Project title	Carrots: Alternative treatments to control volunteer potatoes
Project number:	FV 342
Project leader:	Cathy Knott, Independent Herbicide Specialist 55 Church St., Werrington, Peterborough, Cambs.PE4 6QU
Report:	Final report, 31 March 2009
Previous report	none
Key staff:	Cathy Knott
Location of project:	P Chennells, Clay Farm, South Scarle, Lincs.; C Tompsett, Isleham, Cambs.; Hainford, Norfolk; F Hiam, Tuddenham Corner,Suffolk.
Project coordinator:	David Martin, Plantsystems Ltd., 97 Hollycroft Rd. Emneth, Wisbech PE14 8BB
Date project commenced:	31 March 2008
Date project completed (or expected completion date):	31 March 2009
Key words:	Carrots, parsnips, outdoor, post-emergence herbicides Defy (prosulfocarb), Alpha linuron (linuron), Sumimax (flumioxazin), crop safety, volunteer potato control

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

AUTHENTICATION

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

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Grower Summary

Headline

- Alternatives to Dosaflo (metoxuron) have been found for volunteer potato suppression in carrots: a repeat application of Defy + Alpha Linuron (2.5 + 0.6) L/ha, or a single spray of Sumimax (flumioxazin) 100 ml/ha.

- Defy (prosulfocarb) is available but note that the UK approvals for linuron products now have a maximum rate of application of 600 g a.i./ha/year.

- A SOLA application has been made for Sumimax. However, neither may be as effective as Dosaflo, and Sumimax causes some stunting of carrots. These alternatives are less safe to parsnips but could be used as 'fire engine' treatments.

Background and expected deliverables

The area of carrots grown in the UK in 2007 was c. 10,700 ha, parsnips occupied c. 3,100 ha. In 2008, carrot maincrop output was suggested (Nix: 2007) at £11,050; with a Gross Margin of £5,610/ha. Most of the crop is grown on rented land where volunteer potatoes are often a problem. A key herbicide for carrots metoxuron, was not supported in the 91/414/EEC Pesticide Review and the derogation for 'Essential Use' expired December 2007. Metoxuron applied post-emergence provided good suppression of volunteer potatoes. The last CSL Pesticide Usage Survey for 2007 showed that, after linuron, metoxuron was the next most widely used herbicide, applied to 1535 ha, 11% of the carrot and parsnip crop area. If no herbicidal control was available and if the crop is not harvestable, losses could amount to more than £10 million per annum.

Volunteer potatoes:

- Affect quality in terms of size grade and uniformity of crop (a standard specified by the retailer or processor). Failure to meet specifications results in crop rejection or no sales.
- Reduce harvest work rate, cause harvest losses and increase costs.
- If they are not controlled can be a reservoir of potato blight infection – a concern for potato growers.
- Mechanical weed control is possible in carrots grown in wide rows, but potatoes within the row are not controlled, and it is not an option for baby carrots grown at high densities on a close-row bed system.
- Removal by hand pulling (carrot seedlings within the row are often pulled up as well) or spot glyphosate application by hand for control of volunteer potatoes is costly.

Control with selective application of glyphosate (weed wipers etc.) is another alternative. There is a Hort-Link project HL 0183 on selective application of glyphosate with vision guidance but the system is not available yet.

Possible alternatives to metoxuron were: Sumimax (flumioxazin), registered for use in wheat and residues data for carrots were generated for flumioxazin in 2008/2009 and there is a SOLA for Defy in carrots and parsnips - it was used in tank-mix with linuron in commercial crops in 2008.

Commercial objective

There was a need to investigate alternatives to metoxuron for volunteer potato control/ suppression – possibly Sumimax or Defy + Alpha Linuron at different timings and dose rates.

Summary of the project and main conclusions

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Herbicide Current Approval Status (December 2008)

a.i.	*EC review*	*Product*	*Company*	*Formulation*	*UK Approval Status*
flumioxazin	Annex 1	Sumimax	Sumitomo	300 g/L SC	UK approval wheat, application for a SOLA for carrots and parsnips
linuron	Annex 1	Alpha Linuron	Makhteshim	500 g/L SC	UK approval carrots and parsnips
prosulfocarb	Annex 1	Defy	Syngenta	800 g/L SC	SOLA carrots, parsnips

SOLA Specific Off-Label Approval

Sites

Carrots: all cv. Nairobi Site 1 Isleham, Suffolk; Site2 Hainford, Norfolk; Site 3 South Scarle, Lincs.; Parsnip: cv. Javelin, Site 4 Tuddenham Corner, Suffolk

Carrots

Herbicide treatments carrots 2008, A '+' denotes a tank-mix; & followed by

Herbicide	*g a.i./ha*	*Product/ha*
1. untreated		-
Carrots 3 true leavesT1		
2. Sumimax	15	50ml
3. Sumimax	30	100ml
4. Sumimax	60	200ml
5. Defy + Alpha Linuron	2000 + 325	2.5L + 0.65L
6. Defy + Alpha Linuron	4000 + 325	5.0L +0.65L
Carrots 3 true leaves + 14 daysT2		
7. Sumimax	30	100ml
Carrots 3 true leavesT1 & + 14 daysT2		
8. Sumimax & Sumimax	15 & 15	50ml & 50ml
9. Defy + Alpha Linuron & Defy + Alpha Linuron	2000 + 325 & 2000 + 325	2.5L + 0.65L & 2.5L + 0.65L

Crop tolerance

There was a marked dose response to Sumimax.

At the T1 timing Sumimax 50 ml/ha was very safe to carrots at the 3-4 true-leaf stage at all sites, only a slight growth check was observed.

Sumimax 100 ml/ha (the Normal dose rate for wheat) applied to carrots at T1 timing caused slight scorch at Sites 1 and 2 but more severe scorch (brown/black) where applied at 20°C at Site 3. At all sites the main effects were stunting, although the carrots recovered and were undistinguishable from untreated carrots after 40-50 days. Damage was acceptable at Site 1 and 2 but not at Site 3.

Damage from Sumimax at 200 ml/ha (twice Normal dose) was severe, persistent stunting of the crop was unacceptable at all sites.

At the later T2 application timing to carrots at 5-6 true leaves, Sumimax 100 ml/ha was more damaging than at T1 at all sites: carrot leaves lost colour, stunting was more severe and there was also some leaf loss at Site 3. This was perhaps because at this stage the larger leaf area of carrots caught more spray. Sumimax 50 ml/ha followed by Sumimax 50 ml/ha appeared safe to carrots at Site 1, but there was scorch and some leaf loss after the second application at site 3, stunting at Sites 2

and 3 and recovery was slow. This split dose showed no advantage in terms of crop safety compared with the full dose 100 ml/ha at T1.

At the T1 timing Defy + Linuron at (2.5 + 0.65) or (5.0 + 0.65) L/ha at Site 1 caused very severe scorch, some leaves died and damage was unacceptable. Although new growth was unaffected carrots sprayed with the higher dose rate were slow to recover. Commercial crops sprayed with Defy + Linuron did not suffer severe scorch. The reason for the trial damage is unclear but it may be because a fine spray was used in order to give good spray cover on the potatoes, or possibly some carrot leaves were wet. At Sites 2, 3 and 4 a new sample of Defy was used. At Site 2 there was negligible damage from Defy + Linuron. There were more effects where it was applied at a higher temperature at Site 3 - initial scorch and 1% of plants lost the first true leaf, but the carrots soon recovered.

At Sites 2 and 3, damage from the programme Defy + Linuron (2.5 + 0.65) L/ha at T1 followed by Defy + Linuron (2.5 + 0.65) L/ha at T2, was more severe than the single application, with more scorch, but new growth was unaffected and the crop recovered.

Recovery from Defy + Linuron scorch was much quicker than from Sumimax stunting at both timings.

Volunteer potato control

The population of volunteer potatoes was lower and growth less advanced (70% small) at Site 1 than at Sites 2 and 3 (70% large). The potato population was extremely high at Site 2. Potatoes were classified as 'small' if there was only one shoot c. 3-5 cm tall, and 10 cm across; 'large' potatoes had two or more shoots 20 cm tall, 40 cm or more across. At Site 1 large potatoes had 2-3 shoots; at Site 2, 2-5 shoots, at Site 3, 3-5 shoots.

At Site 1 volunteer potato control was excellent from all treatments except the low dose of Sumimax 50 ml/ha. Sumimax has foliar contact and soil residual activity and at 100 ml/ha gave better control of volunteer potatoes than at other sites possibly because the high rainfall 25 May - 3 June increased the residual effect and also the potato shoots were much smaller. Potato leaves were black/brown and crinkled, stems were dark brown and the potatoes became very stunted.

Sumimax 100 ml/ha at T2 performed slightly better than at T1 at Sites 2 and 3 but the potatoes had already grown above crop height, and it would be better to remove competition early at T1. The Sumimax repeat dose of 50 ml/ha (treatment 8) was marginally better than the full 100 ml/ha dose at T1. However the later timings were less safe to the crop.

At all sites the Defy + Linuron treatments (2.5 + 0.65) L/ha and (5.0 + 0.65) L/ha applied at T1 caused severe scorch and killed most small potato shoots within a week. There was not much difference between these dose rates. The action of Defy + Linuron was faster than Sumimax. At Site 1 large potatoes were also killed but at Sites 2 and 3 the single applications of Defy + Linuron were inadequate on large potatoes.

