

PROJECT REPORT

To:
Horticultural Development Council
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FV 256a

**Continuation: Solutions to the loss of active ingredients for
weed control in vegetable crops**

Final report for the 2007 trial

August 2007

Commercial - in Confidence

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

Project number: FV 256a

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Report: Final report, September 2007

Previous reports: Final reports FV 256 2004, 2005, 2006

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Location of project: Warwick HRI, Kirton, Lincolnshire

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Date project commenced: 01 February 2007

Date completion due: 30 September 2007

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, Springbok (metazachlor/dimethenamid-P). Cadou Star (flufenacet/isoxaflutole), (Muster) (ethametasulfuron)

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The results and conclusions in this report are based on one experiment. The conditions under which the experiment was 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 Date15 August
2007.....

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CONTENTS

	Page
Grower Summary	1
Headline	1
Background and expected deliverables	1
Summary of the project and main conclusions	2
Financial benefits	4
Action points for growers	6
Science section	7
Introduction	7
Materials and Methods	8
Results and Discussion	11
Conclusions	40
Herbicide Approval Status	43
Technology transfer	43
Appendix 1 Common & Latin weed names	44
Appendix 2 Rainfall & Irrigation April – July 2007	45

Grower Summary

Headline

Two 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.

- Springbok (metazachlor/dimethenamid-P) at 2.5 L/ha applied pre-weed-emergence post-transplanting cauliflower, and pre-emergence of swede appeared safe to these crops and controlled a wide weed spectrum. It was also safe when applied post-weed-emergence but less effective on weeds. There will be a 'Gap' when trifluralin, which failed Annex 1 inclusion, is withdrawn from use in these crops (possibly March 2009). Springbok is a residual herbicide with some contact activity.
- Muster (ethametasulfuron) at 26.7 g/ha, applied post-weed-emergence, has potential for use post-transplanting cauliflower and post-emergence of swede. It also appeared safe at 13.3 g/ha in vining pea and at 26.7 g/ha in lettuce. It is very effective on charlock but has a weakness on groundsel. However, it is only authorised in Canada for oilseed rape and a decision has yet to be made regarding introduction in Europe.

Background and expected deliverables

Herbicide screening trials in a range of vegetable crops were funded by the Agrochemical Industry and carried out by 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. Since then, important herbicides for vegetable growers: terbutryn, fenuron, fomesafen, terbacil, cyanazine, sodium monochloroacetate, metoxuron, prometryn, pentanochlor were not supported in the 91/414/EEC Review; others including simazine, atrazine and trifluralin failed to achieve Annex 1 status. Derogations for their "Essential Uses" expire 31 December 2007 and no derogations will be permitted for trifluralin. Alternatives are therefore sought and HDC project FV 256 screened "new" herbicides for crop tolerance in 2004, 2005, 2006 and 2007. The overall aim of this project is to:

- identify candidate herbicides after consultation with crop protection companies, a search of literature and previous data from HRI, Wellesbourne, discussions with vegetable sectors in other European Member States and the USA IR-4 Project. Only herbicides with a future, i.e. on Annex 1 or supported in the Review are selected.
- 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 through HDC obtain Specific Off-Label Approvals (SOLAs).

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 2007 trial Cadou Star was applied at a lower than Normal dose rate for maize. 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 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 2 days post-transplanting: 3 safe; x not safe

Herbicide 'Normal' dose/ha	Onion	Leek	Carrot	Parsnip	Coriander	Celery transplants	Cauliflower transplants	Lettuce transplants	Vining Pea	Swede	Spinach
Springbok N 2.5 L	x	x	x	x	x	x	3 N	x	x	3 N	x
Cadou Star N 0.4 kg	3 ½ N	3 ½ N	x	x	3 ½ N	x	x	x	x	x	x

Table 2. Post-weed-emergence herbicides: 3 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
Springbok N 2.5 L	3 ¼ N	3 ¼ N	x	x	x	x	3 N	3 ½ N	x	x	3 N	3 ½ N
(Muster) N 26.7g	3 ¼ N	3 ¼ N	x	x	x	x	3 N	3 N	x	3 ½ N	3 N	x

Weed species controlled

Appendix 1 shows Common and Latin weed names.

There were very high populations of shepherd's purse, annual meadow-grass and pineappleweed on this trial site. Other predominant weed species were chickweed, knotgrass, groundsel and small nettle. Numbers of pale persicaria, redshank, fat-hen and smooth sow-thistle were variable

Table 3. Pre-weed-emergence herbicides: 3 weed species controlled; **x** poor control or not controlled at various dose rates; - weeds not present on untreated plots; (low populations limited data)

Pre-weed-emergence Herbicide dose rate/ha	Shepherd's purse	Pineappleweed	Small nettle	Knotgrass	Pale persicaria	Redshank	Chickweed	Smooth sow-thistle	Groundsel	Field speedwell	Annual meadow-grass	Fat-hen	Black-bindweed
Springbok 5.0 L	3	3	3	3	3	3	3	3	3	-	3	3	-
Springbok 2.5 L	3	3	3	3	3	3	3	3	3	-	3	3	(x)
Springbok 1.25 L	3	3	3	x	x	x	3	3	3	-	3	3	(x)
Springbok 0.625 L	x	x	3	x	-	-	3	-	x	-	3	x	(x)
Cadou Star 0.8 kg	3	3	3	3	3	3	3	3	3	3	3	3	(3)
Cadou Star 0.4 kg	3	x	3	x	3	x	3	3	3	3	3	3	(x)
Cadou Star 0.2 kg	3	x	3	x	x	x	x	3	3	3	3	3	(x)
Cadou Star 0.1 kg	x	x	x	x	-	-	x	-	x	-	x	x	(x)

Table 4. Post-weed-emergence herbicides: 3 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	Shepherd's purse	Pineappleweed	Small nettle	Knotgrass	Pale persicaria	Redshank	Chickweed	Smooth sow-thistle	Groundsel	Annual meadow-grass	Fat-hen	Field speedwell
Springbok 5.0 L	3	3	3	x	3	3	3	3	3	3	3	(3)
Springbok 2.5 L	3	3	x	x	3	x	3	3	3	3	x	(3)
Springbok 1.25 L	3	x	x	x	x	x	3	3	x	x	x	(3)
Springbok 0.625 L	x	x	-	-	-	-	-	-	x	-	-	-
(Muster) 53.2 kg	3	3	3	3	3	3	3	3	x	3	3	(3)
(Muster) 27.6 g	3	x	3	x	3	3	3	3	x	3	x	(3)
(Muster) 13.8 g	3	x	3	x	3	3	3	x	x	x	x	(3)
(Muster) 6.9 kg	x	x	-	-	-	-	-	-	x	-	-	-

Post-emergence herbicides gave very little suppression of 'volunteer' potatoes.

- Cadou Star, at 0.2 kg/ha appeared safe to onion and leek, and possibly coriander but efficacy on many weed species was poor at this low dose rate. However, 0.2 kg/ha achieved good control of shepherd's purse and small nettle.

Further work is needed to evaluate:

- Springbok (metazachlor/dimethenamid-P) applied pre-weed-emergence post-transplanting leaf and head Brassicas, and pre-emergence of root Brassicas (swede and turnip). The dimethenamid-P improves control of charlock. Springbok applied post-weed-emergence is less effective, particularly on polygonums.
- (Muster) (ethametasulfuron) is only authorised in Canada for oilseed rape therefore further work should be delayed until a decision is made regarding introduction into Europe. (Muster) applied post-weed-emergence has potential for use post-transplanting leaf and head Brassicas, and root Brassicas (swede and turnip). It also appeared safe at 13.3 g/ha in vining pea and at 26.7 g/ha in lettuce. It is very effective on charlock (Dupont data) but has a weakness on groundsel and mayweeds appear only moderately susceptible.

Herbicides: Current Approval Status

Herbicide Product	Company	active substance and formulation	'N' rate/ha	Registered now or in future?
Pre-weed-emergence				
Springbok 2d post transplants	BASF	Metazachlor/dimethenamid-P 200/200 g/L EC	2.5 L	UK oilseed rape
Cadou Star 2d post transplants	Bayer	flufenacet/isoxaflutole 480/100 g/kg	0.4 kg	UK maize
Post-weed-emergence (2+ weeks after transplanting)				
Springbok	BASF	Metazachlor/dimethenamid-P 200/200 g/L EC	2.5 L	UK oilseed rape
(Muster)#	Dupont	ethametasulfuron 75% wg	26.7g	Canada oilseed rape

#(product) registered in Canada; dimethenamid-P, flufenacet, isoxaflutole on Annex 1

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, 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. Without a range of herbicides to control a wide weed spectrum, vegetable growing could become uneconomic. The last Pesticide Usage Survey 2003, showed the % area of crops in Great Britain receiving herbicide sprays (see below).

Comparison of herbicide treated areas and GB crop area (source CSL Pesticide Usage Survey 2003), crop value and gross margins (J Nix, Farm Management Pocketbook, 37th edition 2007) for a range of some important vegetable crops.

Crop	Crop area ha last survey	% Herbicide treated area last survey	Crop value £/ha 2007	Gross Margin £/ha 2007
Brassicas	32,424	195	4,200 cauliflower	1,720
Peas & Beans	46,211	263	1,000 vining peas	750
Onions & leeks	12,397	1101 (low doses)	4,370 bulb onions	1,845
Carrots, parsnips, celery	13,062	594 (low doses)	7,250 maincrop carrots	2,050

As a result of the 91/414/EEC pesticide review programme, growers will lose key herbicides. Some examples of important losses are: prometryn to control fumitory in onions and carrots; cyanazine for charlock in Brassicas, metoxuron for mayweeds and to suppress potato volunteers in carrots; fomesafen for broad-leaved weeds and potato volunteer suppression in dwarf beans; pentanochlor for knotgrass in celery and parsley. Three of the top ten most popular herbicides used in vegetables: cyanazine, terbutryn/terbuthylazine, metoxuron, for broad-leaved weeds will be lost when 'Essential uses' expire 31 December 2007.

Alternatives are urgently needed.

