Project title:	Carrots: Improving the management & control of cavity spot
Project number:	FV 391
Project leader:	Dr P Gladders, ADAS UK Ltd
Report:	Annual report, April 2012
Previous report:	None
Key staff:	Dr M McPherson, STC Kirsty Wright and Cathryn Lambourne, STC Martyn Watling, ADAS Terrington Dr D Barbara & Dr A Jukes, University of Warwick Mr D Martin, Plantsystems Ltd
Location of project:	Commercial site in Notts, STC, University of Warwick, various farm crops
Industry representative:	Keith Mawer, Strawson Ltd, Bilsthorpe,Notts
Date project commenced:	01 May 2011
Date project completed (or expected completion date):	30 April 2014

DISCLAIMER:

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

- Neither SL567A nor any of four novel fungicides, Limex or Perlka reduced cavity spot or increased yield in a dry spring.

- Limited evidence was found that metalaxyl-M half-life in soil diminishes with increasing pH.

Background

Carrot cavity spot remains one of the most important diseases of carrots (Koike et al., 2007), still capable of causing complete loss in parts or even whole crops. Financial losses are particularly high when overwintered crops are lost. Current management of the disease relies on use of partially resistant or tolerant varieties and metalaxyl-M fungicide treatment early in the life of the crop.

Recent HDC projects (FV 353, CP 46) have improved understanding of the pathogen and indicate that the main pathogen *Pythium violae* is able to utilise a wide range of crop and weed hosts. Whilst long rotations (e.g. 1 in 6) benefit carrot production by reducing the risk of damage from various pests and pathogens, they are not very effective for cavity spot. Disease development is strongly influenced by rainfall (soil moisture) and some quantitative data based on irrigation experiments is now available from FV 353.

Whilst this helps explain variation in disease development, weather conditions are outside grower control so fungicide treatment remains the main tool that growers can use to counteract infection triggered by rainfall events. Metalaxyl-M has served the industry well for many years though its efficacy has been affected by enhanced degradation at some sites. As the industry is dependent on a single fungicide with a single site mode of action, the sustainability of this treatment is of major concern. The extent to which fields in carrot production are currently affected by enhanced degradation is unknown. A soil test would be of interest to growers as a chargeable service if enhanced soil degradation can be shown to affect field performance of metalaxyl-M.

New fungicide active ingredients, particularly those used for potato late blight (*Phytophthora infestans*) are candidates for cavity spot control. Screening of new products (mainly strobilurin chemistry) was last reported in 2001 in FV 5f (Pettitt et al., 2001). New candidate active ingredients and products are available from Bayer CropScience, BASF and other companies. Treatment impacts on *Pythium violae* will be appraised during the growing season using quantitative PCR using methodology developed in FV 353. Measures of pathogen activity in relation to treatments will be undertaken in collaboration with Dr D Barbara at the University of Warwick.

There are also opportunities to evaluate non-fungicidal treatments including biological control agents (bacterial and fungal products are available), soil amendments and calcium treatments. The latter provided some useful activity in pot and field tests in FV 5f and have been used successfully against clubroot (*Plasmodiophora brassicae*) in vegetable brassicas (Defra project (HH3227TFV Clubroot control using novel and sustainable methods; HGCA work on oilseed rape (RD-2007-3373)). Calcium applications can be made immediately prior to sowing (e.g. as Limex or Perllka). The effects of calcium are complex, extending beyond changes in soil pH to modification of soil microflora and direct effects on the host plant. Previously, Scaife et al., 1983 reported decreased incidence of cavity spot when soil exchangeable calcium exceeded 8 milliequivalents per 100 g soil.

The use of varieties with resistance to cavity spot is well-established in the industry. Resistance is incomplete and therefore additional control measures, particularly fungicides are still used. Whilst fungicide evaluation will be undertaken on more susceptible varieties, the benefits on the most resistant varieties should also be established. It may be possible, in future to refine at field level, the range of measures that are required to control cavity spot.

The overall aim of this project is to improve the management and control of cavity spot. Specific objectives in Year 1 are:

- Carrot crops already being monitored for cavity spot in project FV 373 will be used to quantify the occurrence enhanced soil degradation.
- Initial screening and optimisation of dose and timing of new products will be investigated.
- The use of calcium applications (as Limex or Perlka) will be investigated top enable rates of application and effects on pH and available calcium on cavity spot to be determined.