Overall the repeat dose of Defy + Linuron (2.5 + 0.65) ml/ha at T1 and T2 performed best.

There was a little re-growth of potato foliage from a few stems where Sumimax was applied at T1, and from stems and occasionally the tuber from Defy + Linuron at all sites.

- The best control of volunteer potatoes was achieved when most potatoes were small and had one shoot (at this stage the carrots were at 3 true-leaves). All herbicides were less effective when 70% of the potatoes were large with two or more shoots at Sites 2 and 3.

- A programme of Defy + Linuron (2.5 + 0.65) L/ha followed by Defy + Linuron (2.5 + 0.65) L/ha 14 days later was the most effective treatment against volunteer potatoes in these trials.

- An early application T1 of Sumimax at 100 ml/ha when most potatoes were small and the crop was at 3 true-leaf stage gave good control. Competition would be removed early and the carrots would also have more time to recover. Sumimax performed better in a trial (not HDC) in the wet conditions of 2007 than in 2008.

- Sumimax has foliar contact and soil residual activity. Irrigation or rainfall increased the residual effect on potatoes, but may also increase damage to the crop.

- Both these treatments are potentially damaging. Sumimax 100 ml/ha in particular caused stunting of carrots. However, volunteer potatoes also suppress the crop.

- At Sites 1 and 2 the potato variety was Maris Piper, at Site 3 it was Saturna. The size of the potatoes when treated had more influence on herbicide efficacy than variety.

Parsnips

Herbicide treatments parsnips 2008, A '+' denotes a tank-mix; & followed by

Herbicide	*g a.i./ha*	*Product/ha*
1. untreated		-
Parsnips 3 true leaves T1		
2. Sumimax	15	50ml
3. Sumimax	30	100ml
4. Sumimax	60	200ml
5. Defy + Alpha Linuron	1600 + 250	2.0L + 0.5L
6. Defy + Alpha Linuron	3200 + 250	4.0L +0.5L
Parsnips 3 true leaves + 14 days T2		
7. Sumimax	30	100ml
Carrots 3 true leavesT1 & + 14 days T2		
8. Sumimax & Sumimax	15 & 15	50ml & 50ml
9. Defy + Alpha Linuron & Defy + Alpha Linuron	1600 + 250 & 1600 + 250	2.0L + 0.5L & 2.0L + 0.5L

Crop tolerance

The parsnips were slow to emerge and at a range of growth stages. Spraying was delayed until most were at 4 true-leaf stage but a few were at 2. The volunteer potatoes were shading the crop.

Sumimax caused crinkling, distortion and brown/black spotting on parsnip leaves followed by severe stunting. All treatments caused loss of two leaves. The

application of Sumimax 100 ml/ha at T2 (treatment 7) caused the most visual damage possibly because more spray was caught by the larger crop leaves.

Lower doses of Defy + Linuron were used in parsnips than for carrots. Defy + Linuron (2.0 + 0.5) L/ha caused initial damage in the form of leaf scorch and distortion later. The first two leaves died and plants that were at 2 true-leaf stage were killed. The programme caused further leaf loss. New parsnip growth after application of Defy + Linuron was normal and the crop made a good recovery from treatment 5.

Parsnips were more sensitive than carrots to Sumimax and Defy + Linuron. Both appeared too damaging in this trial, although they could be considered in a 'fire-engine' strategy. There was loss of leaves from all herbicide treatments and loss of some small plants. The main effects from Defy + Linuron were scorch and there was a quicker recovery than from the severe stunting effects of Sumimax.

There was an early potato blight infection and most potato foliage died by 25 July. The best control of potatoes was with the repeat dose of Defy + Linuron (2.0 + 0.5) L/ha.

Mayweed control
At Site 2 there was a population of 12 plants/m^2 of scentless mayweed *(Matricaria inodorum)* on untreated plots. Mayweeds are resistant to Linuron applied post-emergence. The low dose of Sumimax 50 ml/ha or Defy + Linuron (2.5 + 0.65) L/ha had little effect on mayweed, the repeat doses were more effective and caused stunting. The best control was with Sumimax applied early at 100 ml/ha. Although there were indications of control, the plots were not replicated. It is also likely that the potato plants shielded some mayweeds from spray.

Financial benefits

Volunteer potatoes reduce yield, size grade and quality of carrots and parsnips, and interfere with harvesting. If no herbicidal control was available, then if crops were not harvestable, losses could amount to more than £10 million per annum. Carrots and parsnips are often grown on rented land on farms (or neighbours) that also grow potato crops. If volunteer potatoes are not controlled they act as a reservoir for potato blight infection and carrots and parsnips may be unwelcome.

Control measures were with Dosaflo (metoxuron) but this could not be used after 31 December 2007. About 11% of the carrot and parsnip crop was treated with Dosaflo (metoxuron) mainly for volunteer potato control in 2007, the last season it was available (CSL Pesticide Usage Survey, 2007).

A programme of two applications of a tank-mix of Defy + Linuron or, if a SOLA is approved, one application of Sumimax (flumioxazin), will be cheaper options than hand pulling or spot treatment with glyphosate, and more effective than hoeing.

Selective application of glyphosate (weed wipers etc.) is another alternative but only where there is a height differential between crop and weed. There is a Hort-Link project HL 0183 on selective application of glyphosate with vision guidance but this system is not yet available.

Action points for growers

- Growers will need to review weed control strategy for carrots and parsnips after 2008. Unfortunately aclonifen (tested in FV 263b) as a pre-emergence alternative to linuron will not be available for the UK. In addition, products of linuron (on Annex 1 the EC positive list), have been re-registered and restricted to a maximum dose rate of 600 g a.i./ha per year.

- Defy (prosulfocarb) has a SOLA for carrots and parsnips but the Harvest Interval is long (12 weeks) – a problem for bunching or baby carrots. Post-emergence it is safe to carrots, but less safe in parsnips and it does not control mayweeds, fumitory or groundsel. A programme of two applications of tank-mix Defy + Alpha Linuron 50SC (a 500g/L formulation) (2.5 + 0.65) L/ha or less in carrots and at much lower doses in parsnips was used successfully in 2008 to control volunteer potatoes in many commercial crops. However, the new dose restriction for linuron means that this may not be possible because linuron may be needed for pre-emergence use. Defy on it's own does not control volunteer potatoes.

- Sumimax (flumioxazin), a cereal herbicide, at 100 ml/ha applied post-emergence gave good suppression of volunteer potatoes in these trials. Residues data for carrots were generated for flumioxazin in 2008. SOLAs were requested (December 2008) for Sumimax and other products (300g/L SC formulations of flumioxazin) for post-emergence use at a maximum of 100 ml/ha in carrots (and parsnips) to give suppression of volunteer potatoes. It would also control mayweed, fumitory, volunteer oilseed rape, and possibly groundsel and nightshades (data from other trials).

- Sumimax causes temporary stunting of carrots and more severe effects in parsnips. If a SOLA is authorized, use of Sumimax will be at Grower's Risk. Growers are advised to evaluate the crop safety on a small area of crop prior to wide-scale use especially on parsnip (where it should only be considered as a 'fire engine' treatment). Sumimax has contact and residual activity. Irrigation or rainfall increases the residual effect but may also increase crop damage. It appears best to apply Sumimax early (carrots at three true-leaf stage) when nearly all potato shoots have emerged but are still small. The crop will have more time to recover from an early application.

Site 1: Isleham 15 June (28 DAT1)

Untreated potatoes


Sumimax 50ml/ha at T1 large potatoes not controlled


Sumimax 100ml/ha at T1 large potatoes


Sumimax 100ml/ha at T2 large potatoes, carrot damage

Site 2: Hainford 13 July (15 DAT2)


Sumimax 50ml/ha at T1 followed by 50 ml/ha at T2 (left);
Defy + Linuron (2.5 + 0.65) L/ha at T1 followed by Defy + Linuron (2.5 + 0.65) L/ha at T2 (right)

Science Section

Introduction

The area of carrots grown in the UK in 2007 was c. 10,700 ha, parsnips occupied c. 3,100 ha. Most of the crop is grown on rented land where volunteer potatoes are often a problem. A key herbicide for carrots metoxuron, was not supported in the 91/414/EEC Pesticide Review. The derogations for 'Essential Use' expired December 2007. Metoxuron applied post-emergence provided good suppression of volunteer potatoes. The last CSL Pesticide Usage Survey for 2007 showed that, after linuron, metoxuron was the next most widely used herbicide, applied to 1535 ha (11% of the crop). If no herbicidal control was available and if the crop is not harvestable, losses could amount to more than £10 million per annum.
Volunteer potatoes:

- Affect quality in terms of size grade and uniformity of crop (a standard specified by the retailer or processor). Failure to meet specifications results in crop rejection or no sales.
- Reduce harvest work rate, cause harvest losses and increase costs.
- Can be a reservoir of potato blight infection if they are not controlled – a concern for potato growers.
- Mechanical weed control is possible in carrots grown in wide rows, but potatoes within the row are not controlled, and it is not an option for baby carrots grown at high densities on a close-row bed system.
- Removal by hand pulling (carrot seedlings within the row are often pulled up as well) or spot application of glyphosate by hand is costly.