Active Substance area use	Crop Use until 31 Dcember 2007
Atrazine 1252 ha	Sweetcorn
Cyanazine 40,424 ha	Vining pea, Calabrese/Broccoli, Cauliflower, Cabbage, Bulb Onion, Salad Onion, Leek
Fenuron small	Runner beans, Spinach
Fomesafen 2,766ha	Vining Pea (spring sown), Broad Bean (spring sown), Dwarf French bean, Runner bean
Metoxuron 14,389ha	Carrots, parsnips
Pentachlor 4,144ha	Celeriac, Celery, Carrot, Parsnip Parsley & Herbs (outdoor & protected)
Prometryn 6,327 ha	Bulb & Salad Onion (outdoor), Leek (direct drilled & transplanted), Carrot, Parsnip Celery, Parsley, Herbs, all (outdoor & protected)
Simazine small	Asparagus
Sodium mono-chloroacetate 1,764 ha	Bulb & Salad Onion, Leek, Cabbage, Brussels sprout, Calabrese/ Broccoli, Cauliflower
Terbacil small	Herbs (outdoor & protected)
Terbutryn 16,433ha	Vining, Edible Podded Pea, Broad Bean,

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. At product re-registration stage there may be restrictions on timings and dose rates.
- Need to review their current weed control strategy for several vegetable crops because “Essential Uses” for important herbicides metoxuron, prometryn, terbutryn, fomesafen, cyanazine, pentachlor expire 31 December 2007.
- Some potential alternative herbicides that appear to be safe (non-phytotoxic) to some Brassica crops have been identified in 2007 and further work is 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.

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: terbutryn, fenuron, fomesafen, terbacil, cyanazine, sodium monochloroacetate, metoxuron, prometryn, pentanochlor were not supported in the EC Review, simazine and atrazine failed to achieve Annex 1 status. The derogations for their "Essential Uses" expire 31 December 2007 and alternatives are therefore sought. This work allows the industry to demonstrate to the European Commission that action has been taken to find alternatives so that these uses can continue.

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
- demonstrate to the European Commission that action has been taken to find alternatives to replace the 'Essential Uses' so that they can continue until 31 December 2007

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 sown with a Planet push drill in double rows. Press wheels on drills ensured a fine, firm seedbed – plots were not rolled. Transplants were planted with a Michigan planter 3 rows/plot, except lettuce 4 rows/plot.

Trial Design: Plot size 2 m long x 1 bed width (1.83 m), 2 replicates each treatment (total 400 plots).

Sowing dates and herbicide application dates

<i>Pre-weed-emergence</i>			
<i>Crop (Variety)</i>	<i>Sowing/transplant date</i>	<i>Crop Growth stage</i>	<i>Date applied</i>
Onion (Wellington)	17 April	Pre-emergence	18 April
Leek ((Roxton)	17 April	Pre-emergence	18 April
Dwarf French Bean (Laguna)#	19 May	Pre-emergence	21 May
Pea (Cabree)	19 May	Pre-emergence	21 May
Celery transplant (Victoria)	18 May	A, B after transplanting	21 May
Cauliflower transplant (Fremont)	18 May	A, B after transplanting	21 May
Lettuce iceberg transplant (Challenge)	18 May	A, B after transplanting	21 May
Coriander (Santos)	19 May	Pre-emergence	21 May
Swede (Magres)	19 May	Pre-emergence	21 May
Spinach baby leaf (Whale)	19 May	Pre-emergence	21 May
Carrot (Nairobi)	11 May	Pre-emergence	21 May
Parsnip (Javelin)	11 May	Pre-emergence	21 May

poor emergence not redrilled

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.

<i>Post-weed-emergence</i>			
<i>Crop (Variety)</i>	<i>Sowing/transplant date</i>	<i>Crop Growth stage</i>	<i>Date applied</i>
Onion (Wellington)	17 April	2 Leaves	4 June
Leek ((Roxton)	17 April	2 Leaves	4 June
Dwarf French Bean (Parker)	13 June	1 trifoliolate Leaf	9 July
Pea (Cabree)	19 May	3-4 node	13 June
Celery transplant (Victoria)	18 May	established	11 June
Cauliflower transplant (Fremont)	18 May	established	11 June
Lettuce Iceberg transplant (Challenge)	18 May	established	11 June
Coriander (Santos)	19 May	1-2 True Leaves	13 June
Swede (Magres)	19 May	2 True Leaves	11 June
Spinach baby leaf (Whale)	19 May	2-4 True Leaves	11 June
Carrot (Nairobi)	11 May	2 True Leaves	20 June
Parsnip (Javelin)	11 May	1 True Leaf	20 June
Potatoes	17 April	2-5 shoots/plant, 50 cm tall, flower buds	11 June

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 Normal, ½ Normal, ¼ Normal dose rates. Pre-emergence dose rates appropriate for the light soil type.

Code	Herbicide Product	Company	active substance formulation	N rate/ ha
Pre-weed-emergence				
A	Springbok 2d post transplants	BASF	Metazachlor/dimethenamid-P 200/200 g/L EC	2.5 L
B	Cadou Star 2d post transplants	Bayer	flufenacet/isoxaflutole 480/100 g/kg	0.4 kg
Post-weed-emergence (2+ weeks after transplanting)				
C	Springbok	BASF	Metazachlor/dimethenamid-P 200/200 g/L EC	2.5 L
D	(Muster)#	Dupont	ethametasulfuron 75% wg	26.7g

#(product) registered in Canada; dimethenamid-P, flufenacet, isoxaflutole on Annex 1

Application Data

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

Pre-weed-emergence Herbicide Trial

Date applied	Weather	GS Crop; Soil	GS weeds
<i>Pre-emergence Onion & Leek (sown 17 April)</i>			
18 April tr A & B	10°C; 76% RH; cloud cover 1; wind 3mph; no rain after application until 23 April 3.0mm, irrigated	Pre-emergence crop Sowing depth 1 cm; fine seedbed, surface dry	-
<i>Post-transplant pre-weed-emergence Celery, Lettuce & Cauliflower (planted 18 May); Pre-emergence Carrot & Parsnip (sown 11 May); Peas, Dwarf Beans, Swede, Spinach, Coriander (sown 19 May)</i>			
21 May trs A & B	13.9°C; 64% RH; cloud cover 7; wind 9 mph; no rain after application until 25 May 2.8mm	Post-transplanting/ pre- emergence crop; Sowing depth 1 cm; fine seedbed surface moist	-

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 applied	Weather	GS crop (number leaves L, true leaves TL); Soil	GS weeds (number of True Leaves TL)
<i>Post-weed-emergence Onion & Leek,</i>			
4 June tr C & D	16.4°C; 79% RH; sunny, cloud cover 4; wind 3mph; no rain after application until 13 June 6.8mm	Onion 2 L, Leek 2 L; Soil surface moist	shepherd's purse 6-8 TL; pineappleweed 4-6 TL; groundsel 4 TL
<i>Post-weed-emergence Swede, Spinach, (sown 19 May); Celery, Lettuce & Cauliflower (planted 18 May) Potatoes (planted 18 April)</i>			
11 June tr C & D	12.4°C; 98% RH; cloud cover 8; wind 2mph; no rain after application until 13 June 6.8mm	Swede 2 TL; Spinach 2-4 TL; transplants established. Potatoes 2-5 shoots/plant, 50 cm tall, flower buds. Soil surface dry	pineappleweed 2-4 TL; knotgrass 1-3 TL; shepherd's purse, fat-hen 2-4 TL; groundsel 2 TL
<i>Post-weed-emergence Coriander (sown 19 May)</i>			
13 June tr C & D	18.4°C (20°C later); 82% RH; cloud cover 8; wind 1mph; no rain after application until pm 6.8mm	Coriander 1-2 TL; Soil surface dry	pineappleweed 2-4 TL; groundsel 2 TL; knotgrass, redshank, pale persicaria 3 TL, annual meadow-grass 3 L; shepherd's purse 4-6 TL
<i>Post-weed-emergence Peas (sown 19 May)</i>			
13 June tr C & D	18.4°C; 82% RH; cloud cover 8; wind 1mph; no rain after application until pm 6.8mm	Peas 3-4 node; Soil surface dry	pineappleweed 4 TL; fat-hen, nettle, groundsel 4 TL; knotgrass 3 TL-small plant; redshank, pale persicaria 2-4 TL; shepherd's purse 4-8 TL; annual meadow-grass 3-4 L
<i>Post-weed-emergence Carrot, Parsnip (sown 11 May)</i>			
20 June tr C & D	18.2°C; 69% RH; cloud cover 4; wind speed 4mph; no rain after application	Carrot 2 TL; parsnip 1 TL	No weeds
<i>Post-weed-emergence dwarf beans (re-drilled 13 June)</i>			
9 July tr C & D	15.5°C; 74% RH; cloud cover 4; wind 1mph; no rain after application	Dwarf Beans 1st Trifoliolate Leaf	pineappleweed 6 TL; fat-hen 4 TL; groundsel 5-6 TL; knotgrass, chickweed small plant; shepherd's purse 4 TL; annual meadow-grass 4-7 L

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 on any 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).

Results and Discussion

Crop tolerance (more detail in the following Tables)

April was a warm month and skies were often cloudy but rainfall was negligible 3.5 mm. Irrigation was therefore applied after pre-emergence herbicide applications to onion and leek, and also to carrot and parsnip. From the 6th, May was a very wet month and 109 ml rain fell at Kirton. The last fortnight in June was also exceptionally wet with a total of 126 ml rainfall. Some rainfall events were extremely heavy – 32.7 ml on 27 May and 42 ml on the 24 June. Hence the above average rainfall provided a stringent test for safety of residual soil-acting herbicides Springbok and Cadou Star.

Phytotoxicity symptoms pre-weed-emergence herbicides (Tables 5-9)**Springbok**

Springbok applied pre-emergence of drilled swede and post-transplanting cauliflower but pre-weed-emergence appeared very safe at all dose rates.

Springbok applied at this timing, did not appear safe to any other crop tested.

At 2.5 and 1.25 L/ha it caused stunting and plant loss in onion and leek, and effects became severe.

