindweed smooth sow-thistle redshank	small nettle
Untreated: redshank small nettle fat-hen groundsel black-bindweed smooth sow-thistle		
pyroxulam 100g	fat-hen	redshank (creeping thistle suppressed) groundsel small nettle
pyroxulam 50g	fat-hen	redshank (creeping thistle suppressed) groundsel small nettle
pyroxulam 25g	fat-hen redshank groundsel	small nettle
Untreated: redshank small nettle fat-hen groundsel		
OS159 0.4L	fat-hen redshank groundsel smooth sow-thistle	small nettle
OS159 0.2L	fat-hen redshank groundsel smooth sow-thistle	small nettle
OS159 0.1L	fat-hen redshank groundsel smooth sow-thistle	small nettle
Untreated: redshank small nettle fat-hen groundsel smooth sow-thistle		

Number of weed species / m^2 remaining on 2 June after overall application pre-emergence N dose Stomp + linuron (mean of 24 counts in 0.33 m^2 quadrat) on 2 replicates in **carrot and parsnip**

	Redshank	Small nettle	Groundsel	Fat-hen	TOTAL
Untreated (Standard)	*4*	*2*	*0.5*	*0.5*	*7*

Table 27. **Post-weed-emergence herbicides** applied 17 June to **coriander**, weed species controlled, weed species on untreated. Assessed 30 June and 16 July

Herbicide	Weed species not controlled	Weed species controlled
A 12333D 4.0L	redshank mayweed shepherd's purse chickweed groundsel fat-hen	small nettle (some control)
A 12333D 2.0L	**redshank shepherd's purse** groundsel fat-hen mayweed chickweed	small nettle (some control)
A 12333D 1.0L	**redshank shepherd's purse** groundsel fat-hen chickweed mayweed small nettle	
Untreated: **small nettle shepherd's purse chickweed** redshank mayweed groundsel fat-hen		
pyroxulam 100g	fat-hen smooth sow-thistle mayweed black- bindweed (suppressed creeping thistle)	small nettle shepherd's purse redshank chickweed groundsel
pyroxulam 50g	fat-hen smooth sow-thistle mayweed black-bindweed(suppressed creeping thistle)	small nettle shepherd's purse redshank chickweed groundsel
pyroxulam 25g	fat-hen smooth sow-thistle mayweed groundsel black-bindweed redshank	small nettle chickweed shepherd's purse
Untreated: **small nettle shepherd's purse redshank** chickweed mayweed groundsel smooth sow-thistle fat-hen black-bindweed		
OS159 0.4L	**fat-hen smooth sow-thistle redshank** shepherd's purse mayweed chickweed groundsel	small nettle (some control)
OS159 0.2L	**fat-hen smooth sow-thistle redshank** shepherd's purse mayweed chickweed groundsel small nettle	
OS159 0.1L	**fat-hen smooth sow-thistle redshank** shepherd's purse mayweed chickweed small nettle	
Untreated: **small nettle shepherd's purse chickweed** redshank mayweed groundsel smooth sow-thistle fat-hen		

Number of weed species/m^2 on 13 June on untreated (post-weed-emergence) for each herbicide area (mean 2 counts in 0.33 m^2 quadrat) and overall (mean 6 counts) on 2 replicates of **coriander**

	Small nettle	Shepherd's purse	Redshank	Sow-thistle, smooth	Groundsel	Chickweed	Fat-hen	Mayweed, scentless	TOTAL
Untreated (A 12333D)	69	34	2	1	3	6	1	3	127
Untreated (pyroxulam)	86	22	5	2	1	1	1	1	119
Untreated (OS 159)	32	11	1	1	3	5	1	3	57
Untreated Overall	*62*	*22*	*3*	*1*	*2*	*4*	*1*	*2*	*97*

Table 30. 'Volunteer' potato control; potatoes planted 17 April**.** Pre-emergence herbicides applied 18 April; post-emergence herbicides applied on 10/11 June when shoots were 0.5 m tall. Potato control scores (0=no control, 10=complete kill of foliage); % ground cover compared with untreated =100%