Control with selective application of glyphosate (with weed wipers etc.) is an alternative, but depends on height differential between crop and weed. There is a Hort-Link project HL 0183 on selective application of glyphosate with vision guidance but the system is not available yet.

There are possible herbicide alternatives to metoxuron: Sumimax (a 300 g/L formulation of flumioxazin) is registered for use in wheat. Residues data for carrots were generated for flumioxazin in 2008. There is now a SOLA for Defy in carrots and parsnips and it was used in tank-mix with linuron in commercial crops in 2008.

Materials and methods

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Herbicide Current Approval Status (December 2008)

a.i.	*ECreview*	*Product*	*Company*	*Formulation*	*UK Approval Status*
flumioxazin	Annex 1	Sumimax	Sumitomo	300 g/L SC	UK approval wheat, application for a SOLA for carrots and parsnips
linuron	Annex 1	Alpha Linuron	Makhteshim	500 g/L SC	UK approval carrots and parsnips
prosulfocarb	Annex 1	Defy	Syngenta	800 g/L SC	SOLA carrots, parsnips

SOLA Specific Off-Label Approval

Herbicide treatments carrots 2008, A '+' denotes a tank-mix; '&' followed by

Herbicide	*g a.i./ha*	*Product/ha*
1. untreated		-
Carrots 3 true leaves T1		
2. Sumimax	15	50ml
3. Sumimax	30	100ml
4. Sumimax	60	200ml
5. Defy + Alpha Linuron	2000 + 325	2.5L + 0.65L
6. Defy + Alpha Linuron	4000 + 325	5.0L +0.65L
Carrots 3 true leaves + 14 days T2		
7. Sumimax	30	100ml
Carrots 3 true leavesT1 & + 14 days T2		
8. Sumimax & Sumimax	15 & 15	50ml & 50ml
9. Defy + Alpha Linuron & Defy + Alpha Linuron	2000 + 325 & 2000 + 325	2.5L + 0.65L & 2.5L + 0.65L

Herbicide treatments parsnips 2008, A '+' denotes a tank-mix; '&' followed by

Herbicide	*g a.i./ha*	*Product/ha*
1. untreated		-
Parsnips 3 true leaves T1		
2. Sumimax	15	50ml
3. Sumimax	30	100ml
4. Sumimax	60	200ml
5. Defy + Alpha Linuron	1600 + 250	2.0L + 0.5L
6. Defy + Alpha Linuron	3200 + 250	4.0L +0.5L
Parsnips 3 true leaves + 14 days T2		
7. Sumimax	30	100ml
Parsnips 3 true leaves T1 & + 14 days T2		
8. Sumimax & Sumimax	15 & 15	50ml & 50ml
9. Defy + Alpha Linuron & Defy + Alpha Linuron	1600 + 250 & 1600 + 250	2.0L + 0.5L & 2.0L + 0.5L

Crop; Site Location; OS reference; Soil type

1. Carrots: C Tompsett, Isleham, Suffolk; TL 661 732; Sandy loam
2. Carrots: C Tompsett, Hainford, Norfolk; TG 235 188; Light LS loamy sand
3. Carrots: P Chennells, South Scarle, Lincs.; SK 859 652 ; Very Light LFS loamy fine sand
4. Parsnips: F Hiam, Tuddenham Corner, Suffolk; TL 737 697; Very Light LFS loamy fine sand

Crop variety, sowing date, number of rows

Site 1. Carrots cv. Nairobi, sown 15 March, 4 triple rows/bed
Site 2. Carrots cv. Nairobi, sown 5 May, 4 triple rows/bed
Site 3. Carrots cv. Nairobi, sown 15 May; 4 triple rows/bed
Site 4. Parsnips cv. Javelin, 4 rows/bed, inner single, outer 2 scatter

Trial Design

Each plot was 10 m or 12 m long x one bed (1.83 m) wide, to accommodate a high population of volunteer potatoes, not replicated.

Records/Assessments

The following records and assessments were undertaken following application of the experimental treatments.

- Weather during application.
- Damage symptoms recorded.
- Observations on any phytotoxicity symptoms, crop scores for damage (0=complete kill; 7= acceptable damage; 10=untreated no damage)

Crop tolerance score		crop damage (% photoxicity)
0	=	complete crop kill 100%
1	=	80 - 95% damage
2	=	70 - 80%
3	=	60 - 70%
4	=	50 - 60%
5	=	40 - 50%
6	=	25 - 40%
7#	=	20 - 25% #
8	=	10 - 20%
9	=	5 - 10%
10	=	no damage (or same as untreated)

damage unlikely to reduce yield and acceptable to the farmer

- Assessments of % crop cover, % crop height compared with untreated
- Number of volunteer potatoes (plants or shoots) per plot.
- 5 potatoes per plot were marked with labels and categorised as small (c. one shoot 5cm tall, 10cm across) or large (more than 2 shoots, c. 15cm tall, 20-40cm across.
- % green leaf area of potatoes remaining at intervals after each application.
- Digs of a few potatoes/plot (identified by markers) to establish effect on tubers compared with untreated potatoes.
- Observations on potato control, scores (0=untreated no control, 7= acceptable control, 10= complete control.
- Other weed species present (if any) and counts of numbers of each species/m^2 in 3 random quadrats of 0.33 m^2 per plot also to be assessed.

Application Details
Sprays were applied with an Azo precision plot sprayer, delivering 200 L/ha water volume through Lurmark flat fan nozzles 02F110 at 1.9 bar pressure to give fine spray quality.

Application date	*Weather*	*GS (Growth Stage BBCH) true leaves (TL); seedbed*	*Volunteer potatoes (untreated)*
Site 1 Isleham Carrots			
18 May 8-9am	16°C; 47% RH; cloud cover 50%; wind 10mph; no rain after application	10% 2TL,80% at 3TL (13), 10% 4TL soil surface dry; leaves dry	cv. mainly Maris Piper, a few white flowered; 70% small (c. 5cm tall, 10-15cm across) 30% large (2 – 3 shoots, 15cm tall, 20-40cm across)
29 May 8-9am	16°C ((20°C later); 48% RH; cloud cover 60%; wind 2mph; no rain after application; frost later	80% 5TL (15), 20% 6TL soil surface dry; leaves dry	large (3 or more shoots, 25cm tall, 45cm across) a few flower buds
Site 2 Hainford Carrots			
17 June 10.30-11.30am	16°C (20°C later); 45% RH; thin high cloud cover 60%;, no rain after application	4 TL(14); soil surface dry; leaves dry	cv. Maris Piper; 30% small (c. 3cm tall, 8cm across) 70% large (2 – 5 shoots, 20-25cm tall, 40-50cm across)
28 June 9.30-10.30am	18°C; 34% RH; cloud cover 90%; no rain after application	6 TL(16); soil surface dry; leaves dry	90 -100% plot cover untreated, average (more than 2 shoots, 30cm tall, 50cm across)
Site 3 South Scarle Carrots			
28 June 7pm	20°C; 34% RH; cloud cover 80%; wind 10 mph; no rain after application	70% 4 TL (14), 25% 3 TL, 5% 2 TL; soil surface dry; leaves dry	cv. Saturna from crop 2003; linuron scorch; 30% small (1 shoot, c. 3cm tall, 10cm across) 70% large (3 - 5 shoots, 15-20cm tall, 40cm across)
10 July 12 – 12.30pm	19°C; 39% RH; cloud cover 50%; no rain after application before 3pm	5 ½ - 6 ½ TL (15-16); soil surface damp; leaves dry	80% plot cover on untreated. Potatoes flowering
Site 4 Tuddenham Parsnips			
15 June 9-10am	18°C; 35% RH; cloud cover 30%; no rain after application	2-4 true leaves, mainly 4 (14); soil surface dry; leaves dry	40% small (1 shoot, 20cm tall, 25cm across) 60% large (2-4 shoots, 50cm tall, 60cm across); flower buds
24 June 8-9am	16°C; 38% RH; sunny, thin high cloud; no rain after application	4-5 true leaves, (14-15); soil surface dry; leaves dry	Untreated small (1 shoot 20cm tall, 25cm across) large (2-4 shoots, 55cm tall, 65cm across); most potatoes open flower. A few newly emerged.

Weather

May was a very dry month and there was no rainfall until the last week, temperatures were above average. In June temperatures and rainfall were average. In July temperatures and rainfall were close to average. The period 25 May to 3 June was very wet, and 6 to 11 July was also wet – otherwise the weather was dry. The high rainfall events followed spray applications at Sites 1 and 3. All sites were irrigated.

Results and Discussion

Carrots Site 1 Isleham: Crop Tolerance Table 1

There was a marked dose response to Sumimax. New growth produced after all the Sumimax applications appeared normal and there was no leaf loss.

At the first T1 timing there was a negligible effect on carrots from Sumimax applied at the 50ml/ha dose rate.
Sumimax applied at 100ml/ha (the dose rate for winter wheat), caused slight stunting and occasional carrot leaves were black/brown (24 May). The slight stunting persisted but the carrots began to recover and were almost indistinguishable from the untreated on 11 July.
Sumimax at the 200ml/ha dose rate carrot leaves had a dull grey appearance initially, and the crop suffered a growth check, stunting was severe, and unacceptable by the 15 June. Crop height was only 60% of untreated carrots on 20 June. Stunting persisted and was still apparent (90% of untreated height) on 25 July, 68 days after treatment.