All dose rates caused delayed emergence and plant loss in carrots and parsnips. Coriander was less sensitive possibly because it emerged through the soil-treated layer faster than carrots. Later, the leaves of these crops became distorted, crinkled and stuck together (damage from dimethenamid-P). Springbok caused similar crinkling effects and stunting on celery transplants. Springbok at all dose rates caused severe necrosis of leaf margins and distortion of the growing points in peas and unacceptable stunting of dwarf French beans. Spinach treated with Springbok at 5.0 or 2.5 L/ha emerged but soon died.

Cadou Star

Cadou Star, at 0.2 kg/ha appeared safe to onion and leek, and possibly coriander but efficacy on many species was poor at this low dose rate. However, 0.2 kg/ha achieved good control of shepherd's purse and small nettle.

Cadou Star at all dose rates tested caused severe chlorosis and stunting in other crops, and necrosis of the lower leaves of peas. Baby-leaf spinach was the most sensitive crop - there was total kill in 20 days from all dose rates tested.

Phytotoxicity symptoms post-weed-emergence herbicides (Tables 10-15)

All except dwarf beans were sprayed in June and high rainfall after the 13 June may have increased the residual activity of Springbok.

Springbok

Springbok applied post-weed-emergence was safe at all dose rates tested (5.0, 2.5 and 1.25 L/ha) to transplanted cauliflower and drilled swede, although there was some initial leaf scorch to swede from the higher doses (5.0, 2.5 L/ha).

Springbok at 1.25 L/ha may be safe to lettuce. Springbok at 0.625 L/ha appeared safe to drilled onion and leek, and killed the pineappleweed that escaped control with the pre-emergence standard.

Springbok applied at 5.0 and 2.5 L/ha post-weed-emergence caused severe necrosis and plant loss in pea and remaining plants were stunted.

Carrots, parsnip and coriander were stunted and later all developed crinkled, distorted leaves. Any leaf blemish is unacceptable in coriander. There was less effect on celery.

(Muster)

(Muster), a herbicide for oilseed rape, was very safe to transplanted cauliflower and drilled swede (safer than Springbok post-weed-emergence) at all dose rates 53.4, 26.7 and 13.35 g/ha. (Muster), was safe to onion and leek at 6.68 g/ha, but weed control was poor at this $\frac{1}{4}$ N dose.

(Muster) appeared safe to lettuce at 26.7 g/ha (Normal dose), and to peas at 13.35 g/ha ($\frac{1}{2}$ N). Baby-leaf spinach was very sensitive to even low doses and it was completely killed 10 days after application.

Crop Safety (summary)

The following information is based on only one trial, on an irrigated, light soil. For 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 2 days post-transplanting: 3 safe; x not safe

Herbicide 'Normal' dose/ha	Onion	Leek	Carrot	Parsnip	Coriander	Celery transplants	Cauliflower transplants	Lettuce transplants	Vining Pea	Swede	Spinach
Springbok N 2.5 L	x	x	x	x	x	x	3 N	x	x	3 N	x
Cadou Star N 0.4 kg	3 ½ N	3 ½ N	x	x	3 ½ N	x	x	x	x	x	x

Table 2. Post-weed-emergence herbicides: 3 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
Springbok N 2.5 L	3 ¼ N	3 ¼ N	x	x	x	x	3 N	3 ½ N	x	x	3 N	3 ½ N
(Muster) N 26.7g	3 ¼ N	3 ¼ N	x	x	x	x	3 N	3 N	x	3 ½ N	3 N	x

Crop Tolerance Scores (mean of two replicates) pre-weed-emergence herbicides**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 6/5 crook	30/5 1 ½ L	10/6 2-2 ½ L	27/6 3-4 L	10/7 4L	Leek 8/5 crook	30/5 1 ½ L	10/6 2-2 ½ L	27/6 3 L	10/7 3-4L
Springbok 2.5 L	N	9 red em del	5 cl st	5	2.5	2.5 thin	9	5 st cl	5	2 st	2 thin
Springbok	½ N	10	8	7	5	5	10	8 st cl	7	4	4
Springbok	¼ N	10	10	10	9	9	10	10	10	8	8
Cadou Star 0.4 kg	N	10	9	8 st	8 st	7 thin	10	8 st	8 st	8 st	7 thin
Cadou Star	½ N	10	10	10	10	9	10	10	10	10	9
Cadou Star	¼ N	10	10	10	10	10	10	10	10	10	10

red em reduced emergence; del delayed emergence or maturity; st stunting; loss plant loss; cl chlorosis; thin thinning

Table 6. Carrot and parsnip sown 11 May, pre-emergence herbicides applied 21 May, carrot emerged 30 May, parsnip 10 June. Coriander sown 19 May, pre-emergence herbicides applied on 21 May, coriander emerged on 1 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 3/6 cot	10/6 1 TL	27/6 3 TL	10/7 5 TL	Parsnip 16/6 cot	27/6 2 TL	10/7 4 TL	Coriander 3/6 cot	10/6 1 TL	27/6 4 TL	10/7 bolting
Springbok	2N	4 red em st	2	0	0	0	0	0	1 del	4 del	0 cr	0 cr
Springbok 2.5 L	N	6 red em	4	1.5 cr	1 cr	0	0	0	3	6	4 st cr	4 st cr
Springbok	½ N	10	8 del	4	3	2	2	1	5	8	6 st	6
Cadou Star	2N	5 red em cl	1	0	0	2 cl	1	0	7 st	7 cl	4 st	4 st
Cadou Star 0.4 kg	N	8 cl	6 cl	3	2	4	3	1	9	8	5	5
Cadou Star	½ N	10	8	6 st	5	7	5	3	10	10	9	9

red em reduced emergence; del delayed emergence or maturity; st stunting; cl chlorosis; cr severe distortion and crinkling new leaves

Table 7. Celery, cauliflower and lettuce transplanted 18 May: pre-weed-emergence herbicides applied post-transplanting 21 May, assessment date, growth stage, crop damage score (0 total kill; 7 acceptable; 10 no damage)

Herbicide Assessment date:	Rate	Celery 3/6	10/6	27/6	10/7	Cauliflower 3/6	10/6	27/6	10/7	Lettuce 3/6	10/6	27/6	10/7 harvest
Springbok	2N	5 st new growth	4 st cr	2 cr	1 cr st	5 st	6 st	6 st	8 st	5 st cl cr sc	3st cr sc	1.5 st	1 st
Springbok 2.5L	N	8 st	6	4 cr	3 cr st	6	9	8	9	8 sc	6	3 st	3 st
Springbok	½ N	10	8	6	5 st	10	10	10	10	10	8 cl	6 st	5 del
Cadou Star	2N	5 cl	0	0	0	4 cl st	2 cl st	0	0	2 cl sc	0	0	0
Cadou Star 0.4 kg	N	6 cl	2	1 st severe	0	6 cl	4	1 st	0	4 cl	2	1	1
Cadou Star	½ N	9 cl new growth	5	2	1	8	5	2	2	6	4	3	2 del

cl chlorosis; del delayed maturity; dist distortion; sc scorch; st stunting; cr distortion and crinkling new leaves

Table 8. Vining peas, dwarf French beans sown 19 May, pre-emergence herbicides applied 21 May. Dwarf Bean emergence too poor to assess. Assessment date, growth stage, crop damage score (0 total kill; 7 acceptable; 10 no damage)

Herbicide Assessment date: Untreated GS:	Rate	Pea 10/6 3 node	27/6 1 st flower open	10/7 flat pod	Dwarf beans 27/6 2 trifoliolate
Springbok	2N	2 red em cr nec	0 nec cr	0	8 st
Springbok 2.5 L	N	4 nec cr	2 nec cr	1.5	9
Springbok	½ N	6 nec cr	4 nec cr	3	10
Cadou Star	2N	2 red em nec leaf margins	0	0	0
Cadou Star 0.4 kg	N	4 nec	2 st nec	1severe st	1 st
Cadou Star	½ N	6	3	2	1 st

red em reduced emergence; st stunting; dist distortion; nec necrosis; cr severe crinkling and distortion of growing point, leaves stuck together

Table 9. Swede and spinach sown 19 May, pre-emergence herbicides applied 21 May, emerged 30 May. Assessment date, growth stage (cot cotyledon, 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 30/5 cot	10/6 2-3TL	27/6 5 TL	10/7 6-7 TL	Spinach 30/5 cot	3/6 2TL	10/6 4TL	27/6 7 TL
Springbok	2N	10	8 red em	6 st	6 st	9 del	3	0	0
Springbok 2.5 L	N	10	10	10	10	10	5	2	2
Springbok	½ N	10	10	10	10	10	6	4	4
Cadou Star	2N	10	0 cl *	0	0	9	1 cl	0	0
Cadou Star 0.4 kg	N	10	2 cl	0	0	10	2 cl	0	0
Cadou Star	½ N	10	5 cl	3	3 severe st	10	5 cl	0	0

red em reduced emergence; * emerged then died; cl chlorosis; st stunting; del delay

Crop Tolerance Scores (mean of two replicates) post-weed-emergence herbicides**Table 10.** 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 <i>Assessment Date:</i> <i>Untreated GS:</i>	Rate	Onion			Leek		
		16/6 3 L	23/6 3-4 L	10/7 4 L	16/6 3 L	23/6 3-4 L	10/7 4 L
Springbok 2.5 L	N	8	5	5 st leaf tip nec	8	6	5 st nec
Springbok	½ N	9cl	6 leaf curl	8	9 slight cl	7 st	8
Springbok	¼ N	10	10	10	10	10	10
(Muster) 26.7g	N	9cl st	6 cl st	4 st	9cl st	6 cl st	4 st
(Muster)	½ N	10	7 leaf curl cl	6	10	7 cl base stem	6 st
(Muster)	¼ N	10	10	10	10	10	10

del em delayed emergence; st stunting; cl chlorosis; nec necrosis

Table 11. Carrot and parsnip sown 11 May, carrot emerged 30 May, parsnip 10 June. Coriander sown 19 May, emerged on 1 June. Post-emergence herbicides applied 20 June carrot and parsnip, 13 June coriander. 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	Carrot		Parsnip		Coriander		
		27/6 3-4 TL	10/7 5 TL	27/6 2 TL	10/7 3 TL	16/6 2TL	23/6 3 ½ TL	10/7 bolting
Springbok	2N	2.5 st cr	0 st cr	1 st cr	0	9 st	3 st sc, severe cr	0
Springbok 2.5 L	N	4 cr st	1.5 cr black	3	0	10	5 sc cr st	2 cr black
Springbok	½ N	6 cr st	2.5 cr black	5	0	10	7 sc cr st	3 cr
(Muster)	2N	2.5 st cl	0	2 st cl	0	5 st cl	1 st cl cot	0
(Muster) 26.7g	N	4.5	2.5	3	0	7 st cl	3 st cl cot	0
(Muster)	½ N	6	4 st	4	0	9 st cl	5 cl st	3 st del

st stunting; cl chlorosis; sc scorch, cr leaf crinkling and distortion; sc scorch; del delay