Summary of the results and main conclusions

The first year of this project comprised two replicated field experiments (Retford Notts cv. Chantenay and STC, Cawood, Yorks cv. Maestro) to evaluate new fungicides and biological products and testing of soils from carrot crops for enhanced degradation of metalaxyl-M. In addition, the effects of pre-sowing calcium treatments (as Limex or Perlka) were also Investigated (Table 1).

Cavity spot levels were low in 2012 because of the dry spring conditions and no significant treatment differences were observed on cavity spot incidence or yield in the two field experiments (Table 1). Neither the standard fungicide metalaxyl-M (SL567A) nor the other treatments decreased cavity spot at the STC, where 9% of carrots were affected in untreated plots. A soil test indicated this site did not give enhanced degradation of the fungicide. The dry season appears to have impaired fungicide activity and treatments probably work best when soils remain moist and *Pythium* spp. are active.

Table 1. Effects of novel fungicides, Limex and Perlka in comparison with SL567A on the incidence of cavity spot and yield -2011

	Timing 1 Pre-drilling	Timing 2 4-6 weeks after drilling	Timing 3 4-6 weeks after Timing 2	% roots with cavity spot		Yield (t/ha)	Yield (kg/ plot 2.7m^2)
				Retford	STC	Retford	STC
1	Untreated	Untreated	Untreated	0.5	9.3	68.6	22.7
2		SL567A (1.3 L/ha)	-	0.0	14.3	64.7	26.4
3		HDC F50	-	2.0	12.3	75.9	21.4
4		HDC F52		1.0	5.8	69.0	23.5
5	HDC F51	-	-	2.0	6.0	73.0	24.1
6		HDC F53		2.8	7.0	69.0	22.8
7		SL567A (0.65 L/ha)	SL567A (0.65 L/ha)	1.5	9.8	65.4	22.9
8		HDC F50	HDC F50	1.5	3.3	78.3	24.3
9		HDC F52	HDC F52	0.8	9.5	82.7	22.6
10	HDC F51	HDC F51		0.5	6.3	61.6	27.0
11		HDC F53	HDC F53	3.3	6.3	63.8	25.6
12	Limex 5 t/ha	-	-	1.3	13.5	74.0	20.7
13	Limex 10 t/ha	-	-	0.5	5.5	78.9	25.5
14	Limex 15 t/ha	-	-	0.3	6.5	85.2	27.2
15	Perlka 250 kg/ha	-	-	0.5	7.0	77.4	19.8

At both sites, the calcium treatments (as Limex) showed trends for decreased cavity spot and higher yields at the higher rates of application (Table 1). There were significant increases in soil pH and extractable calcium in June at the STC site, with the higher rates of Limex. These effects were not significant at the end of the experiment though positive trends remained (Table 2). Low levels of carrot scab were present at the Retford site, but this was unaffected by any of the test treatments including calcium applications.

Table 2. Soil pH and extractable calcium levels in relation to Limex treatments at STC - 2011

	Timing 1 Pre-drilling	Mean pH		Extractable Calcium (mg/L)		
		21 June	2 November	10 May	21 June	2 November
1	Untreated	6.2	7.0	1486	1778	1911
12	Limex 5 t/ha	6.5	7.3	1499	2009	2153
13	Limex 10 t/ha	6.8	7.5	1478	2301	2091
14	Limex 15 t/ha	6.9	7.2	1429	2323	2431

Tests for enhanced degradation of metalaxyl-M

Soil from 32 fields (including the two fungicide trial sites) was assessed for the persistence of metalaxyl-M in 2011. In 15 soils the half-life was less than the 10 days previously associated with control failure in 15 soils and in 12 soils was greater than 20 days. The remaining 5 soils fell between 10 and 20 days. Examples of fast and slow degrading soils are shown in Figure 1 and Figure 2 (respectively). More detailed results of soil tests will be presented in the HDC Cavity spot study project FV 373.