Application of Sumimax 100ml/ha at the T2 timing (treatment 7) caused more initial damage than the earlier timing (treatment 3) – 20% of the leaf area was scorched, stunting was severe but there was no leaf loss. Treatment 8, the programme of Sumimax 50ml/ha at T1 followed by Sumimax 50ml/ha at T2: the second application caused slight scorch to 5% of the leaf area (8 June) and stunting but no leaf loss. The sequence was no safer than the earlier T1 single treatment at the full dose (treatment 3) and there was less time for recovery.

Defy + Linuron caused severe damage at this site and there was leaf scorch and some leaves died. The commercial crop was treated the previous day and suffered little damage. Analysis of the Defy sample was undertaken by the company and eventually found to be correct. The reason for the damage is unclear, but it may be related to the fine spray used or to leaf wetness. At Sites 2, 3 and 4 a new sample of Defy was used. Assessments on 15 June showed that two leaves died on most plants treated with Defy + Linuron (2.5 + 0.65) L/ha (treatment 5 and 9), three died on treatment 6 Defy + Linuron (5.0 + 0.65) L/ha and all treatments caused stunting. Damage was unacceptable. Damage from the programme, Defy + Linuron (2.5 + 0.65) L/ha at T1 followed by Defy + Linuron (2.5 + 0.65) L/ha at T2, was more severe.

The carrots eventually recovered from all treatments. The field crop was harvested 15 August.

Site 1 Isleham: Volunteer potato control Table 2

At the time of spray applications on 18 May most potato shoots had emerged and an estimated 70% were small (c. 5cm tall, 10-15cm across) 30% large (2–3 shoots, 15cm tall, 20-40cm across), very few emerged later (Table 2). The potatoes were mainly cv. Maris Piper.

The Defy + Linuron treatments 5, 6 and 9 caused severe scorch and killed small potato shoots (assessed 24 May) within six days. The action of Sumimax was slower, and potato leaves were black/brown and crinkled. Assessments on 29 May, 11 days after treatment (DAT) showed Sumimax at the low dose rate of 50ml had damaged 90% of small shoots.

A frost on 29 May increased damage to potatoes from the herbicides applied at T2 (treatments 7, 8 and 9) so the kill was more rapid than earlier applications (8 June, Table 2). Untreated potatoes showed slight blackening later but carrots were not affected by frost. On 8 June untreated potatoes, several flowering, were 40-50cm tall, and above untreated crop height 25-30cm.
Counts of live potato shoots on 15 June showed there was further death of shoots and area of damage on large potatoes from the early applications of Sumimax (treatments 2, 3 and 4).

On 15 June re-growth was observed on live potato stems remaining on treatment with the split dose of Sumimax (treatment 8) and new growth from tubers on the Defy + Linuron programme (treatment 9). On 3 July re-growth on earlier applications was also observed on a few potato plants and was from the stem on Sumimax treatments. Height of the untreated carrots was 45cm, potatoes were above the crop. Potatoes on all treated plots were below crop height.

Sumimax has foliar contact and soil residual activity. Sumimax 100 ml/ha gave better control of volunteer potatoes than at other sites possibly because high rainfall 25 May - 3 June after application increased the residual effect and also the potato shoots were much smaller.

On 25 July, five potato plants (3 small, 2 large) marked by labels on each plot were dug to see whether any potato tubers had formed. There were several on the untreated plot from small and large plants; none from treated small potatoes (treatments 2-9). On the large plants, tubers had formed on all except the early application of treatment 4, Sumimax 200ml/ha and the late Sumimax 100ml/ha. On the late treatments 8 and 9, there were tubers on two of three large potatoes, tubers on the Sumimax treatment 8 were tiny.

Table 1. Site 1 Isleham: Crop tolerance scores (0=complete kill; 7=acceptable damage; 10=no damage). Carrot plant height % compared with height of untreated (=100%); % plot cover carrot; assessment dates; growth stage of untreated carrots that were not suppressed by potatoes (true leaf TL)

Herbicide	*Product/ha carrots*	*29 May* score	*8 June* score	*15 June* score	*no. TL lost*	*20 June* score	*% height /%cover*	*3 July* score *(%height) bunching*	*11 July* score	*%height/ %cover*	*25 July* score	*%height/ %cover*
	Untreated GS:	*5TL*	*6TL*	*7TL*								
1. untreated	-	10	10	10	0	10	100/95	10 (100)	10	100/100	10	100/100
Carrots 3 true leaves T1 18 May												
2. Sumimax	50ml	10	10	10	0	10	100/90	10 (100)	10	100/100	10	100/100
3. Sumimax	100ml	9 st	8	8	0	8	90/80	9 (95)	9.5	95/100	10	100/100
4. Sumimax	200ml	7 st	6	6	0	6	60/50	7 (70)	8	80/95	9	90/100
5. Defy + linuron	2.5L + 0.65L	6 d sc	6	6	2	6	60/50	8 (100)	9	95/95	10	100/100
6. Defy + linuron	5.0L +0.65L	2 d	3	3	3	3	50/30	7 (70)	8.5	90/95	9	90/90
Carrots 3 true leaves + 14 days T2 29 May												
7. Sumimax	100ml	-	5st sc	6 st	0	7	60/60	7.5 (80)	8	80/90	8.5	90/90
Carrots 3 true leavesT1 & + 14 daysT2												
8. Sumimax & Sumimax	50ml & 50ml	10	9 st sc	8.5 st	0	8	80/70	9 (90)	9.5	95/95	10	100/100
9. Defy + linuron & Defy + linuron	2.5L + 0.65L & 2.5L + 0.65L	6 d sc	5	4	2-3	4	50/30	6 (60)	9	95/95	10	100/100

st stunted; sc scorch; d some plant death

Table 2. Site 1 Isleham. Potatoes: number of potato plants per plot on 18 May + those emerged after 18 May; % leaf area damaged of small and large potatoes; score for control (0=no control=untreated, 7=acceptable control, 10 complete control of foliage); number of live shoots and live plants/plot; % number of dead potato plants; number of large plants with re-growth; % plot cover potatoes. A potato blight infection was observed on 25 July.

Herbicide	*Product/ha*	*18 May*	*29 May*		*8 June*			*15 June*			*3 July*		*11 July*		
		No./plot + after	*% leaf area damage*		*No. live shoots/ plants*	*%dead*	*score*	*No. live shoots*	*% leaf area damage*		*Score*	*No. plants regrowth*	*Score*	*% cover*	*% dead*
			small	*large*					*small*	*large*		*large*			
1. untreated	-	44	0	0	84/44	0	10	84	0	0	0	0	0	50	0
Carrots 3 true leaves T1 18 May															
2. Sumimax	50ml	28	90	25	21/17	39.3	6	18	90	50	7	3 reg	8	2	78.6
3. Sumimax	100ml	29 + 2	95	50	12/8	79.3	9	4	100	90	9	1 reg	9	<1	89.7
4. Sumimax	200ml	27 + 1	100	90	4/3	88.9	9.5	0	100	100	9	1 reg	9	<1	89.0
5. Defy + linuron	2.5L + 0.65L	29	100	95	3/3	89.6	9.5	3	100	95	8	2 reg	9	<1	88. 5
6. Defy + linuron	5.0L +0.65L	26 + 1	100	100	2/1	96.1	10	2	100	100	9	1 reg	9	<1	89.7
Carrots 3 true leaves + 14 days T2 29 May															
7. Sumimax	100ml	33 + 1	-	-	0/0	100	10	0	100	100	10	0	10	0	100
Carrots 3 true leaves T1 & + 14 daysT2															
8. Sumimax & Sumimax	50ml & 50ml	35	90	25	2/2	94.3	9	2 reg	100	99	10	2 reg	10	0	94.3
9. Defy + linuron & Defy + linuron	2.5L + 0.65L & 2.5L + 0.65L	41	100	90	4/1	97.6	9.5	8 new	100	80	9	4 reg #	10	0	95.1

reg regrowth; reg # regrowth from tuber and stem

Carrots Site 2 Hainford: Crop Tolerance Table 3

Sumimax applied at 50ml/ha dose rate had a negligible effect on carrots.
Sumimax 100ml/ha at T1caused slight stunting and 1% of leaves were blackened and scorched on a few carrots (28 June). The crop became stunted and slight stunting persisted but the carrots recovered and were almost undistinguishable from the untreated on 1 August. There were unacceptable effects from the 200ml/ha dose rate - 80% blackening and scorch on true-leaves 1 –4 on 6 July, 1-2 leaves were lost by13 July. The carrots became very stunted and did not recover.

The late application T2 of Sumimax 100 ml/ha on 28 June when temperatures were higher caused more damage than treatment 3. On 13 July 50% of the leaf area suffered colour-loss and there was also some scorch/blackening. This was followed by severe stunting, thinning, and some leaf loss and by 1 August the carrots were only half the height of the untreated crop. The second dose 50 ml/ha of Sumimax (treatment 8) also caused more damage, severe stunting initially (13 July) but made a good recovery.