Table 12. Celery, cauliflower, iceberg lettuce transplanted 18 May, post-emergence herbicides applied 11 June. Assessment date, growth stage, crop damage score (0 total kill; 7 acceptable; 10 no damage)

Herbicide Assessment date:	Rate	celery 16/6	23/6	10/7	cauliflower 16/6	23/6	10/7	lettuce 16/6	23/6	10/7
Springbok	2N	7 cl sc	4 cl st	3 st	10	10	9	9 cl st	8 st curled	5 st del
Springbok 2.5 L	N	8	6 st cl	5 st	10	10	10	10	10	6 del
Springbok	½ N	9.5 sc	9 st	7 st	10	10	10	10	10	10
(Muster)	2N	1severe sc cl	1 no new leaves cl st	0	10	8 st	8	9 cl st	8 cl st	7.5 del
(Muster) 26.7g	N	3 sc	2 no new leaves	0	10	10	10	9.5 cl	10	9
(Muster)	½ N	5 sc	3 st cl	0	10	10	10	10	10	10

sc scorch; cl chlorosis; st stunting; del delay

Table 13. Peas sown 19 May, post -weed-emergence applied 13 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	peas 16/6 5 node	23/6 encl bud	10/7 flat pod
Springbok	2N	4 nec 20% leaf area	3 cl st plant death	1 cr st nec, del no flowers
Springbok 2.5 L	N	8.5 slight nec	6 st nec	6 st nec
Springbok	½ N	10	10	10
(Muster)	2N	10	6 cl st	3.5
(Muster) 26.7g	N	10	8	7
(Muster)	½ N	10	10	10

cl chlorosis; st stunting; cr leaves crinkled; nec necrosis; del delay

Table 14. Dwarf French beans re-drilled 13 June, emerged 21 June, post-emergence herbicides applied 9 July. 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	Dwarf F beans 16/7 1 ½ trifoliolate leaf	2/8 green bud	10/8 flowering
Springbok	2N	6 st nec	4 st nec	2
Springbok 2.5 L	N	8 st	6 st nec	4
Springbok	½ N	10	8	8
(Muster)	2N	5 dist st	2 dist y severe st	1
(Muster) 26.7g	N	6 dist st	3 st y	2
(Muster)	½ N	7 dst st	4 st y	3

st stunting; nec necrosis; dist leaf cupping downwards; y yellow vein clearing

Table 15. Swede and spinach sown 19 May: post -weed-emergence applied 11 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 3 TL	23/6 4 TL	10/7 6 TL	spinach 16/6 4 TL	23/6 6 TL	10/7 bolting
Springbok	2N	8 sc	9.5	10	8 sc cr	6 w	6
Springbok 2.5 L	N	9 sc	10	10	9 st	8 st	8
Springbok	½ N	10	10	10	9 st	10	10
(Muster)	2N	10	10	10	3 severe w cl	0 nec	0
(Muster) 26.7g	N	10	10	10	5	0	0
(Muster)	½ N	10	10	10	6	0	0

cl chlorosis; st stunting; sc scorch; cr leaves crinkled; nec necrosis; w leaves wilting

Weed Control (more detail in the following Tables)

Pre-weed-emergence herbicides (Tables 16-25)

There were very high populations of shepherd's purse and pineappleweed on this area of the trial. Other predominant weed species were chickweed, groundsel and small nettle. Numbers of pale persicaria, redshank, knotgrass and annual meadow-grass were variable, low to high. There were a few fat-hen and smooth sow-thistle.

Springbok

Springbok applied pre-emergence at dose rates of 5.0 L/ha, 2.5 L/ha (N normal) controlled a wide weed spectrum (Table 3). Springbok was particularly effective on the very high population of shepherds purse and pineappleweed. At 1.25 L/ha it was insufficient to control Polygonums - knotgrass, pale persicaria and redshank. In onion and leek weed control was inadequate at the lowest dose rate 0.625 L/ha – although it controlled annual meadow-grass, small nettle and chickweed, other species remained.

Cadou Star

There are label recommendations for 0.75 or 0.5 kg/ha of Cadou Star for maize. Lower doses 0.4 kg/ha as 'N' were tested for vegetables. Cadou Star at 0.8 kg/ha controlled all species at the site (Table 3). Cadou Star at 0.4 kg/ha did not control knotgrass, redshank or black-bindweed and activity on pineappleweed was poor. Cadou Star at 0.2 kg/ha was also ineffective on pale persicaria or chickweed but controlled the high population of shepherd's purse and also small nettle, annual meadow-grass, and groundsel. The lowest dose (0.1 kg/ha) in onion and leek had very little activity on the species present.

Post-weed-emergence herbicides (Tables 26-37)

Onions and leeks were treated pre-emergence with the standard Stomp + Ramrod (1.5 + 9.0) L/ha but a high population of shepherd's purse, and some pineappleweed and groundsel remained. In contrast, carrots and parsnips treated pre-emergence with standard Stomp + Linuron (500 g/L formulation) (1.6 + 1.0) L/ha on 11 May were weed free, thus there were no weed assessments for the experimental treatments.

In the other crops there were very high populations of shepherd's purse, pineappleweed, annual meadow-grass and knotgrass; other predominant weed species were chickweed and groundsel. The numbers of small nettle was variable. There was also an uneven distribution of pale persicaria, redshank and smooth sow-thistle.

Springbok

Springbok was less active on emerged weeds, particularly where they were large on the pea area, than where applications were made pre-weed-emergence. However, Springbok at 5.0 L/ha (2N dose) controlled all species present except knotgrass. Springbok at 2.5 L/ha did not control knotgrass, redshank or small nettle and was unreliable on fat-hen. Springbok at half dose 1.25 L/ha gave good control of the high populations of shepherd's purse and pineappleweed was controlled by 1.25 and 0.625 kg/ha.

(Muster)

(Muster), a contact-acting sulfonylurea, controlled all species (Table 4) except groundsel at the 2N dose 53.4 g/ha. At 26.7 g/ha it also had weaknesses on pineappleweed, knotgrass and fat-hen. The half dose rate controlled small nettle, redshank, pale persicaria and the high population of shepherd's purse.

Volunteer potato control post-emergence (Table 26)

Potatoes are a frequent problem in vegetable crops and the means of control in carrots, with metoxuron, will be lost after 2007. Volunteer potatoes were chitted and planted at the same time as onions and leeks (17 April). Growth was very advanced - flower buds had formed and there were up to five shoots c. 0.5m tall per plant at the time of post-emergence applications on 11 June. Scores for control are shown in Table 26. The potatoes were affected by potato blight later in July. Springbok had negligible effect on the potatoes. (Muster) at N (26.7 g/L) and 2N dose rates caused chlorosis of the growing point, some stunting and delayed flowering of the potatoes, but the ½ N dose had no effect.

Weed species controlled (summary)

Table 3. Pre-weed-emergence herbicides: 3 weed species controlled; **x** poor control or not controlled at various dose rates; - weeds not present on untreated plots; (low populations limited data)

Pre-weed-emergence Herbicide dose rate/ha	Shepherd's purse	Pineappleweed	Small nettle	Knotgrass	Pale persicaria	Redshank	Chickweed	Smooth sow-thistle	Groundsel	Field speedwell	Annual meadow-grass	Fat-hen	Black-bindweed
Springbok 5.0 L	3	3	3	3	3	3	3	3	3	-	3	3	-
Springbok 2.5 L	3	3	3	3	3	3	3	3	3	-	3	3	(x)
Springbok 1.25 L	3	3	3	x	x	x	3	3	3	-	3	3	(x)
Springbok 0.625 L	x	x	3	x	-	-	3	-	x	-	3	x	(x)
Cadou Star 0.8 kg	3	3	3	3	3	3	3	3	3	3	3	3	(3)
Cadou Star 0.4 kg	3	x	3	x	3	x	3	3	3	3	3	3	(x)
Cadou Star 0.2 kg	3	x	3	x	x	x	x	3	3	3	3	3	(x)
Cadou Star 0.1 kg	x	x	x	x	-	-	x	-	x	-	x	x	(x)

Table 4. Post-weed-emergence herbicides: 3 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	Shepherd's purse	Pineappleweed	Small nettle	Knotgrass	Pale persicaria	Redshank	Chickweed	Smooth sow-thistle	Groundsel	Annual meadow-grass	Fat-hen	Field speedwell
Springbok 5.0 L	3	3	3	x	3	3	3	3	3	3	3	(3)
Springbok 2.5 L	3	3	x	x	3	x	3	3	3	3	x	(3)
Springbok 1.25 L	3	x	x	x	x	x	3	3	x	x	x	(3)
Springbok 0.625 L	x	x	-	-	-	-	-	-	x	-	-	-
(Muster) 53.2 kg	3	3	3	3	3	3	3	3	x	3	3	(3)
(Muster) 27.6 g	3	x	3	x	3	3	3	3	x	3	x	(3)
(Muster) 13.8 g	3	x	3	x	3	3	3	x	x	x	x	(3)
(Muster) 6.9 kg	x	x	-	-	-	-	-	-	x	-	-	-

Weed species controlled

Appendix 1 shows Common and Latin weed names.