Herbicide/ha ***Assessment date:***	**Potato control 30/6**	**Potato suppression compared with untreated 30/6**
DAT:	***20***	***20***
Pre-emergence		
Nirvana pre-em 3.5 L	0	0 (no suppression,100 % plants flowers/berries)
Nirvana pre-em 7.0 L	0	0 (no suppression,100 % plants flowers/berries)
A 12333D 4.0L	0	0 (no suppression,100 % plants flowers/berries)
A 12333D 2.0L	0	0 (no suppression,100 % plants flowers/berries)
A 12333D 1.0L	0	0 (no suppression,100 % plants flowers/berries)
Post-emergence		
A 12333D 4.0L	0	0 (weed suppression no flowers = untreated)
A 12333D 2.0L	0	0 (no flowers too weedy = untreated)
A 12333D 1.0L	0	0 (no flowers too weedy = untreated)
pyroxulam 100g	1 st	0 (100 % plants flowers /berries)
pyroxulam 50g	1 st	0 (100 % plants flowers /berries)
pyroxulam 25g	0	0 (100 % plants flowers /berries)
OS159 0.4L	1 st (10% crinkled leaves)	0 (100 % plants flowers /berries)
OS159 0.2L	0	0 (100 % plants flowers /berries)
OS159 0.1L	0	0 (100 % plants flowers /berries)

st stunted

No herbicide treatment controlled potatoes.

Weed Control Scores Post-weed-emergence herbicides

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 assessed.

Table 31. Post-weed-emergence herbicides applied 17 June to **coriander** (later timing and larger weeds than other crops); Assessed 30 June and 16 July (past harvest stage, bolting). Weed control score (0 no control; 7 acceptable; 10 complete control)

Herbicide	**Coriander**	
DAT:	***13***	***29***
A 12333D 4.0L	2	2
A 12333D 2.0L	1	1
A 12333D 1.0L	0	0
pyroxulam 100g	7	6
pyroxulam 50g	5	4
pyroxulam 25g	3	2
OS159 0.4L	5	1#
OS159 0.2L	3	0#
OS159 0.1L	1	0#

fat-hen above the crop

Table 32. Post-weed-emergence herbicides applied 10/11 June to **celery, cauliflower, lettuce** transplants. Assessed 30 June and 16 July. Weed control score (0 no control; 7 acceptable; 10 complete control). Cauliflower harvest date 1 August.

Herbicide	**Celery**		**Cauliflower**		**Lettuce**	
DAT:	***19***	***35***	***19***	***35***	***19***	***35 harvest***
A 12333D 4.0L	5	3	4	3	4	4
A 12333D 2.0L	3	2	2	2	2	3
A 12333D 1.0L	2	0	1	0	1	0
pyroxulam 100g	10# 6	5	9	6	9	7
pyroxulam 50g	8.5# 4	3	8	5	8.5	6
pyroxulam 25g	7# 2	1	7	4	7	5
OS159 0.4L	6	3	6	3	6.5	4
OS159 0.2L	5	2	5	2	6	3
OS159 0.1L	3	0	3	0	4	0

#Score for all other weeds except fat-hen which was not controlled

Table 33. Post-weed-emergence herbicides applied 10/11 June to **peas, swede, baby-leaf spinach** and 17 June to **dwarf French beans** (later timing and larger weeds than other crops); Assessed 30 June and 16 July. Pea harvest date 46 DAT, beans 60 DAT Weed control score (0 no control; 7 acceptable; 10 complete control)

Herbicide	**Peas**		**D F Beans**		**Swede**		**Spinach**	
DAT:	***19***	***35***	***19***	***35***	***19***	***35***	***19***	***35***
A 12333D 4.0L	4	2	4	1	5	2	5	3
A 12333D 2.0L	2.5	1	2.5	0	3	1	3	2
A 12333D 1.0L	1	0	1	0	1	0	1	1
pyroxulam 100g	9	4	9	3	9	3	9	3
pyroxulam 50g	7	2	7	1	8	2	8.5	2
pyroxulam 25g	6	0	5.5	0	7	0	7	0
OS159 0.4L	5	3	5	1	5	3	5	4
OS159 0.2L	4	2	4	0	4	1	4	2
OS159 0.1L	2	0	1	0	2	0	2	0

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.

Crop safety (Tables 1, 2, 5 – 14)
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 some vegetable crops, at the timing and dose rates suggested. The most promising safe and effective herbicides, rate product/ha were for:

- Onion, leek: pre-emergence A12333D (prodiamine) at 2.0 L/ha, post-emergence pyroxulam at 50 g/ha; OS 159 at 0.1 L/ha.
- Carrot: pre-emergence A12333D at 2.0 L/ha, pyroxulam 50 g/ha.
- Parsnip: pre-emergence A12333D at 2.0 L/ha.
- Coriander: pre-emergence A12333D at 2.0 L/ha.
- Vining peas: pre-emergence A12333D at 0.1 L/ha,
- Dwarf French beans: pre-emergence A12333D at 1.0 L/ha was possibly safe.
- Celery transplants: pre-emergence A12333D at 2.0 L/ha.
- Cauliflower transplants: pre-emergence A12333D at 2.0 L/ha.
- Lettuce transplants: pre-emergence A12333D at 1.0 L/ha, also safe post-planting.
- Swede: no herbicide was safe and effective.
- Baby-leaf spinach: no herbicide was safe.