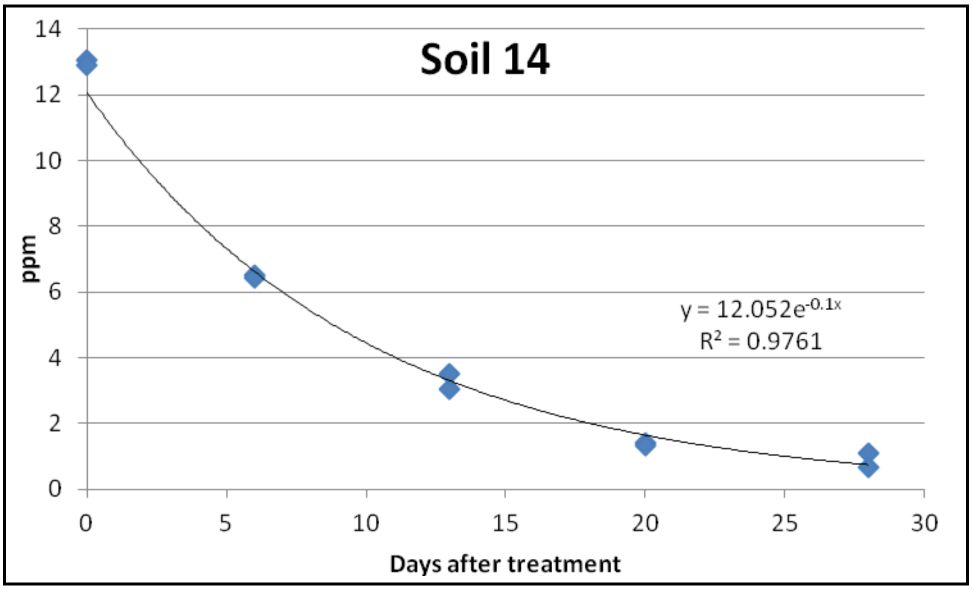

Figure 1. Example of plot of ‘fast’ degrading soil.

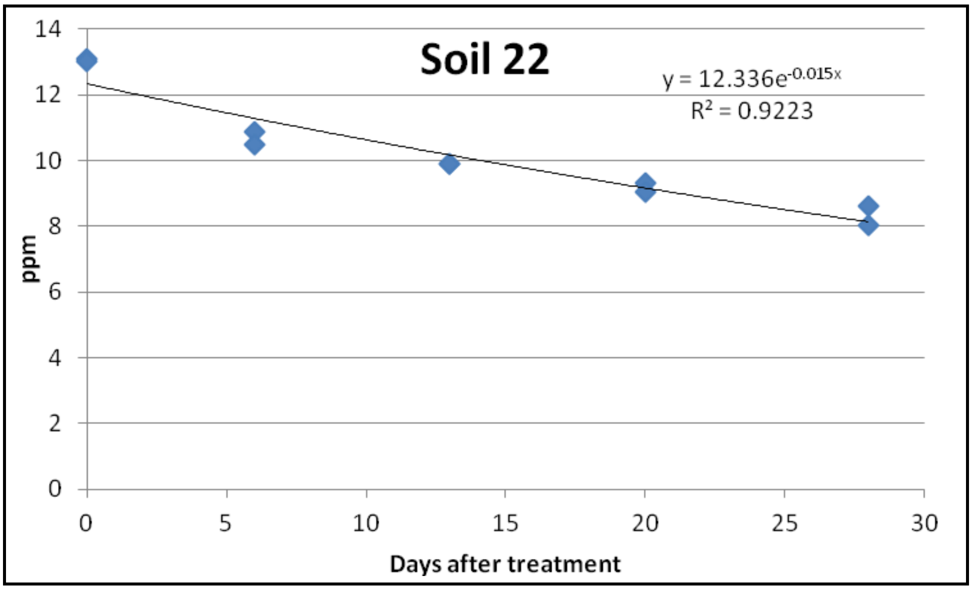

Figure 2. Example of plot of 'slow' degrading soil.

Half-lives of metalaxyl-M degradation were plotted against the measured soil pH (Figure 3) and also against soil organic content values. There was some evidence of correlation between half-life and pH with half-life appearing to diminish with increasing pH. The effect of organic matter was weak. Further examination of these relationships is required so that previous cropping, metalaxyl-M usage histories and weather factors can be taken into account.