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

Table 16. Pre-weed-emergence herbicides 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 10 June and 27 June. Related weed counts see below

Herbicide	Weed species not controlled	Weed species controlled
Springbok N 2.5 L	black-bindweed	shepherd's purse pineappleweed annual meadow-grass chickweed small nettle fat-hen knotgrass groundsel
Springbok ½ N	knotgrass black-bindweed	shepherd's purse pineappleweed annual meadow-grass chickweed small nettle fat-hen groundsel
Springbok ¼ N	shepherd's purse black-bindweed knotgrass pineappleweed fat-hen groundsel	annual meadow-grass chickweed small nettle
Untreated: shepherd's purse pineappleweed annual meadow-grass chickweed small nettle fat-hen knotgrass groundsel black-bindweed redshank		
Cadou Star N 0.4 kg	knotgrass pineappleweed black-bindweed	shepherd's purse annual meadow-grass chickweed small nettle fat-hen groundsel
Cadou Star ½ N	pineappleweed knotgrass black-bindweed chickweed fat-hen	shepherd's purse annual meadow-grass small nettle groundsel
Cadou Star ¼ N	pineappleweed knotgrass chickweed black-bindweed fat-hen groundsel shepherd's purse small nettle annual meadow-grass	
Untreated: shepherd's purse pineappleweed annual meadow-grass chickweed small nettle fat-hen knotgrass groundsel black-bindweed		

Number of weed species/m² on 3 June on untreated (pre-weed-emergence) for each herbicide area (mean 4 counts in 0.33 m² quadrat) and overall (mean 8 counts) in 2 replicates **onion** and **leek**

	Shepherd's purse	Pineappleweed	Annual meadow-grass	Knotgrass	Small nettle	Groundsel	Chickweed	Fat-hen	Black-bindweed	TOTAL
Untreated (Springbok)	120	87	42	6	11	5	11	9	4	295
Untreated (Cadou Star)	126	100	32	8	5	7	9	5	4	296
Untreated overall	123	94	37	7	8	6	10	7	7	296

Table 17. Pre-weed-emergence herbicides applied 21 May: weed species remaining after treatment, weed species controlled, weed species on untreated plots of **carrot** and **parsnip**. Assessed 19 June and 7 July. Related weed counts see below

Herbicide	Weed species not controlled	Weed species controlled
Springbok 2N	-	shepherd's purse pineappleweed knotgrass small nettle groundsel chickweed fat-hen annual meadow-grass
Springbok N 2.5 L	-	shepherd's purse pineappleweed knotgrass small nettle groundsel chickweed fat-hen annual meadow-grass
Springbok ½ N	knotgrass small nettle fat-hen	shepherd's purse pineappleweed groundsel chickweed annual meadow-grass
Untreated: shepherd's purse pineappleweed knotgrass small nettle groundsel annual meadow-grass chickweed fat-hen		
Cadou Star 2 N	-	shepherd's purse pineappleweed knotgrass small nettle groundsel black-bindweed chickweed fat-hen redshank pale persicaria annual meadow-grass
Cadou Star N 0.4 kg	pineappleweed black-bindweed knotgrass redshank	shepherd's purse small nettle groundsel chickweed fat-hen pale persicaria annual meadow-grass
Cadou Star ½ N	pineappleweed black-bindweed knotgrass redshank	shepherd's purse small nettle groundsel chickweed fat-hen pale persicaria annual meadow-grass
Untreated: shepherd's purse pineappleweed knotgrass small nettle groundsel black-bindweed annual meadow-grass chickweed fat-hen pale persicaria redshank		

Number of weed species/m² on 10 June on untreated (pre-weed-emergence) for each herbicide area (mean 4 counts in 0.33 m² quadrat) and overall (mean 8 counts) in 2 replicates of **carrot** and **parsnip**

	Shepherd's purse	Pineappleweed	Knotgrass	Small nettle	Groundsel	Annual meadow-grass	Chickweed	Redshank	Pale persicaria	Black-bindweed	Fat-hen	TOTAL
Untreated (Springbok)	134	151	8	5	7	10	3	0	0	0	4	322
Untreated (Cadou Star)	128	163	5	3	7	11	3	2	2	6	3	333
<i>Untreated overall</i>	<i>137</i>	<i>157</i>	<i>6.5</i>	<i>4</i>	<i>7</i>	<i>23</i>	<i>3</i>	<i>1</i>	<i>1</i>	<i>3</i>	<i>3.5</i>	<i>328</i>

Table 18. Pre-weed-emergence herbicides applied 21 May: weed species remaining after treatment, weed species controlled, weed species on untreated plots of **coriander**. Assessed 19 June and 7 July. Related weed counts see below

Herbicide	Weed species not controlled	Weed species controlled
Springbok 2N	-	shepherd's purse pineappleweed annual meadow-grass knotgrass small nettle fat-hen chickweed groundsel smooth sow-thistle pale persicaria
Springbok N 2.5 L	-	shepherd's purse pineappleweed annual meadow-grass knotgrass small nettle fat-hen chickweed groundsel smooth sow-thistle pale persicaria
Springbok ½ N	knotgrass	shepherd's purse pineappleweed annual meadow-grass small nettle fat-hen chickweed groundsel smooth sow-thistle pale persicaria
Untreated: shepherd's purse pineappleweed annual meadow-grass knotgrass small nettle fat-hen chickweed groundsel smooth sow-thistle pale persicaria		
Cadou Star 2 N	-	shepherd's purse pineappleweed annual meadow-grass knotgrass small nettle redshank smooth sow-thistle groundsel chickweed
Cadou Star N 0.4 kg	-	shepherd's purse pineappleweed annual meadow-grass small nettle groundsel smooth sow-thistle redshank knotgrass chickweed
Cadou Star ½ N	knotgrass pineappleweed redshank	shepherd's purse annual meadow-grass small nettle chickweed groundsel smooth sow-thistle
Untreated: shepherd's purse pineappleweed annual meadow-grass knotgrass small nettle chickweed groundsel smooth sow-thistle redshank		

Number of weed species / m² on 14 June on untreated (pre-weed-emergence) for each herbicide area (mean 2 counts in 0.33 m² quadrat) and overall (mean 4 counts) in 2 replicates of **coriander**

	Shepherd's purse	Pineappleweed	Annual meadow-grass	Knotgrass	Small nettle	Fat-hen	Chickweed	Sow-thistle, smooth	Groundsel	Pale persicaria	Redshank	TOTAL
Untreated (Springbok)	136	64	45	22	15	10	8	3	6	2	0	314
Untreated (Cadou Star)	142	56	6	6	9	0	3	3	6	0	3	234
Untreated overall	139	60	26	14	12	5	5.5	3	6	1	1.5	274

Table 19. Pre-weed-emergence herbicides applied post-transplanting 21 May; weed species remaining after treatment, weed species controlled, weed species on untreated plots of **lettuce, cauliflower** and **celery**. Assessed 19 June and 7 July. Related weed counts see below

Herbicide	Weed species not controlled	Weed species controlled
Springbok 2N	-	shepherd's purse pineappleweed small nettle pale persicaria groundsel chickweed annual meadow-grass redshank knotgrass fat-hen smooth sow-thistle
Springbok N 2.5 L	-	shepherd's purse pineappleweed small nettle pale persicaria groundsel chickweed annual meadow-grass redshank knotgrass fat-hen smooth sow-thistle
Springbok ½ N	pale persicaria redshank knotgrass	shepherd's purse pineappleweed small nettle groundsel chickweed annual meadow-grass fat-hen smooth sow-thistle
Untreated: shepherd's purse pineappleweed small nettle pale persicaria groundsel chickweed annual meadow-grass knotgrass fat-hen smooth sow-thistle redshank		
Cadou Star 2 N	-	shepherd's purse pineappleweed small nettle groundsel chickweed annual meadow-grass fat-hen smooth sow-thistle knotgrass pale persicaria
Cadou Star N 0.4 kg	-	shepherd's purse pineappleweed small nettle groundsel chickweed annual meadow-grass fat-hen smooth sow-thistle knotgrass pale persicaria
Cadou Star ½ N	knotgrass pineappleweed pale persicaria chickweed	shepherd's purse small nettle groundsel annual meadow-grass fat-hen smooth sow-thistle
Untreated: shepherd's purse pineappleweed small nettle groundsel chickweed annual meadow-grass knotgrass pale persicaria fat-hen smooth sow-thistle		

Number of weed species / m² on 16 June on untreated (pre-weed-emergence) for each herbicide area (mean 6 counts in 0.33 m² quadrat) and overall (mean 12 counts) in 2 replicates weed species on untreated plots of **lettuce, cauliflower** and **celery**.

	Shepherd's purse	Pineappleweed	Chickweed	Small nettle	Annual meadow-grass	Knotgrass	Groundsel	Fat-hen	Sow-thistle, smooth	Redshank	Pale persicaria	TOTAL
Untreated (Springbok)	145	82	7	14	6	5	7	2	2	3	12	285
Untreated (Cadou Star)	150	86	7	16	10	7	7	2	3	1	4	293
<i>Untreated overall</i>	<i>147.5</i>	<i>84</i>	<i>7</i>	<i>15</i>	<i>8</i>	<i>6</i>	<i>7</i>	<i>2</i>	<i>2.5</i>	<i>2</i>	<i>8</i>	<i>289</i>

Table 20. Pre-weed-emergence herbicides applied 21 May: weed species remaining after treatment, weed species controlled, weed species on untreated plots of **peas** and **dwarf French beans**. Assessed 19 June and 7 July. Related weed counts see below

Herbicide	Weed species not controlled	Weed species controlled
Springbok 2N	-	shepherd's purse pineappleweed small nettle pale persicaria groundsel chickweed knotgrass redshank
Springbok N 2.5 L	knotgrass pale persicaria	shepherd's purse pineappleweed small nettle groundsel chickweed redshank
Springbok ½ N	shepherd's purse knotgrass pale persicaria pineappleweed	small nettle groundsel chickweed redshank
Untreated: shepherd's purse pineappleweed small nettle pale persicaria groundsel chickweed knotgrass redshank		
Cadou Star 2 N	-	shepherd's purse pineappleweed small nettle pale persicaria knotgrass chickweed smooth sow- thistle field speedwell groundsel
Cadou Star N 0.4 kg	knotgrass pineappleweed chickweed pale persicaria	shepherd's purse small nettle smooth sow-thistle field speedwell groundsel
Cadou Star ½ N	knotgrass pineappleweed chickweed pale persicaria groundsel	shepherd's purse small nettle smooth sow-thistle field speedwell
Untreated: shepherd's purse pineappleweed small nettle pale persicaria knotgrass chickweed smooth sow-thistle field speedwell groundsel		