Defy + Linuron caused less damage than at Site 1. At T1 Defy + Linuron (2.5 + 0.65) L/ha (treatment 5) caused slight scorch and a few plants c. 1% suffered leaf loss. Defy + Linuron (5.0 + 0.65) L/ha (treatment 6) also caused scorch and leaf loss but there was little difference between them. The carrots recovered by 13 July. Damage from the programme Defy + Linuron (2.5 + 0.65) L/ha at T1 and at T2, was more severe, with more scorch, but the carrots soon recovered.

The field crop was harvested 24 October. No treatment caused plant loss at this site.

Carrots Site 2 Hainford: Volunteer Potato control Table 4

The potato population, cv.Maris Piper, was very high and at the time of the first application potatoes were at an advanced growth stage but with no buds or flowers. It was not possible to distinguish individual plants therefore the numbers of potato shoots per plot were counted on 17 June. Up to 90% of the plot area was covered by potatoes on some plots. A few potatoes had just emerged but no more appeared after 17 June, 30% were small (c. 3cm tall, 8cm across), 70% were large (2-5 shoots, mainly 3, 20-25cm tall, 40-50cm across).

Defy + Linuron treatments 5, 6 and 9 caused severe scorch and killed several small potato shoots (28 June) within 11 days. Action of Sumimax at 50 or 100ml/ha was slower, as at Site 1, leaves were blackened and crinkled, and Sumimax at 200ml caused severe stem damage.

Although the damage (% leaf area) from early treatments had increased by 6 July there was re-growth of large potatoes on all except the high dose of Sumimax. Re-growth was from stems for Sumimax treatments 2, 3 and 8; from stems and tubers for Defy + Linuron treatments 5 and 6. There was more re-growth from treatment 5 than 6 (the higher dose rate). Sumimax 100 ml/ha caused more stunting than Defy + Linuron (2.5 + 0.65) L/ha.

The later sprays T2 were applied when potatoes were above crop height on treatment 7. On 13 July potatoes were 40cm tall and crop height 35cm on untreated plots and several treatments had stunted the potatoes, particularly Sumimax. Visual assessments of the % plot covered by potatoes were recorded on 13 July and 1 August but the population of potatoes was uneven for the treatments and should be compared with % cover for untreated and each plot on 17 June (before spraying). On 20 July (not shown) the single late dose of Sumimax 100ml, had caused scorch mainly to the upper part of potato plants, small shoots were dead.

The repeat dose of Defy + Linuron (2.5 + 0.65) L/ha (treatment 9) was much more effective than the single dose. At this site the repeat dose of Sumimax 50 ml (treatment 8) was slightly more effective than the single dose of 100 ml/ha at T1. Sumimax 100ml/ha applied at T2 was probably too late to prevent competition.

Control of the high population of volunteer potato was poor at this site - treatments were applied when potatoes were too large. Rainfall was lower after sprays were applied than at other sites. The most successful treatment was with two applications of Defy + Linuron (2.5 + 0.65) L/ha.

All herbicide treatments reduced potato flowering compared with untreated potatoes, on 6 July. Flower buds were already present when the late Sumimax 100ml application was made at T2 (treatment 7), but they were killed by the herbicide spray. The potatoes became infected with blight on 15 August. On 15 August, the five potato plants (2 small and 3 large) marked by labels on each plot were dug to see whether any potato tubers had formed. There were several on the untreated plot from small and large plants; and they were also found on all other treatments.

Table 3 . Site 2 Hainford. Crop tolerance scores (0=complete kill; 7=acceptable damage; 10=no damage). carrot plant height % compared with height of untreated (=100%); carrot % plot cover; assessment date, growth stage of untreated carrots that were not suppressed by potatoes, true leaf (TL)

Herbicide	*Product/ha*	*28 June*	*6 July*		*13 July*		*20 July*		*1 Aug*		*15 Aug*		*3 Sept*	
		Score	*score*	*% cover*	*score*	*% height /%cover*	*score*	*%height/ %cover*	*score*	*%height/ %cover*	*score*	*%height/ %cover*	*score*	*%height/ %cover*
		6 TL	*7 TL*		8 TL									
1. untreated		10	10	70	10	100/95	10	100/100	10	100/100	10	100/100	10 L	100/100
Carrots 4TL T1 17June														
2. Sumimax	50ml	9.5	9 st	70	10	100/90	10	100/100	10	100/100	10	100/100	10 L	100/100
3. Sumimax	100ml	8 st	8 st sc b	60	9	90/80	9	90/90	9	100/90	10	100/100	10 L	100/100
4. Sumimax	200ml	5 st	5 st sc b	40	4	70/60	5	70/60	5	70/70	6	80/80	9	100/95
5. Defy + linuron	2.5L + 0.65L	9 sc	9 sc	70	10	100/95	10	100/100	10	100/100	10	100/100	10 L	100/100
6. Defy + linuron	5.0L + 0.65L	8.5 sc st	9 sc	70	10	100/90	10	100/100	10	100/100	10	100/100	10 L	100/100
Carrots 4 TL+ 14 days T2 28 June														
7. Sumimax	100ml	-	6 st b	70	3 st sc	90/80	3	80/50	4	50/50	5	60/80	8	90/90
Carrots 4 TLT1 & + 14 days T2														
8. Sumimax & Sumimax	50ml & 50ml	9.5	4 st	40	5 st	80/60	6	70/80	6.5	60/80	8	100/80	10	100/100
9. Defy + linuron & Defy + linuron	2.5L + 0.65L & 2.5L + 0.65L	9 sc	6 sc	70	9 sc	90/80	9 sc	100/90	9	100/90	10	100/100	10	100/100

Sc scorched; st stunted; b brown/black; L lodged

Table 4. Site 2 Hainford Potatoes: number of potato shoots per plot; % leaf area damaged of small and large potatoes; score for control (0=no control=untreated, 7=acceptable control, 10 complete control of foliage); number of flowers. Visual assessments of the % plot covered by potatoes were recorded on 13 July and 1 August but the population of potatoes was uneven for the treatments and should be compared with % cover for untreated and each plot before spraying

Herbicide	*Product/ha*	*17 June* *No. shoots/% cover plot*	*28 June* *% leaf area damage*		*6 July* *% leaf area damage*		*no. flowers*	*score*	*13 July* *% cover*	*score*	*1 August* *score*	*% cover*
			small	*large*	*small*	*large*						
1. untreated	-	186/80	0	0	0	0	46	0 a	95	0 a	0	95
Carrots 4 TL T1 17 June												
2. Sumimax	50ml	135/ 30	50	20	80	30 reg	2	2	80	3 st a	2 a	60
3. Sumimax	100ml	159/50	80	30	80-100	50 st reg	5	4 st	60	5 st b	4 b	50
4. Sumimax	200ml	203/90	100	50	100	60	4	5 st	70	6 st b	5 b	30
5. Defy + linuron	2.5L + 0.65L	155/50	80-100	50	80-100	50 reg#	0	4 st	70	5 st a	3 a	60
6. Defy + linuron	5.0L +0.65L	126/40	80-100	60	80-100	60 reg#	0	5 st	70	5 st a	4 a	50
Carrots 4TL+ 14 days T2 28 June												
7. Sumimax	100ml	201/80	-	-	60-80	50sc	25 dead	4 sc	70	5 st a	6## b	30
Carrots 4TL T1 & + 14 days T2												
8. Sumimax & Sumimax	50ml & 50ml	71/30	50	20	90	40 reg	6	4 st	50	5 st b	6 b	40
9. Defy + linuron & Defy + linuron	2.5L + 0.65L & 2.5L + 0.65L	93/30	80 - 100	50	100	80 reg	0	8 sc st	10	8 st b	7 b	10

Key: st stunted; potatoes: a above crop; b below crop; c crop height; untreated crop height 35cm on 13 July; reg regrowth; reg# potato regrowth from stem and tuber;
small shoots dead, large 90% leaf area damaged

Carrots Site 3 South Scarle: Crop Tolerance Table 5
At the first T1 timing, Sumimax at 50ml/ha had little effect on carrots. Sumimax applied at 100ml/ha caused slight scorch/blackening of carrot leaves (4 July). The main effect was stunting, which persisted until 40 DAT on 8 August when carrots were almost undistinguishable from the untreated. Carrots suffered a very severe growth check from the 200ml/ha dose rate. However there was no leaf loss at the T1 timing.

Application of Sumimax 100ml/ha at the T2 timing (treatment 7) caused more damage (black/brown scorch) than at T1 (treatment 3); there was increased damage from the second application of Sumimax 50 ml/ha (treatment 8) and stunting from both treatments. By 8 August there was some leaf loss but new growth was unaffected. Treatment 8 the split dose caused more stunting of carrots than the full dose applied at T1.

Defy + Linuron caused initial damage in the form of leaf scorch (4 July) followed by slight temporary stunting. Assessments 12 days after treatment showed that 1% of plants treated with Defy + Linuron (treatments 5, 6) lost one true leaf, Defy + Linuron (5.0 + 0.65) L/ha caused more scorch and stunting. Damage from the programme of Defy + Linuron (2.5 + 0.65) L/ha at T1 followed by Defy + Linuron (2.5 + 0.65) L/ha at T2, was more severe (23 July). New growth was undamaged. Recovery from Defy + Linuron damage was much quicker than from Sumimax.

Overall the most severe damage was from Sumimax 200 ml/ha at T1, but carrots treated with Sumimax 100ml/ha at the T2 timing (treatment 7) had less time to recover and on 1 September 53 DAT (harvest stage) were only 80% of the untreated crop height.
No treatment caused plant loss at this site.