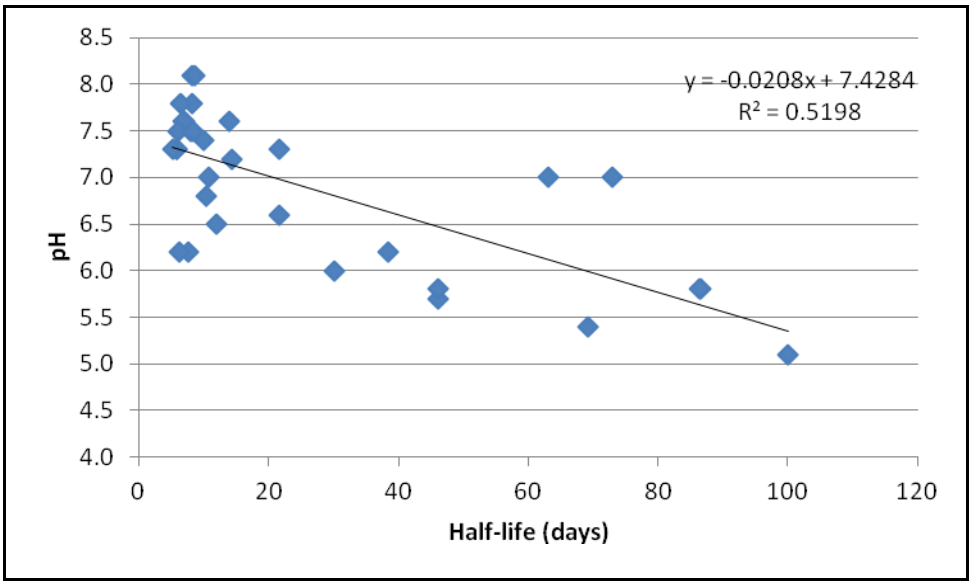

Figure 3. Relationship between Soil pH and metalaxyl-M half-life.

Financial benefits

There are no alternatives to SL567A as chemical control for carrot cavity spot. The financial benefits are likely to be greatest where the fungicide application timing is optimised. This should be post-emergence to moist soil no later than 6 weeks after sowing.

Action points for growers

- Growers need to interpret disease control with SL567A cautiously as poor control may be due to other factors (e.g. low rainfall) than enhanced degradation.

- Consider testing calcium treatments (e.g. Limex) for effect on cavity spot and yield; there were trends in this project for beneficial effects at higher rates of use.

SCIENCE SECTION

Introduction

Carrot cavity spot remains one of the most important diseases of carrots (Koike et al., 2007), still capable of causing complete loss in parts or even whole crops. Financial losses are particularly high when overwintered crops are lost. Current management of the disease relies on use of partially resistant or tolerant varieties and metalaxyl-M fungicide treatment early in the life of the crop. Recent HDC projects (FV 353, CP 46) have improved understanding of the pathogen and indicate that the main pathogen *Pythium violae* is able to utilise a wide range of crop and weed hosts. Whilst long rotations (e.g. 1 in 6) benefit carrot production by reducing the risk of damage from various pests and pathogens, they are not very effective for cavity spot. Disease development is strongly influenced by rainfall (soil moisture) and some quantitative data based on irrigation experiments is now available from FV 353. Whilst this helps explain variation in disease development, weather conditions are outside grower control so fungicide treatment remains the main tool that growers can use to counteract infection triggered by rainfall events. Metalaxyl-M has served the industry well for many years though its efficacy has been affected by enhanced degradation at some sites. Grower expenditure on this fungicide is >£1 million per annum. The extent to which fields in carrot production are currently affected by enhanced degradation is unknown. Suitable methodology for soil testing is available (see FV 5f). A soil test would be of interest to growers as a chargeable service if enhanced soil degradation can be shown to affect field performance of metalaxyl-M.

The window for using metalaxyl-M was defined in early experiments (Gladders & McPherson, 1986) and more recent work in FV 5f indicates timing at early post-emergence is rather more effective than pre-emergence applications. Some evaluation of later timings to protect crops over-winter has been undertaken in response to French research on secondary infection (Suffert et al., 2008). The results were disappointing and it seems unlikely that further residue work to secure new recommendations can be justified.

As the industry is dependent on a single fungicide with a single site mode of action, the sustainability of this treatment is of major concern. New fungicide active ingredients, particularly those used for potato late blight (*Phytophthora infestans*) are candidates for cavity spot control. Screening of new products (mainly strobilurin chemistry) was last reported in 2001 in FV 5f (Pettitt et al., 2001). New candidate active ingredients and products are available from Bayer CropScience, BASF and other companies. These include active ingredients already showing promise in the USA (Farrar, 2009; University of Florida

2010. Plant Disease Management Guide: Chemical Control Guide for Diseases of Vegetables, Revision No.21). There are opportunities to appraise treatment impacts on *Pythium violae* during the growing season using quantitative PCR using methodology developed in FV 353. Measures of pathogen activity in relation to treatments will be undertaken in collaboration with Dr D Barbara at the University of Warwick.