Number of weed species / m² on 10 June on untreated (pre-weed-emergence) for each herbicide area (mean 2 counts in 0.33 m² quadrat) and overall (mean 4 counts) in 2 replicates of **peas**

	Shepherd's purse	Pineappleweed	Pale persicaria	Small nettle	Chickweed	Knotgrass	Groundsel	Redshank	Field speedwell	Sow-thistle, smooth	TOTAL
Untreated (Springbok)	162	105	32	30	10	6	6	6	0	0	357
Untreated (Cadou Star)	189	129	21	60	6	12	4	1	6	6	434
<i>Untreated overall</i>	175.5	117	26.5	45	8	9	5	3.5	3	3	396

Table 21. Pre-weed-emergence herbicides Cadou Star and Springbok applied 21 May: weed species remaining after treatment, weed species controlled, weed species on untreated plots of **spinach** and **swede**. Assessed 19 June and 7 July. Related weed counts see below

Herbicide	Weed species not controlled	Weed species controlled
Springbok 2N	-	shepherd's purse pineappleweed pale persicaria annual meadow-grass chickweed groundsel small nettle knotgrass redshank smooth sow-thistle
Springbok N 2.5 L	-	shepherd's purse pineappleweed pale persicaria annual meadow-grass chickweed groundsel small nettle knotgrass redshank smooth sow-thistle
Springbok ½ N	pale persicaria knotgrass redshank	shepherd's purse pineappleweed annual meadow-grass chickweed groundsel small nettle smooth sow-thistle
Untreated: shepherd's purse pineappleweed pale persicaria annual meadow-grass chickweed groundsel small nettle knotgrass redshank smooth sow-thistle		
Cadou Star 2 N	-	shepherd's purse pineappleweed pale persicaria annual meadow-grass chickweed groundsel small nettle knotgrass redshank smooth sow-thistle fat-hen
Cadou Star N 0.4 kg	-	shepherd's purse pineappleweed pale persicaria annual meadow-grass chickweed groundsel small nettle knotgrass redshank smooth sow-thistle fat-hen
Cadou Star ½ N	knotgrass pineappleweed groundsel chickweed redshank pale persicaria	shepherd's purse annual meadow-grass small nettle smooth sow-thistle fat-hen
Untreated: shepherd's purse pineappleweed pale persicaria annual meadow-grass chickweed groundsel small nettle knotgrass redshank smooth sow-thistle fat-hen		

Number of weed species / m² on 16 June on untreated (pre-weed-emergence) for each herbicide area (mean 4 counts in 0.33 m² quadrat) and overall (mean 8 counts) in 2 replicates of **spinach** and **swede**

	Shepherd's purse	Pineappleweed	Pale persicaria	Annual meadow-grass	Groundsel	Chickweed	Small nettle	Redshank	Knotgrass	Sow-thistle, smooth	Fat-hen	TOTAL
Untreated (Springbok)	95	44	13	14	9	10	5	4	4	4	1	203
Untreated (Cadou Star)	82	50	17	22	11	8	5	4	4	3	3	209
<i>Untreated overall</i>	<i>88.5</i>	<i>47</i>	<i>15</i>	<i>18</i>	<i>10</i>	<i>9</i>	<i>5</i>	<i>4</i>	<i>4</i>	<i>3.5</i>	<i>2</i>	<i>206</i>

Weed Control Scores pre-weed-emergence herbicides assessed Days After Treatment (DAT) mean of two replicates

Table 22. Pre-weed-emergence herbicides applied 18 April **onion, leek** sown 17 April. Assessment dates 30 May and 19 June; weed control score (0 no control; 7 acceptable; 10 complete control); DAT; growth stage (L leaf),

Herbicide	Onion		Leek	
	1 L	2 L	1 L	2 L
<i>DAT:</i>	42	63	42	63
Springbok N 2.5 L	9.5	9	9.5	9
Springbok ½ N	9	5	9	5
Springbok ¼ N	6	3	6	3
Cadou Star N 0.4 kg	9	7	9	7
Cadou Star ½ N	5	4	5	4
Cadou Star ¼ N	2	1	2	1

Table 23. Pre-weed-emergence herbicides applied 21 May **carrot, parsnip** sown 11 May: weed control score (0 no control; 7 acceptable; 10 complete control) Assessment dates 19 June and 7 July; DAT; growth stage (TL true leaf)

Herbicide	Carrot		Parsnip	
	2TL	4 TL	1TL	3 TL
<i>DAT:</i>	29	47	29	47
Springbok 2N	10	9.5	10	9.5
Springbok N 2.5 L	9	8	9	8
Springbok ½ N	9	6	9	6
Cadou Star 2N	10	9	10	9
Cadou Star N 0.4 kg	9.5	8	9.5	8
Cadou Star ½ N	7	6	7	6

Note: a few cotyledon weeds had emerged at the time of application.

Table 24. Pre-weed-emergence herbicides applied on 21 May drilled crops **peas, dwarf French beans** drilled 19 May; weed control score (0 no control; 7 acceptable; 10 complete control) assessment dates 19 June and 7 July; DAT; growth stage

Herbicide	Peas		D Beans	
	2node	Flat pod	1-2 trifoliolate	Green bud
<i>Untreated GS</i>				
<i>DAT:</i>	29	47	29	47
Springbok 2N	10	10	10	10
Springbok N 2.5 L	10	9	10	9
Springbok ½ N	6	6	7	6
Cadou Star 2N	10	9	10	9
Cadou Star N 0.4 kg	9	6	9	6
Cadou Star ½ N	5.5	4	6	4

Table 25. Pre-weed-emergence herbicides applied on 21 May drilled crops **swede, spinach, coriander** drilled 19 May; applied post transplanting 21 May, **lettuce, cauliflower, celery** transplanted 18 May: weed control score (0 no control; 7 acceptable; 10 complete control) assessment dates 19 June and 7 July coriander and baby leaf spinach were past harvest date; DAT

Herbicide <i>Untreated GS</i> DAT:	Celery		Cauliflower		Lettuce		Swede		Spinach		Coriander	
	29	47	29	47	29	47	3 TL 29	5 TL 47	5 TL 29	bolting 47	3 TL 29	5-6 TL bolting 47
Springbok 2N	10	10	10	10	10	10	10	10	10	10	10	10
Springbok N 2.5 L	10	9.5	10	9.5	10	9.5	10	9.5	10	9.5	10	9.5
Springbok ½ N	9.5	6	9.5	6	9.5	6	9	7	9	7	9.5	7
Cadou Star 2N	10	9	10	9.5	10	9.5	10	9.5	10	9.5	10	9
Cadou Star N 0.4 kg	10	7	10	7.5	10	7.5	10	9	10	9	10	7
Cadou Star ½ N	9	5	8.5	6	8.5	6	9	5.5	9	5.5	9	5

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

Table 26. ‘Volunteer’ potato control; potatoes planted 17 April; herbicides applied on 11 June when there were 2-5 shoots/ potato plant and shoots were 0.5 m tall. Potato control scores (0=no control, 10=complete kill of foliage); % ground cover compared with untreated =100%

Herbicide <i>Assessment date:</i> <i>DAT:</i>	Potato control 19/6 8	Potato control 10/7 (flowers open% plants) 29
Springbok 2N	0	0 (100)
Springbok N 2.5 L	0	0 (100)
Springbok ½ N	0	0 (100)
(Muster) 2N	2 st cl centre	3cl st (50)
(Muster) N 26.7g	1	2 cl st (50)
(Muster) ½ N	0	0 (100)

st stunting; cl chlorosis; 26 DAT potatoes were infected by potato blight. No herbicide treatment controlled potatoes.

Table 27. Post-weed-emergence herbicides applied 4 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 23 June and 10 July. Related weed counts below

Herbicide	Weed species not controlled	Weed species controlled
Springbok N 2.5L	groundsel	shepherd’s purse pineappleweed
Springbok ½ N	groundsel shepherd’s purse pineappleweed	
Springbok ¼ N	shepherd’s purse groundsel pineappleweed	
Untreated: shepherd’s purse pineappleweed groundsel		
(Muster) N 26.7g	groundsel	shepherd’s purse pineappleweed
(Muster) ½ N	groundsel pineappleweed	shepherd’s purse
(Muster) ¼ N	groundsel shepherd’s purse pineappleweed	
Untreated: shepherd’s purse pineappleweed groundsel		

Number of weed species / m² remaining on 6 June after pre-emergence N dose Stomp + Ramrod (mean of 16 counts in 0.33 m² quadrat) on 2 replicates in **onion** and **leek**

	Shepherd’s purse	Pineappleweed	Groundsel	TOTAL
<i>Untreated (Standard)</i>	100	5	5	110

There were no weeds remained on the post-emergence area of carrot and parsnip after the overall application pre-emergence of Stomp + linuron.