Carrots Site 3 South Scarle: Potatoes Table 6
The volunteer potato population was also uneven at this site. The cv. Saturna, from the 2003 crop on the trial field, was not as vigorous as Maris Piper but there were more shoots per plant. There was some scorch on small shoots from linuron applied earlier to the carrots. All potatoes had emerged by the first spray application on 28 June: 30% were small (c. 3cm tall, 10cm across) 70% large (3-5 shoots, 15-20cm tall and 40cm across).

On the 4 July, Defy + Linuron (treatments 5, 6 and 9) at T1had caused severe scorch and killed all small potato shoots within six days. Action of Sumimax was slower, leaves were blackened and crinkled, the highest dose rates Sumimax 100ml/ha or 200 ml/ha had also caused stunting. Sumimax at 50 ml/ha had little effect.

The damage (% leaf area) from T1 treatments increased by 10 July but there was re-growth of large potatoes. Re-growth was all on damaged stems for Sumimax and Defy + Linuron. Sumimax 100 ml/ha caused more stunting than Defy + Linuron (2.5 + 0.65) L/ha.

Potatoes were above crop height when Sumimax 100 ml/ha was applied at T2 on 10 July small plants died and 80-90% of the leaf area on large potatoes were damaged (8 August) – it was quicker to act and more effective than the earlier treatment 3, possibly because weather conditions were wetter. On 8 August potatoes were stunted and below crop height for Sumimax treatments 3, 4 and 8. The repeat dose of Sumimax 50 ml/ha also performed slightly better than treatment 3. A few potatoes were above the crop on Defy + Linuron treatment 5 and a few had new shoots from the tuber. Potatoes on Defy + Linuron treatments 6 and 9 were all below crop height and all small plants were dead.

Sumimax caused stunting of the potatoes, but the most effective treatment was the programme with two applications of Defy + Linuron (2.5 + 0.65) L/ha - small potatoes were killed early at T1 and the follow-up T2 killed remaining green foliage and re-growth.

Potato blight began to infect the trial area on 8 August and by the 1 September the potato foliage had died.

On 1 September, the five potato plants (2 small and 3 large) marked by labels on each plot were dug to see whether any potato tubers had formed. There were several on the untreated plot from small and large plants; and on all large potatoes on all plots. However no tubers had formed on small plants on any treatment with the exception of the early Defy + Linuron treatment 5 and tubers were small compared with untreated tubers.

Table 5. Site 3 South Scarle. Crop tolerance scores (0=complete kill; 7=acceptable damage; 10=no damage); % of plants with one TL lost; % leaf area scorched; carrot plant height % compared with height of untreated (=100%); carrot % plot cover on 23 July and 8 August; assessment date; GS growth stage of untreated carrots that were not suppressed by potatoes (true leaf TL)

Herbicide	*Product/ha carrots*	*4 July*		*10 July*			*23 July*			*8 Aug*		*1 Sept*	
		score	*% leaf area scorched*	*Score (% height)*	*% leaf area scorched*	*lost 1 TL (% plants)*	*score*	*% leaf area scorched*	*% height /%cover*	*score*	*%height/ %cover*	*score*	*%height/ %cover*
	GS:	*4-5 TL*		*5 -6 TL*									
1. untreated	-	10	0	10 (100)	0	0	10	0	100/100	10	100/100 L	10 L	100/100 L
Carrots 3-4 TL T1 28 June													
2. Sumimax	50ml	9 b	<1	8 (90)	1	0	8		90/95	10	100/100 L	10 L	100/100 L
3. Sumimax	100ml	8 st b	5	5 (60)	30	0	7 st		80/90	9	90/100	10 L	100/100 L
4. Sumimax	200ml	6 st b	10	3 (30)	60	0	4 st		50/50	6 st	70/90	9	95/100 L
5. Defy + linuron	2.5L + 0.65L	6 sc	20	6 (50)	40	1	8		100/95	10	100/100 L	10 L	100/100 L
6. Defy + linuron	5.0L +0.65L	6 sc	20	5 (40)	50	1	8		95/95	10	100/100 L	10 L	100/100 L
Carrots 3-4 TL + 14 days 10 July T2													
7. Sumimax	100ml	-	-	-	-	-	5 sc b	50	70/95	5 sc lf loss	60/80	8st	80/100
T1 Carrots 3-4 TLT1 & + 14 daysT2													
8. Sumimax & Sumimax	50ml & 50ml	10	1	8 (90)	1	0	4 sc b	30	60/50	6 sc lf loss	70/80	9	95/100
9. Defy + linuron & Defy + linuron	2.5L + 0.65L & 2.5L + 0.65L	6 sc	20	6 (50)	40	1	5 st sc	50	70/80	8 st	90/100 L	10 L	100/100 L

st stunting; sc scorch; b brown/black; lf loss leaf loss

Table 6. Site 3 South Scarle. Potatoes: number of potato shoots per plot on 28 June; % leaf area damaged of small and large potatoes; score for control (0=no control=untreated, 7=acceptable control, 10 complete control of foliage); number of live shoots and live plants; % plot potato cover; potato plants with re-growth. Visual assessments of the % plot covered by potatoes were recorded on 10 and 23 July but should be compared with % cover for untreated and each plot before spraying because the population of potatoes was uneven

Herbicide	*Product/ha*	*28 June* *No shoots (%cover)*	*4 July* *% leaf area damage*		*10 July* *% cover*	*% leaf area damage*		*23 July* *score*	*%cover*	*8 Aug* *score*	*% leaf area damage*	
			small	*large*		*small*	*large*				*small*	*large*
1. untreated	-	111(25)	0	0	80 f	0	0	0	90	0	0	0
Carrots 4TL T1 28 June												
2. Sumimax	50ml	116 (30)	2cr br	1 cr br	50 f	30 st reg	20 st reg	2	20	2 a	reg	reg
3. Sumimax	100ml	180 (80)	10 cr br st	5 cr br st	70 f	60 st reg	40 st reg	4	30	5 b	reg	reg
4. Sumimax	200ml	93 (20)	50 cr br st	10 cr br st	20	80	50 st reg	6	10	6 b	-	slight reg
5. Defy + linuron	2.5L + 0.65L	120 (20)	100 sc	50 sc	30	100	50 reg	6	15	6 a	reg tuber	reg
6. Defy + linuron	5.0L +0.65L	135 (40)	100 sc	70 sc	40	100	70 reg	6.5	10	6 b	-	reg
Carrots 4 TL + 14 days T2 10 July												
7. Sumimax	100ml	100 (20)	-	-	-	-	-	5	20	7 st	90	80
Carrots 4TL T1 & + 14 days T2												
8. Sumimax & Sumimax	50ml & 50ml	57 (10)	2cr br	1 cr br	30	30 st reg	20 st reg	5	10	6 b st	100 reg	60 st reg
9. Defy + linuron & Defy + linuron	2.5L + 0.65L & 2.5L + 0.65L	82 (20)	100 sc	50 sc	30	100	50 reg	8	5	9 b	100	100

cr leaves crinkled; br brown spotting leaves and brown stems; st stunting; sc scorch; f potato flowers white; reg re-growth; a= potatoes above crop height; b =below crop height

Although potato flowers and berries do not affect the carrot crop they are toxic contaminants in vining pea produce. Flowering on untreated plots began on 10 July. Potatoes treated with Sumimax produced a few flowers (Table7), but Defy + linuron suppressed flowering. Assessments for the number of potato plants flowering on 23 July showed Sumimax applied on 10 July killed the flowers. Only a very few plants produced berries, but Sumimax did not appear to prevent berry formation in this trial.

Table 7. Site 3 South Scarle: number of potato plants flowering; number of potato plants with berries per plot

Herbicide	*Product/ha*	*23 July* *No. flowers*	*8 Aug* *No. plants with berries*
1. untreated		37	2
Carrots 4TL 28 June			
2. Sumimax	50ml	14	1
3. Sumimax	100ml	11	2
4. Sumimax	200ml	2	2
5. Defy + linuron	2.5L + 0.65L	0	0
6. Defy + linuron	5.0L +0.65L	1	1
Carrots 4 TL + 14 days 10 July			
7. Sumimax	100ml	0 (killed)	2
Carrots 4TL & + 14 days			
8. Sumimax & Sumimax	50ml & 50ml	0	0
9. Defy + linuron & Defy + linuron	2.5L + 0.65L & 2.5L + 0.65L	0	*0*

Parsnips Site 4 Tuddenham: Crop Tolerance Table 8
The parsnips were slow to emerge and spraying was delayed until most were at 4 true-leaf stage. At the time of the first application, T1 on 15 June, parsnip growth stages ranged from 2-4 true leaves. Lower dose rates of Defy and Linuron were used in the parsnip trial.

Five days after T1 on 20 June, Sumimax caused crinkling, distortion and brown/black spotting on parsnip leaves. On 3 July the first two leaves on parsnips treated with Sumimax timing at T1 at all dose rates (treatments 2, 3, 4, 8) suffered 100% scorch and these leaves were lost by 11 July. The third leaf was distorted and remained so (11 July). New growth appeared undamaged after application of the lower doses, but after Sumimax at 200ml/ha (treatment 4) new growth was severely stunted.