There are also opportunities to evaluate non-fungicidal treatments including biological control agents (bacterial and fungal products are available), soil amendments and calcium treatments. The latter provided some useful activity in pot and field tests in FV 5f and have been used successfully against clubroot in vegetable brassicas (Defra project HH3227TFV - Clubroot control using novel and sustainable methods; HGCA work on oilseed rape (RD-2007-3373). Calcium applications can be made immediately prior to sowing (e.g. as Limex or Perllka). The effects of calcium are complex, extending beyond changes in soil pH to modification of soil microflora and direct effects on the host plant. There were beneficial effects against cavity spot even on high pH soils in pot tests in FV 5f. Previously, Scaife et al., 1983 reported decreased incidence of cavity spot when soil exchangeable calcium exceeded 8 milliequivalents per 100 g soil. Further study is required to quantify the benefits of liming against cavity spot and to understand when to integrate calcium into management regimes in carrots.

The use of varieties with resistance to cavity spot is well-established in the industry. Resistance is incomplete and therefore additional control measures, particularly fungicides are still used. Whilst fungicide evaluation will be undertaken on more susceptible varieties, the benefits on the most resistant varieties should also be established. There may be opportunity to decrease dose or number of applications on the more resistant varieties. The contribution of host resistance and the need to add one or more control components should be tested on contrasting resistant and susceptible cultivars. It may be possible, in future to refine at field level, the range of measures that are required to control cavity spot.

The overall aim of this project is to improve the management and control of cavity spot. Specific objectives in Year 1 are:

- Carrot crops already being monitored for cavity spot in project FV 373 will be used to quantify the occurrence enhanced soil degradation.
- Initial screening and optimisation of dose and timing of new products will be investigated.

- The use of calcium applications (as Limex or Perlka) will be investigated to enable rates of application and effects on pH and available calcium on cavity spot to be determined.

Materials and methods

Field experiments

1. Retford, Notts

This replicated field experiment using a Chantenay variety was sown on 5 May 2011 immediately after soil treatments (Limex at three rates, Perlka and one of the coded products (as high volume spray) had been applied and incorporated. There were a total of 15 treatments (Table1) replicated four times in a randomised block design. Plot sizes were 10m of bed length where incorporation of treatments (plus 2m guard at each end) was required and a 5m bed length for post-emergence spray treatments (Appendix 1). Soil samples were taken for routine soil analysis and pH and calcium tests, a metalaxyl-M degradation test and a Pythium soil test.

There was very light rain at the end of drilling but not sufficient to wet the soil surface.
There was 22 mm of rain on 7 May and 2 mm of rain on 9 May. The site had low rainfall for most of the season. The second spray timing on 9 June and followed 4 mm rain on 7 June. The third spray timing was on 13 July when the soil was dry to 10 cm depth. The trial crop received 12 mm of irrigation on 2 August.

The crop grew slowly in the dry conditions and regular assessments were made of crop vigour (1-9 score) and of herbicide damage on 9 June. Carrot samples were taken regularly (3 and 24 August, 22 September) from control plots and examined for cavity spot.

Additional soil samples were taken from all the control plots and Limex treatments on 21 June and 2 November for pH and Extractable (=free) calcium analyses. Soils for Pythium tests were taken from all plots on 2 November.

The final harvest was delayed as long a possible because cavity spot incidence was low. Harvest yields were based on a harvested area of 2m x 1m at the centre of the bed. Cavity spot assessments were done on 100 roots per plot. Site details are given in Appendix 3.

Table 1. Treatments for cavity spot control in 2011

	Timing 1 Pre-drilling	Timing 2 4-6 weeks after drilling	Timing 3 4-6 weeks after Timing 2
1	Untreated	Untreated	Untreated
2		SL567A (1.3 L/ha)	-
3		HDC F50	-
4		HDC F52	
5	HDC F51	-	-
6		HDC F53	
7		SL567A (0.65 L/ha)	SL567A (0.65 L/ha)
8		HDC F50	HDC F50
9		HDC F52	HDC F52
10	HDC F51	HDC F51	
11		HDC F53	HDC F53
12	Limex 5 t/ha	-	-
13	Limex 10 t/ha	-	-
14	Limex 15 t/ha	-	-
15	Perlka 400 kg/ha	-	-

2. STC, Yorks

This replicated field experiment was sown (cv. Maestro) on 12 May 2011, the day after soil treatments (Limex at three rates, Perlka and coded product (as high volume spray)) had been applied and incorporated. Treatments were identical to those applied at Retford (Table 1). Plot sizes were 10m of bed length where incorporation of treatments (plus 2m guard at each end) was required and 5m bed length for post-emergence spray treatments (Appendix 2). Soil samples were taken for routine soil analysis and pH and calcium tests, a metalaxyl-M degradation test and a Pythium soil test.