Table 28. Post-weed-emergence herbicides applied 13 June to **coriander**, weed species controlled, weed species on untreated. Assessed 28 June and 10 July

Herbicide	Weed species not controlled	Weed species controlled
Springbok 2N	-	shepherd's purse pineappleweed annual meadow-grass knotgrass small nettle chickweed groundsel pale persicaria smooth sow-thistle fat-hen
Springbok N 2.5 L	knotgrass small nettle	shepherd's purse pineappleweed annual meadow-grass chickweed groundsel pale persicaria smooth sow- thistle fat-hen
Springbok ½ N	knotgrass small nettle groundsel pale persicaria annual meadow- grass	shepherd's purse pineappleweed chickweed smooth sow-thistle fat-hen
Untreated: shepherd's purse pineappleweed annual meadow-grass knotgrass small nettle chickweed groundsel pale persicaria smooth sow-thistle fat-hen		
(Muster) 2N	groundsel	shepherd's purse pineappleweed annual meadow-grass knotgrass small nettle chickweed smooth sow-thistle redshank
(Muster) N 26.7g	groundsel pineappleweed	shepherd's purse annual meadow-grass knotgrass small nettle chickweed smooth sow-thistle redshank
(Muster) ½ N	groundsel pineappleweed knotgrass annual meadow-grass	shepherd's purse small nettle chickweed smooth sow-thistle redshank
Untreated: shepherd's purse pineappleweed annual meadow-grass knotgrass small nettle chickweed groundsel smooth sow-thistle redshank		

Number of weed species/m² on 14 June on untreated (post-weed-emergence) for each herbicide area (mean 2 counts in 0.33 m² quadrat) and overall (mean 4 counts) in 2 replicates on **coriander**

	Shepherd's purse	Pineappleweed	Annual meadow-grass	Knotgrass	Small nettle	Chickweed	Groundsel	Fat-hen	Sow-thistle, smooth	Pale persicaria	Redshank	TOTAL
Untreated (Springbok)	135	63	45	24	15	9	6	4	3	3	0	307
Untreated ((Muster))	141	57	6	4.5	9	3	6	0	3	0	3	233
Untreated overall	138	60	25.5	14	12	6	6	2	3	1.5	1.5	270

Table 29. Post-weed-emergence herbicides applied 11 June to small (cotyledon stage) weeds **celery**, **lettuce** and **cauliflower** transplants: weed species not controlled, weed species controlled, weed species on untreated. Assessed 23 June and 10 July

Herbicide	Weed species not controlled	Weed species controlled
Springbok 2N	knotgrass small nettle	shepherd's purse pineappleweed annual meadow-grass chickweed groundsel fat-hen smooth sow-thistle pale persicaria
Springbok N 2.5 L	knotgrass small nettle	shepherd's purse pineappleweed annual meadow-grass chickweed groundsel fat-hen smooth sow-thistle pale persicaria
Springbok ½ N	small nettle knotgrass pale persicaria pineappleweed groundsel annual meadow-grass	shepherd's purse chickweed fat-hen smooth sow-thistle
Untreated: shepherd's purse pineappleweed annual meadow-grass small nettle chickweed knotgrass groundsel fat-hen smooth sow-thistle pale persicaria		
(Muster) 2N		shepherd's purse pineappleweed annual meadow-grass small nettle chickweed knotgrass groundsel fat- hen smooth sow-thistle
(Muster) N 26.7g	groundsel pineappleweed	shepherd's purse annual meadow- grass small nettle chickweed knotgrass fat-hen smooth sow-thistle
(Muster) ½ N	groundsel pineappleweed knotgrass annual meadow-grass fat-hen	shepherd's purse small nettle chickweed smooth sow-thistle
Untreated: shepherd's purse pineappleweed annual meadow-grass small nettle chickweed knotgrass groundsel fat-hen smooth sow-thistle		

Number of weed species/m² on 16 June on untreated (post-weed-emergence) for each herbicide area (mean 6 counts in 0.33 m² quadrat) and overall (mean 12 counts) on 2 replicates of **celery**, **cauliflower** and **lettuce**

	Shepherd's purse	Pineappleweed	Annual meadow-grass	Small nettle	Chickweed	Knotgrass	Fat-hen	Groundsel	Pale persicaria	Sow-thistle, smooth	TOTAL
Untreated (Springbok)	66	18	93	3	6	5	6	6	2	4	209
Untreated ((Muster))	76	48	127	7	6	5	4	8	0	2	284
Untreated overall	71	33	110	5	6	5	5	7	1	3	247

Table 30. Post-weed-emergence herbicides applied 13 June to **peas**: weed species controlled, weed species on untreated. These crops were covered initially to prevent attack by

birds, and weeds were at a more advanced growth stage than in other crops. Assessed 28 June and 10 July

Herbicide	Weed species not controlled	Weed species controlled
Springbok 2N	knotgrass	shepherd's purse pineappleweed fat-hen chickweed groundsel small nettle pale persicaria redshank smooth sow-thistle field speedwell annual meadow-grass
Springbok N 2.5 L	knotgrass groundsel small nettle fat-hen shepherd's purse annual meadow-grass	pineappleweed chickweed pale persicaria redshank smooth sow-thistle field speedwell
Springbok ½ N	knotgrass redshank fat-hen groundsel shepherd's purse small nettle annual meadow-grass pale persicaria	pineappleweed chickweed smooth sow-thistle field speedwell
Untreated: shepherd's purse pineappleweed knotgrass fat-hen chickweed groundsel small nettle pale persicaria redshank smooth sow-thistle field speedwell annual meadow-grass		
(Muster) 2N	groundsel knotgrass annual meadow-grass	shepherd's purse pineappleweed fat-hen chickweed small nettle pale persicaria smooth sow-thistle field speedwell
(Muster) N 26.7g	groundsel knotgrass annual meadow-grass smooth sow-thistle fat-hen pineappleweed	shepherd's purse chickweed small nettle pale persicaria field speedwell
(Muster) ½ N	groundsel knotgrass annual meadow-grass fat-hen smooth sow-thistle pineappleweed	shepherd's purse chickweed small nettle pale persicaria field speedwell
Untreated: shepherd's purse pineappleweed knotgrass fat-hen chickweed groundsel small nettle pale persicaria smooth sow-thistle field speedwell annual meadow-grass		

Number of weed species/m² on 10 June on untreated (post-weed-emergence) for each herbicide area (mean 2 counts in 0.33 m² quadrat) and overall (mean 4 counts) on 2 replicates of **peas**

	Shepherd's purse	Annual meadow-grass	Pineappleweed	Knotgrass	Fat-hen	Chickweed	Groundsel	Small nettle	Pale persicaria	Redshank	Field speedwell	Sow-thistle, smooth	TOTAL
Untreated (Springbok)	112	74	36	21	24	15	9	9	8	6	2	2	328
Untreated ((Muster))	201	64	60	15	30	12	9	8	4	0	2	7	412
<i>Untreated overall</i>	<i>156.5</i>	<i>69</i>	<i>48</i>	<i>18</i>	<i>27</i>	<i>13.5</i>	<i>9</i>	<i>8.5</i>	<i>6</i>	<i>3</i>	<i>2</i>	<i>4.5</i>	<i>370</i>

Table 31. Post-weed-emergence herbicides applied 9 July to re-drilled dwarf French beans: weed species controlled, weed species on untreated. Assessed 23 July and 2 August

Herbicide	Weed species not controlled	Weed species controlled
Springbok 2N	knotgrass groundsel	annual meadow-grass shepherd's purse pineappleweed fat-hen chickweed small nettle
Springbok N 2.5 L	knotgrass groundsel	annual meadow-grass shepherd's purse pineappleweed fat-hen chickweed small nettle
Springbok ½ N	knotgrass groundsel pineappleweed small nettle annual meadow-grass fat- hen shepherd's purse	chickweed
Untreated: annual meadow-grass shepherd's purse pineappleweed knotgrass groundsel fat-hen chickweed small nettle		
(Muster) 2N	groundsel	annual meadow-grass shepherd's purse pineappleweed knotgrass fat- hen chickweed small nettle
(Muster) N 26.7g	groundsel pineappleweed	annual meadow-grass shepherd's purse knotgrass fat-hen chickweed small nettle
(Muster) ½ N	groundsel small nettle pineappleweed annual meadow-grass knotgrass	shepherd's purse fat-hen chickweed
Untreated: annual meadow-grass shepherd's purse pineappleweed knotgrass groundsel fat-hen chickweed small nettle		

Number of weed species/m² on 10 July on untreated (post-weed-emergence) for each herbicide area (mean 2 counts in 0.33 m² quadrat) and overall (mean 4 counts) on 2 replicates of **dwarf French beans**

	Annual meadow-grass	Shepherd's purse	Pineappleweed	Knotgrass	Fat-hen	Chickweed	Groundsel	Small nettle	TOTAL
Untreated (Springbok)	153	35	39	9	3	5	18	6	268
Untreated ((Muster))	189	45	54	6	12	12	15	2	335
<i>Untreated overall</i>	<i>171</i>	<i>40</i>	<i>46</i>	<i>8</i>	<i>8</i>	<i>8</i>	<i>16</i>	<i>4</i>	<i>301</i>

Table 32. Post-weed-emergence herbicides applied 11 June to **swede, baby-leaf spinach**: weed species controlled, weed species on untreated. Assessed 27 June and 10 July. These crops suppressed weeds

Herbicide	Weed species not controlled	Weed species controlled/crop suppression
Springbok 2N	knotgrass	shepherd's purse annual meadow-grass pineappleweed fat-hen chickweed pale persicaria smooth sow-thistle groundsel redshank
Springbok N 2.5 L	knotgrass fat-hen redshank	shepherd's purse annual meadow-grass pineappleweed chickweed pale persicaria smooth sow-thistle groundsel
Springbok ½ N	knotgrass fat-hen redshank shepherd's purse annual meadow-grass pale persicaria	pineappleweed chickweed smooth sow-thistle groundsel
Untreated: shepherd's purse annual meadow-grass pineappleweed fat-hen chickweed pale persicaria smooth sow-thistle groundsel knotgrass redshank		
(Muster) 2N	knotgrass groundsel	shepherd's purse annual meadow-grass pineappleweed fat-hen chickweed pale persicaria smooth sow-thistle redshank
(Muster) N 26.7g	knotgrass fat-hen groundsel pineappleweed	shepherd's purse annual meadow-grass chickweed pale persicaria smooth sow-thistle redshank
(Muster) ½ N	knotgrass groundsel fat-hen pineappleweed	shepherd's purse annual meadow-grass chickweed pale persicaria smooth sow-thistle redshank
Untreated: shepherd's purse annual meadow-grass pineappleweed fat-hen chickweed smooth sow-thistle groundsel knotgrass redshank pale persicaria		

Number of weed species/m² on 16 June on untreated (post-weed-emergence) for each herbicide area (mean 4 counts in 0.33 m² quadrat) and overall (mean 8 counts) in 2 replicates of areas on **swede, baby-leaf spinach**

	Shepherd's purse	Pineappleweed	Annual meadow-grass	Fat-hen	Knotgrass	Chickweed	Pale persicaria	Sow-thistle, smooth	Groundsel	Redshank	TOTAL
Untreated (Springbok)	62	28	64	22	18	13	9	6	6	3	231
Untreated ((Muster))	102	45	78	30	4	9	3	6	6	3	286
Untreated overall	82	36.5	71	26	11	11	6	6	6	3	259