Sumimax 100ml/ha (treatment 7) applied at T2 also caused 100% scorch on the first two leaves, 30% scorch on the third leaf and slight distortion of leaves four and five, as did the follow-up treatment with Sumimax 50 ml/ha. Stunting from these treatments was severe (25 July).
On 26 August assessments of crop height and cover showed there was still severe stunting and thinning of the crop from Sumimax 200 ml/ha at T1. The application of Sumimax 100 ml/ha at T2 (treatment 7) caused the most damage possibly because more spray was caught by the larger crop leaves.

Defy + Linuron (treatments 5 and 6) caused initial damage in the form of leaf scorch on 20 June and scorch was more severe than from Sumimax. On 3 July the first two leaves on parsnips treated with Defy + linuron (treatments 5, 6, 9) L/ha at timing T1 had died and there was loss of plants that were at 2 TL stage when sprayed. On 11 July the programme (treatment 9) caused additional severe scorch 80 - 50% to other leaves. New parsnip growth on Defy + Linuron plots was normal and remaining plants made a good recovery from the (2.0 + 0.5) L/ha dose. There was thinning of the crop from Defy + Linuron (4.0 +0.5) L/ha (treatment 6) and the programme caused more leaf loss and a severe growth check although plants eventually recovered (26 August).

There was loss of leaves from all herbicide treatments. The main effects from Defy + Linuron were scorch but there was a quicker recovery than from the severe stunting effects of Sumimax. Parsnips were more sensitive than carrots to Sumimax and Defy + Linuron and neither was safe, although perhaps could be considered as a 'fire-engine' treatment.

Parsnips Site 4 Tuddenham: Volunteer potato control Table 9
The parsnips were slow to emerge and the volunteer potatoes shaded the crop. The population of potato plants (Table 9) was lower than at other sites, 40% were small with 1 shoot (c. 12cm tall, 20cm across) 60% were large (2-4 shoots, 50cm tall, 60cm across) and flower buds were present on 15 June. At the second application T2 on 24 June, a few more had emerged.

As at the other sites the Defy + Linuron treatments 5, 6 and 9 were fast-acting causing severe scorch to small potato shoots within five days. The action of Sumimax was slower - it caused black/brown spotting and crinkling of leaves, and brown stems followed by stunting. The low dose of Sumimax 50ml/ha was the least effective on large potatoes.

On 3 July the potatoes on the untreated and the late application of Sumimax 100 ml/ha were the only ones flowering. There was re-growth from the Defy + Linuron treatments.

Potato blight began to infect the potatoes on 11 July and by the 25 July most potato foliage had died.

On 25 July, the five potato plants (3 small and 2 large) marked by labels on each plot were dug to see whether any potato tubers had formed. There were several tubers on the untreated plot from small and large plants; and they were also found on all large potatoes on all plots. However, no tubers had formed on the three small plants treated with early Sumimax 100 ml/ha and 200 ml/ha. There were small tubers on only two of the three small plants for Defy + Linuron treatments 5, 6 and 9 and Sumimax treatments 8 and 7.

Table 8. Site 4 Parsnips Tuddenham: Crop tolerance scores (0=complete kill; 7=acceptable damage; 10=no damage); crop height % compared with height of untreated (=100%); parsnip % plot cover on 11 and 25 July; assessment date; growth stage of untreated parsnips that were not suppressed by potatoes (true leaf TL)

Herbicide	*Product/ha*	*20 June*	*24 June*		*3 July*	*11 July*			*25 July*		*26 Aug*
		score	*score*	*% leaf area damage*	*score*	*score*	*% height /%cover*	*No. leaves lost (effects on other leaves)*	*Score*	*% height /%cover*	*score*
		4 TL	4-5 TL		*5-6TL*	*6 TL*					
1. untreated		10	10	0	10	10	100/100	0	10	100/100	10
Parsnips 4TL T1 15 June											
2. Sumimax	50ml	7cr br	5	50	6	8	100/95	2 (3 cr)	10	100/100	10
3. Sumimax	100ml	6cr sc	3	70	4	6	90/90	2 (3 cr)	9	100/90	10
4. Sumimax	200ml	4 cr st sc	2	90	2	4	80/60	2 (3 4 cr)	5	80/60	9 thinning
5. Defy + linuron	2.0L + 0.5L	4sc cr	5	20	6	7	100/90	2 (3 cr)	9	100/100	10
6. Defy + linuron	4.0L + 0.5L	3sc	3	80	3	5	90/80	2 (3 4 cr) st	7 plant loss	90/80	10
Parsnips 2-4TL+ 14 days T2 24 June											
7. Sumimax	100ml		-	-	4	3	80/50	1 (50%plant damage)	3 severe st	50/50	8 thinning st
Parsnips 2-4TL T1 & T2											
8. Sumimax & Sumimax	50ml & 50ml	7cr b	5	60	4	5	80/60	2 (3 4 cr, L5 & 6 normal)	6	70/70	10
9. Defy + linuron & Defy + linuron	2.0L + 0.5L & 2.0L + 0.5L	4 sc	5	50	2	3	30/20	2 (3 4 cr) Some plants only 1L left	4 plant loss	60/60	10

br dark brown spotting; cr leaves crinkled; sc scorched; st stunting; L leaf

Table 9. Site 4 Tuddenham parsnips. Potatoes: number of potato shoots per plot on 28 June; % leaf area damaged of small and large potatoes; score for control (0=no control=untreated, 7=acceptable control, 10 complete control of foliage); number of live shoots per plot; % plot cover potatoes

		15 June	*20 June*		*2 July*				*11 July*			
Herbicide	*Product/ha*	*No potato shoots /plot*	*% leaf area damage*		*% leaf area damage*		*Score*	*% cover*	*% leaf area damage*		*score*	*% cover*
			small	*large*	*small*	*large*			*small*	*large*		
1. untreated		40	0	0	0	0	0	70	0	0	0	70
Parsnips 2-4TL 15 June												
2. Sumimax	50ml	48	5 b	1 b	60 st	50	3	50	80	50	4	30
3. Sumimax	100ml	39	10 b	5	70 st	60	4	40	90	60	6	10
4. Sumimax	200ml	47	25 b	10	80 st	80	6	20	100	80	8	10
5. Defy + linuron	2.0L + 0.5L	39	80 sc	40 sc	90 #	60 # ##	6	10	100	50 # ##	6	30
6. Defy + linuron	4.0L + 0.5L	26	90 sc	70 sc	90 #	70 #	8	5	100	70 #	8	3
Parsnips 2-4 TL+ 14 days 24 June												
7. Sumimax	100ml	50	-	-	20 st	10	3	40	100	10	5	40
Parsnips 2-4 TL & + 14 days												
8. Sumimax & Sumimax	50ml & 50ml	34	5 b	1 b	80 sev st	60	4	30	100	80	5	30
9. Defy + linuron & Defy + linuron	2.0L + 0.5L & 2.0L + 0.5L	21	80 sc	40 sc	100 #	80	9	2	100	95	10	0

b brown/black crinkling; sc scorch; st stunted, cr crinkled, # regrowth from stem, ## regrowth from tuber

Control of weed species

At Site 2 Hainford there was a population of scentless mayweed *(Matricaria inodorum)* 12/m^2 on untreated plots (Table 10). Mayweed is resistant to Linuron applied post-emergence. The low dose of Sumimax 50 ml/ha or Defy + Linuron had little effect on mayweed, the repeat doses caused stunting. The best control was with Sumimax applied at 100 ml/ha. There were indications of some control but the plots were not replicated. It is also likely that the potato plants shielded some mayweeds from spray.

There were only three scentless mayweeds *(Matricaria inodorum)* on the untreated plot at Site 3 South Scarle. Sumimax 100 ml/ha early and late, 200 ml/ha and the split dose (8) appeared to be effective but Defy + Linuron was not.

Table 10. Site 2 Hainford: *Matricaria inodorum* numberplants/m^2; % control

Herbicide	*Product/ha*	*20 July No./ m^2*	*% control*
1. untreated	-	12 f	0
Carrots 3-4 TL 17 June			
2. Sumimax	50ml	11 f	1
3. Sumimax	100ml	3 st	75
4. Sumimax	200ml	2 st	83
5. Defy + linuron	2.5L + 0.65L	9 f	25
6. Defy + linuron	5.0L +0.65L	10 f	16
Carrots 3-4 TL + 14 days 28 June			
7. Sumimax	100ml	3	75
Carrots 3 true leaves & + 14 days			
8. Sumimax & Sumimax	50ml & 50ml	7 st, some f	42
9. Defy + linuron & Defy + linuron	2.5L + 0.65L & 2.5L + 0.65L	7 severe st	42

st stunted; f flowering

Conclusions

Carrots

There was a marked dose response to Sumimax.

Sumimax was very safe to carrots at a dose rate of 50 ml/ha at the 3-4 true-leaf stage T1 timing at all sites, only a slight growth check was observed.

Sumimax 100 ml/ha (the Normal dose rate for wheat) applied to carrots at the T1 timing caused slight scorch at Sites 1 and 2 but more severe scorch (brown/black) where applied at 20°C at Site 3. At all sites the main effects were stunting of the crop although the carrots recovered and were undistinguishable from untreated carrots after 40-50 days. Damage was acceptable at Site 1 and 2 but not at Site 3.