There had been some rain in the period immediately prior to drilling (16.3 mm on 8 May and 3.6 mm on 10 May). There was very little rain for a fortnight following drilling (<1 cm over a 14 day period), but irrigation was applied to the trial during this period (a total of approximately 5 cm). A fairly dry season was experienced but irrigation was applied to the trial at regular intervals. The second spray timing on 15 June was applied in the afternoon following a period of irrigation in the morning. The third spray timing was on 23 July following a week with some rainfall (22.8 mm in the period 16 July to 22 July).

The crop grew well, although it was patchy in places. Regular assessments were made of any phytotoxicity symptoms and foliar disease. Carrot samples were taken regularly (5 and 24 August, 5 October) from control plots and examined for cavity spot.

Additional soil samples were taken from all the control plots and Limex treatments on 21 June and 2 November for pH and Extractable (=free) calcium analyses. Soil samples for Pythium tests were taken from control plots only on 5 October.

The final harvest was delayed as long a possible because cavity spot incidence was low. Harvest yields were based on a harvested area of 3m x 2 rows at the centre of the bed. Cavity spot assessments were done on 100 roots per plot on 20-21 November 2011. Site details are given in Appendix 4.

Metalaxyl-M degradation

Sampling for Degradation Study 2011

During the spring of 2011, representative soil samples of approx 1kg in weight were collected from each of thirty commercial carrot sites. The samples were kept cool and transported to Warwick Crop Centre, Wellesbourne for subsequent analysis. The sites were provided by members of the British Carrot Growers Association (BCGA) and were also used in another cavity spot project FV 373. Records are therefore available for the incidence and severity of cavity spot from these sites, together with soil analysis and previous cropping details and will be reported in FV 373.

The commercial samples of field soils and the two field experiment samples were received at Warwick Crop Centre, Wellesbourne. On receipt the soils were logged, sieved and stored at 5 ^{o}C.

Soil properties

a) Moisture holding capacity

Moisture holding capacity (MHC) was determined by saturating duplicate soil samples contained within a filter paper cone inside a plastic funnel. The soil surface was covered with polythene to prevent evaporation and excess water was allowed to drain for 24 hours into a conical flask. Sub-samples of the soil were dried to constant mass in a microwave oven to determine the moisture holding capacity of each soil. Subsequent degradation experiments were conducted at 50 % of the moisture holding capacity.

b) pH

A sub-sample of each soil was air-dried and sieved to 2 mm. 10 ml of soil was shaken with 25 ml R.O. water for 15 min and the pH measured using a calibrated pH meter. Results are presented in Figure 3.

c) Organic matter

A sub-sample of each soil was oven dried at 80 ^{o}C to constant mass. Organic matter was determined by measuring the change in weight after combustion at 450 ^{o}C. (Data not presented).

Degradation studies

a) Treatment and sampling

The soils were treated in 2 batches. Batch 1 contained soils 1, 2, 4, 5, 6, 8, 9, 13, 14, 15, 17, 18, 22, 26, 31 and 32. Batch 2 contained soils 3, 7, 10, 11, 12, 16, 19, 20, 21, 23, 24, 25, 27, 28, 29 and 30. Both soil batches were treated in the same way. Soils were allowed to dry to a moisture level below 50% MHC. The moisture content was calculated by drying a sub-sample to constant mass in a microwave oven. Then, a mass equivalent to 600 g dry soil was taken and spread out on polythene sheets. A solution of metalaxyl-M was prepared from Subdue (Fargro) containing 0.6 mg a.i./ml. Each soil was treated with 10 ml of the treatment solution (6 mg a.i.) by ‘dribbling’ from a 10 ml pipette over the soil surface. Further water was added, as required, to take the soil moisture content up to 50% MHC. The soils were allowed to equilibrate (15 – 30 minutes), mixed by hand and split equally between two polythene bottles (600 ml). The bottles were loosely sealed and transferred to an incubator maintained at 15 ^{o}C. Sub samples (20 g) were taken from each bottle 0, 6, 13, 20 and 28 days after treatment (Batch 1) or 0, 5, 12, 19 and 27 days after treatment (Batch 2) and weighed into polythene centrifuge tubes (50 ml). The centrifuge tubes were sealed and frozen until extraction.