Weed Control Scores Post-weed-emergence herbicides

Table 33. Post-weed-emergence herbicides applied 4 June to onion and leek. A N dose of standard pre-emergence Stomp + Ramrod (1.5 + 9.0) L/ha was applied 18 April and main weeds remaining were: shepherd's purse, pineappleweed, and small nettle. Weed control score for the **programme** (0 no control; 7 acceptable; 10 complete control) assessed 23 June and 10 July

Herbicide	Onion		Leek	
	<i>DAT:</i> 19	36	19	36
Springbok N2.5L	9	8	9	8
Springbok ½ N	6	6	6.5	6
Springbok ¼ N	1	1	1	1
(Muster) N 26.7g	9	9	9	9
(Muster) ½ N	8	7	8	7
(Muster) ¼ N	6	4	6	4

Table 34. Post-weed-emergence herbicides applied 11 June to **celery, cauliflower, lettuce** transplants. Assessed 23 June and 10 July. Weed control score (0 no control; 7 acceptable; 10 complete control)

Herbicide	Celery		Cauliflower		Lettuce	
	<i>DAT:</i> 12	29	12	29	12	29 harvest
Springbok 2N	9	8.5	9	8.5	9	8.5
Springbok N 2.5 L	8	7	7.5	7	7.5	7
Springbok ½ N	6	5	5.5	4.5	5.5	4.5
(Muster) 2N	10	9.5	9.5	9.5	9.5	9.5
(Muster) N 26.7g	9	8	9	8.5	8.5	8.5
(Muster) ½ N	6.5	5.5	7.5	6.5	7.5	6.5

Table 35. Post-weed-emergence herbicides applied 13 June to **peas, coriander**; Assessed 26 June and 10 July unless past harvest stage. Weed control score (0 no control; 7 acceptable; 10 complete control)

Herbicide	Peas#		Coriander	
	<i>DAT:</i> 13	27	13	27
Springbok 2N	8	6.5	10	9.5
Springbok N 2.5 L	6	4.5	8.5	7
Springbok ½ N	3	2	7	6
(Muster) 2N	9	7	10	10
(Muster) N 26.7g	6	5	9	7
(Muster) ½ N	4	3	5	4

#lower scores for peas weeds were more advanced at application because peas were covered to prevent bird attack

Table 36. Post-weed-emergence herbicides applied 9 July to re-drilled dwarf French beans. Assessed 27 July and 13 August. Weed control score (0 no control; 7 acceptable; 10 complete control)

Herbicide	D F Beans	
	<i>DAT:</i> 18	35
Springbok 2N	6	5
Springbok N 2.5 L	4	3
Springbok ½ N	2	1
(Muster) 2N	8.5	7.5
(Muster) N 26.7g	6.5	5.5
(Muster) ½ N	4	3

Table 37. Post-weed-emergence herbicides applied 11 June to **swede, baby-leaf spinach**; Assessed 26 June and 10 July. Weed control score (0 no control; 7 acceptable; 10 complete control)

Herbicide	Swede		Spinach	
	<i>DAT:</i> 15	29	15	29
Springbok 2N	8.5	7	8.5	7.5
Springbok N 2.5 L	6	5	6	5
Springbok ½ N	4	3	4	3
(Muster) 2N	9.5	8.5	9.5	8.5
(Muster) N 26.7g	8	6.5	8	6.5
(Muster) ½ N	7	5	7	5

Conclusions

The aim of this trial was to screen herbicides for crop safety, with a view to further development and applications for SOLAs.

April was a very dry month and rainfall was negligible 3.5 mm. Irrigation was therefore applied after pre-emergence herbicide applications to onion and leek, and also to carrot and parsnip. From the 6th, May was a very wet month with 109 ml rain. The last fortnight in June was also exceptionally wet with a total of 126 ml rainfall, with some very heavy rainfall events – 32.7 ml on 27 May and 42 ml on the 24 June. Hence the above average rainfall provided a stringent test of crop safety of residual soil-acting herbicides Springbok and Cadou Star.

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 – 15)

This study has identified potential alternative active substances (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:

- Carrot, Parsnip – no herbicide was safe.
- Vining peas – post-weed-emergence (Muster) at 13.3 g/ha appeared safe.
- Dwarf French beans – no herbicide was safe.
- Celery transplants – no herbicide was safe.
- Cauliflower transplants – Springbok 2.5 L/ha applied post-transplanting pre- or post-weed-emergence appeared safe to cauliflower. (Muster) 26.7 g/ha, a foliar-acting sulfonylurea, applied post-weed-emergence, post-transplanting was also very safe.
- Lettuce transplants – (Muster) at 26.7 g/ha applied post-weed-emergence, post-transplanting, but efficacy on groundsel and mayweeds was poor; Springbok at ½ N dose (1.25 L/ha) was marginally safe.
- Swede – Springbok at 2.5 L/ha applied pre-emergence of the crop. It was also safe when applied post-emergence, but less effective on emerged weeds. (Muster) at 26.7 g/ha, applied post-weed-emergence, and post-emergence of swede was also safe
- Coriander – Cadou Star pre-weed-emergence was marginally safe at 0.2 kg/ha but several weed species were not controlled at this low dose.
- Baby-leaf spinach – was tolerant of Springbok applied post-emergence at 1.25 L/ha, but no pre-emergence herbicide was safe.

In bulb onion and leek pre-emergence Cadou Star appeared safe at 0.2 kg/ha L/ha, post-emergence Springbok at 0.625 L/ha and (Muster) at 6.68 g/ha were also safe but all these dose rates were too low for effective weed control.

Weed control (Tables 3, 4, 16 – 37)

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.

On untreated areas there were very high populations of shepherd's purse, pineappleweed and annual meadow-grass, other predominant weed species were small nettle, chickweed, groundsel and knotgrass. There were lower, and more variable, numbers of redshank, pale persicaria, fat-hen, smooth sow-thistle and black-bindweed.

- Springbok was a very effective residual pre-emergence herbicide. It controlled a wide weed spectrum (Table 3) knotgrass, small nettle, field speedwell, redshank, smooth sow-thistle. It was particularly effective on the very high population of shepherd's purse, annual meadow-grass and pineappleweed and also controlled groundsel and small nettle. At the ½ N dose of 1.25 L/ha it failed to control polygonums.
- Springbok was less effective on emerged weeds. Activity on polygonums was poor at 2.5 L/ha, although it gave good control of pineappleweed and shepherd's purse even at 1.25 L/ha
- Cadou Star was applied pre-weed-emergence at a lower "N" dose (0.4 kg/ha) than the recommended rate for maize (0.75 kg/ha). At 0.8 kg/ha Cadou star controlled all weed species present, lower doses controlled the high population of shepherd's purse, groundsel and small nettle but 0.4 kg/ha was inadequate on pineappleweed and knotgrass.
- (Muster) a foliar-acting post-weed-emergence treatment, controlled all species at the 2N dose 53.4 g/ha, but at 26.7 g/ha weaknesses were groundsel, pineappleweed and possibly knotgrass. The high population of shepherd's purse and nettle were controlled by 13.4 g/ha. (Muster) is of interest because it is known to be very effective

on charlock, a frequent problem in Brassica crops, but there were none on the trial area.

Recommendations

Some of the herbicides identified as potentially useful are not yet available to UK growers. 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).

Further work is needed to evaluate:

- new herbicides and to continue this early stage screening system on the irrigated site at Kirton.
- Springbok applied pre-weed-emergence post-transplanting leaf and head Brassicas, and pre-emergence of root Brassicas (swede and turnip), and Springbok applied post-weed-emergence. It is less effective post-emergence on polygonums. There will be a 'Gap' when trifluralin, which failed Annex 1 inclusion, is withdrawn from use (possibly March 2009) in these crops. Springbok (metazachlor/dimethenamid-P), a residual herbicide with some contact activity, is authorised for use in UK oilseed rape. Dimethenamid-P improves charlock control.
- (Muster) applied post-weed-emergence has potential for use post-transplanting leaf and head Brassicas, and root Brassicas (swede and turnip). It also appeared safe at ½ N (13.3 g/ha) in vining pea and lettuce. It is very effective on charlock but has a weakness on groundsel and mayweeds appear moderately susceptible. However, it is only authorised in Canada for oilseed rape therefore further work should be delayed until a decision is made regarding introduction into Europe.
- 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.

Herbicides: Current Approval Status

Herbicide Product	Company	active substance and formulation	'N' rate/ha	Registered now or in future?
Pre-weed-emergence				
Springbok 2d post transplants	BASF	metazachlor/dimethenamid-P 200/200 g/L EC	2.5 L	UK oilseed rape

FV 256a FINAL REPORT 2007

Cadou Star 2d post transplants	Bayer	flufenacet/isoxaflutole 480/100 g/kg	0.4 kg/ha	UK maize
<i>Post-weed-emergence (2+ weeks after transplanting)</i>				
Springbok	BASF	metazachlor/dimethenamid-P 200/200 g/L EC	2.5 L	UK oilseed rape
(Muster)#	Dupont	ethametasulfuron 75% wg	26.7g	<i>No UK registration Canada oilseed rape</i>

registered as product Muster in Canada; dimethenamid-P, flufenacet, isoxaflutole on Annex 1

Technology Transfer

2007

Field demonstration of trial:

3 July 2007: HDC open day at Kirton, followed by 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
<i>Capsella bursa-pastoris</i>	Shepherd's purse
<i>Chenopodium album</i>	Fat-hen
<i>Matricaria discoidea</i>	Pineappleweed
<i>Persicaria maculosa</i>	Redshank
<i>Poa annua</i>	Annual meadow-grass
<i>Polygonum aviculare</i>	Knotgrass
<i>Polygonum convolvulus</i>	Black-bindweed
<i>Polygonum lapathifolium</i>	Pale persicaria
<i>Senecio vulgaris</i>	Groundsel
<i>Sonchus oleraceus</i>	Smooth sow-thistle
<i>Stellaria media</i>	Common chickweed
<i>Urtica urens</i>	Small nettle
<i>Veronica persica</i>	Common field speedwell

Appendix 2

Rainfall and irrigation 2007