OS 159 was also safe to vining peas at 0.2 L/ha, and at 0.1 L/ha to onion, cauliflower, leek and swede but at the dose rates tested was ineffective on weeds. Pyroxulam appeared safe to cauliflower and lettuce applied post- transplanting at 25 g/ha but only controlled a few weed species at this dose rate. For swede, A12333D applied post–emergence at 2.0 L/ha, and OS 159 0.1 L/ha were possibly safe, but both were ineffective on emerged weeds except for small nettle.

Many of the lost herbicides are for post-emergence use on weed species that escape pre-emergence control, however a pre-emergence residual herbicide is essential for slow-emerging crops, such as parsnips, or in a quick growing crop (coriander, lettuce, baby-leaf spinach) where the time from planting/sowing to harvest is short.

Weed control (Tables 3, 4, 15 – 33)
On untreated areas there were very high populations of small nettle and high populations of shepherd's purse. Other predominant weed species were redshank and chickweed. Numbers of groundsel, mayweeds, fat-hen, smooth sow-thistle, pale persicaria and black-bindweed were variable.

A12333D (prodiamine) is a very effective soil-acting residual herbicide. In this trial, applied pre-weed-emergence at dose rates of 4.0, 2.0 and 1.0 L/ha, it controlled a wide spectrum of important weeds that affect vegetable crops, including Polygonums: shepherd's purse, redshank, black-bindweed, chickweed, mayweeds and it was particularly effective on the very high population of small nettle. Groundsel appeared to be resistant and it was less reliable at the lower dose rates on smooth sow-thistle.

A12333D applied post-weed-emergence had little foliar activity on emerged weeds. At the 4.0, 2.0 and 1.0 L/ha dose rate it had good residual soil activity on nettle except on large nettle plants.

Pyroxulam applied at 50 or 100 g/ha controlled several weed species. It did not control fat-hen, scentless mayweed or smooth sow-thistle even at the 100 g/ha dose. It was very effective on small nettle, shepherd's purse and chickweed and at 50 g/ha killed redshank, pale persicaria and groundsel.

OS 159 is used at 0.8 L/ha to desiccate potatoes. At the low dose rates applied in this trial 0.4, 0.2, 0.1 and 0.05 L/ha, efficacy of OS 159 was poor and it failed to control the species present with the exception of small nettle, which was well controlled.

Recommendations
A12333D pre-emergence herbicide was identified as potentially useful for a wide range of vegetables but is not yet available in the EU. Company decisions on its future have yet to be made.

Further work is needed to evaluate:

- A12333D in several vegetable crops depending on company decisions.
- new herbicides and to continue this early stage screening system.
- To obtain residues data, if available from other countries, to support SOLA applications by HDC and to set up trials where they are not available.

Close co-operation with Crop Protection Companies is needed to encourage Extension of Authorisation as soon as herbicides are registered for minor uses in other Member States in the same climatic zone (e.g. Germany).

Herbicides: Current Approval Status (August 2008)

Herbicide Product	Company	Active substance and formulation	'N' rate/ ha	EC Review status	Registered now *or in future?*
Pre-weed-emergence					
A 12333D Pre-transplants	Syngenta	prodiamine 480 g/l SC	2.0 L		*cereals, grass?*
Post-weed-emergence (2+ weeks after transplanting)					
A 12333D	Syngenta	prodiamine 480 g/l SC	2.0 L		*cereals, grass?*
	Dow	pyroxulam 75% wg	50 g	New not on Annex 1 yet	Submitted UK registration cereals
OS159	Nihon-Nohyaku	pyraflufen-ethyl # 20 g/L SC	0.2 L	Annex 1	UK potato desiccant at 0.8 L/ha

tested in formulation with bifenox FV 256 in 2004, not tested alone

Technology Transfer

2008
Field demonstration of trial: 25 June 2008: HDC open day at Kirton, in addition visits from Crop Protection Companies.

(Article FV 256a results 2007 trial to be submitted for HDC News)

Appendix 1: Weeds found on the untreated trial areas

Latin name	Common name

Capsella bursa-pastoris	Shepherd's purse
Chenopodium album	Fat-hen
Matricaria discoidea	Pineappleweed
Matricaria inodorum	Scentless mayweed
Persicaria maculosa	Redshank
Poa annua	Annual meadow-grass
Polygonum aviculare	Knotgrass
Polygonum convolvulus	Black-bindweed
Polygonum lapathifolium	Pale persicaria
Senecio vulgaris	Groundsel
Sonchus oleraceus	Smooth sow-thistle
Stellaria media	Common chickweed
Urtica urens	Small nettle
Veronica persica	Common field speedwell

Appendix 2: Rainfall and Irrigation