Damage from Sumimax at 200 ml/ha was severe, and persistent stunting of the crop was unacceptable at all sites.

At the later T2 application timing to carrots at 5-6 true leaves, Sumimax 100 ml/ha was more damaging than at T1 at all sites: carrot leaves lost colour, stunting was more severe and there was some leaf loss at Site 3. This was perhaps because the larger leaf area of carrots caught more spray. The repeat dose Sumimax 50 ml/ha

followed by Sumimax 50 ml/ha appeared safe to carrots at Site 1, but there was scorch and some leaf loss at site 3; stunting at Sites 2 and 3 and recovery was slow. This split dose showed no advantage in terms of crop safety compared with the full dose 100 ml/ha.

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At Site 1 Defy + Linuron at (2.5 + 0.65) or (5.0 + 0.65) L/ha caused very severe scorch, some leaves died and damage was unacceptable. Although new growth was unaffected, carrots sprayed with the higher dose rate were slow to recover. Commercial crops sprayed with Defy + Linuron did not suffer severe scorch. The reason for the trial damage is unclear but it may be because a fine spray was used in order to give good spray cover on the potatoes, or possibly carrot leaf wetness. At Sites 2, 3 and 4 a new sample of Defy was used. At Site 2 there was negligible damage from Defy + Linuron, there were more effects at the higher temperature at Site 3, where there was some initial scorch and 1% of plants lost the first true leaf but the carrots recovered. At Sites 2 and 3, damage from the programme Defy + Linuron (2.5 + 0.65) L/ha at T1 followed by Defy + Linuron (2.5 + 0.65) L/ha at T2, was more severe than the single application, with more scorch, but new growth was unaffected and the carrots soon recovered.

Recovery from Defy + Linuron scorch was much quicker than from Sumimax stunting at both timings.

The population of volunteer potatoes was lower and growth less advanced (70% small) at Site 1 than at Sites 2 and 3 (70% large). The potato population was particularly high at site 2. Potatoes were classified as 'small' if there was only one shoot c. 3-5 cm tall, and 10 cm across; 'large' potatoes had two or more shoots 20 cm tall, 40 cm or more across. Large potatoes had 2 - 3 shoots at Site 1, 2 - 5 shoots at Site 2 and 3 - 5 shoots at Site 3.

At Site 1 volunteer potato control was excellent from all treatments except the low dose of Sumimax 50 ml/ha. Sumimax has foliar contact and soil residual activity and at 100 ml/ha gave better control of volunteer potatoes than at other sites possibly because the high rainfall 25 May - 3 June increased the residual effect and also the potato shoots were much smaller. Potato leaves were black/brown and crinkled, stems were dark brown and the potatoes became very stunted.

At all sites the Defy + Linuron treatments (2.5 + 0.65) L/ha caused severe scorch and killed most small potato shoots within a week. At Site 1 large potatoes were also killed. The action was faster than Sumimax.

There was a little re-growth from a few stems where Sumimax was applied at T1, and from stems and occasionally the tuber from Defy + Linuron at all sites.

Sumimax 100 ml/ha at T2 performed slightly better than at T1 at Sites 2 and 3 but the potatoes had already grown above crop height, and it would be better to removed competition early at T1. The Sumimax repeat dose of 50 ml/ha (treatment 8) was also marginally better than the full 100 ml/ha dose at T1. However, the later timings were less safe to the crop.

At all sites the Defy + Linuron treatments (2.5 + 0.65) L/ha and (5.0 + 0.65) L/ha caused severe scorch and killed most small potato shoots within a week. There was not much difference between these dose rates. The action of Defy + Linuron was faster than Sumimax. At Site 1 large potatoes were also killed but at Sites 2 and 3 the single applications of Defy + Linuron were inadequate on large potatoes.

Overall the repeat dose of Defy + Linuron (2.5 + 0.65) ml/ha at T1 and T2 performed best.

There was a little re-growth of potato foliage from a few stems where Sumimax was applied at T1, and from stems and occasionally the tuber from Defy + Linuron at all sites.

- The best control of volunteer potatoes was achieved when most potatoes were small and had one shoot (at this stage the carrots were at 3 true-leaves). All herbicides were less effective when 70% of the potatoes were large with two or more shoots at Sites 2 and 3.

- A programme of Defy + Linuron (2.5 + 0.65) L/ha followed by Defy + Linuron (2.5 + 0.65) L/ha 14 days later was the most effective treatment against volunteer potatoes in these trials.

- An early application T1 of Sumimax at 100 ml/ha when most potatoes were small and the crop is at 3 true-leaf stage gave good control. Competition would be removed early and the carrots would also have more time to recover from damage. Sumimax performed better in a trial (not HDC) in the wet conditions of 2007 than in 2008.

- Sumimax has foliar contact and soil residual activity. Irrigation or rainfall increased the residual effect on potatoes, but may also increase damage to the crop.

- Both these treatments are potentially damaging. Sumimax in particular at 100 ml/ha caused stunting of carrots. However, volunteer potatoes also suppress the crop.

- At Sites 1 and 2 the potato variety was Maris Piper, at site 3 it was Saturna, a shorter variety. The size of the potatoes when treated had more influence on efficacy than variety.

Although potato flowers and berries do not affect the carrot crop they are toxic contaminants in vining pea produce. At Site 3 flowering on untreated plots began on 10 July. Potatoes treated with Sumimax produced a few flowers but Defy + Linuron (which is not safe to peas) suppressed flowering. Assessments for the number of potato plants flowering on 23 July showed Sumimax applied on 10 July killed the flowers. Only a very few plants produced berries, but Sumimax did not appear to prevent berry formation in this trial.

Parsnips

The parsnips were slow to emerge and at a range of growth stages. Spraying was delayed until most were at 4 true-leaf stage but a few were at 2 true leaves.

Sumimax caused crinkling, distortion and brown/black spotting on parsnip leaves followed by severe stunting. All treatments caused loss of two leaves. The application of Sumimax 100 ml/ha at T2 (treatment 7) caused the most damage possibly because more spray was caught by the larger crop leaves.

Lower doses of Defy + Linuron were used in parsnips than for carrots. Defy + Linuron (2.0 + 0.5) L/ha caused initial damage in the form of leaf scorch and distortion later. The first two leaves died and plants that were at 2TL stage when sprayed were killed.

The repeat dose of Defy + Linuron caused further leaf loss but gave the best control of potatoes.

Parsnips were more sensitive than carrots to Sumimax and Defy + Linuron and no treatment was safe. There was loss of leaves from all herbicide treatments and loss of some small plants (at 2TL growth stage). The main effects from Defy + Linuron were scorch but there was a quicker recovery than from the severe stunting effects of Sumimax. These herbicides could perhaps be considered as 'fire-engine' treatments.

Mayweed control

At Site 2 there was a population 12/m^2 of scentless mayweed *(Matricaria inodorum)* on untreated plots. Mayweed is resistant to Linuron applied post-emergence. The low dose of Sumimax 50 ml/ha or Defy + Linuron (2.5 + 0.65) L/ha had little effect on mayweed, the repeat doses were more effective and caused stunting. The best control was with Sumimax applied at 100 ml/ha. There were indications of some control but the plots were not replicated. It is also likely that the potato plants shielded some mayweeds from spray.

Options for 2009

- Growers will need to review weed control strategy for carrots and parsnips after 2008. Unfortunately aclonifen (tested in FV 263b) as a pre-emergence alternative to linuron will not be available for the UK. In addition products of linuron have been re-registered and restricted to a maximum dose rate of 600 g a.i./ha per year.

- Defy (prosulfocarb) has a SOLA for carrots and parsnips but the Harvest Interval is long (12 weeks) – a problem for bunching or baby carrots. Post-emergence it is safe to carrots, but less safe in parsnips and it does not control mayweeds, fumitory or groundsel. A programme of two applications of tank-mix Defy + Alpha Linuron 50SC (a 500g/L formulation) (2.5 + 0.65) L/ha or less in carrots and at much lower doses in parsnips was used successfully in 2008 to control volunteer potatoes in many commercial crops. However, the new dose restriction for linuron means that this may not be possible because linuron may be needed for pre-emergence use. Defy on its' own does not control volunteer potatoes.

- Sumimax (flumioxazin), a cereal herbicide, at 100 ml/ha applied post-emergence has given good suppression of volunteer potatoes in these trials. Residues data for carrots were generated for flumioxazin in 2008. SOLAs were requested (December 2008) for Sumimax and other products (300g/L SC formulations of flumioxazin) for post-emergence use at a maximum of 100 ml/ha in carrots and parsnips to give some control of volunteer potatoes. It would also control mayweed, fumitory, volunteer oilseed rape, and possibly groundsel and nightshades (data from other trials).

- Sumimax causes temporary stunting of carrots and more severe effects in parsnips. If a SOLA is authorized, use of Sumimax will be at Grower's Risk. Growers are advised to evaluate the crop safety on a small area of crop prior to wide-scale use especially on parsnip (where it should only be considered as a 'fire engine' treatment). Sumimax has contact and residual activity. Irrigation or rainfall increases the residual effect but may also increase crop damage. It appears best to apply Sumimax early (at three true-leaf stage of the crop) when nearly all potato shoots have emerged but are still small. The crop will have more time to recover from an early application.

Technology transfer

2008 (FV 342 results 2008 trial - Article submitted for HDC News)