b) Extraction and analysis

The centrifuge tubes were removed from the freezer and the soil was allowed to defrost. Methanol (30 ml, HPLC grade) was added and the tubes were shaken (end-over-end) for 1 hour. The tubes were centrifuged (1 min, 9000 rpm) and a sub-sample (approximately 1.5 ml) of the supernatant was transferred to an HPLC vial using a polythene Pasteur pipette. The vial was sealed and frozen until analysis.

Before analysis, samples were allowed to warm to room temperature and shaken. Analysis was performed on a 1100 series Agilent High Performance liquid Chromatograph (HPLC) fitted with a Genesis C8 column (25 cm x 4.6 mm). The mobile phase was Acetonitrile:Water (70:30) at a flow rate of 1.2 ml/min and detection was by UV absorbtion at 220 nm. The retention time of metalaxyl-M was 3.6 mins and quantification was performed by comparison with an external standard of metalaxyl-M (6 µg/ml in methanol).

c) Half-life

The results for each soil were plotted. First order kinetics was assumed so the plots were fitted to an exponential curve. Half-lives were calculated based on the formulae of the curves.

Results

Field experiments

1. Retford, Notts

Harvesting of the plots was delayed as long as possible to allow cavity spot to develop.
Cavity spot levels were very low (<1% in untreated) in this experiment and no significant treatment effects were recorded on incidence or severity (Table 2). This reflected the low rainfall and dry soil for the major part of the season. There was 22 mm of rain within 2 days of drilling and another 2mm on 9 May but emergence was still rather variable and slow. The smaller seedlings were affected by herbicide (assessed 9 June) but this did not interact with the cavity spot treatments (Table 3). Similarly there were no significant differences in vigour and ground cover between treatments during June/July (Table 3) or August/September (Table 4).

No *Pythium* was detected by PCR tests in soil samples taken from control plots on 13, 23 and 30 June 1 September and 27 October. Pre-harvest samples from treated plots were not examined because of the low disease incidence. The metalaxyl-M degradation test indicated this site had a ‘fast’ degrading soil.

Table 2. Incidence and severity of cavity spot, Retford, Notts - 2011

	Timing 1 Pre-drilling	Timing 2 4-6 weeks after drilling	Timing 3 4-6 weeks after Timing 2	% roots with cavity spot	Mean no. lesions per root	% root area affected	% Yield with cavity spot
1	Untreated	Untreated	Untreated	0.5	0.01	0.01	0.4
2		SL567A (1.3 L/ha)	-	0.0	0.00	0.00	0.0
3		HDC F50	-	2.0	0.03	0.04	2.4
4		HDC F52		1.0	0.01	0.01	1.6
5	HDC F51	-	-	2.0	0.03	0.03	2.1
6		HDC F53		2.8	0.03	0.05	3.0
7		SL567A (0.65 L/ha)	SL567A (0.65 L/ha)	1.5	0.03	0.04	1.7
8		HDC F50	HDC F50	1.5	0.02	0.06	1.7
9		HDC F52	HDC F52	0.8	0.01	0.01	1.0
10	HDC F51	HDC F51		0.5	0.01	<0.01	0.3
11		HDC F53	HDC F53	3.3	0.05	0.09	3.9
12	Limex 5 t/ha	-	-	1.3	0.02	0.11	1.3
13	Limex 10 t/ha	-	-	0.5	0.01	0.01	0.6
14	Limex 15 t/ha	-	-	0.3	0.05	0.16	0.1
15	Perlka 250 kg/ha	-	-	0.5	0.01	0.01	0.5
			F Pr	NS (0.438)	NS (0.557)	NS (0.657)	NS (0.352)
			SED (42 df)	1.318	0.024	0.075	1.482
			LSD	2.660	0.049	0.152	2.991

Table 3. Vigour, ground cover and herbicide scorch assessments, June/July Retford, Notts - 2011.

	Timing 1 Pre-drilling	Timing 2 4-6 weeks after drilling	Timing 3 4-6 weeks after Timing 2	Vigour score 9 June	Herbicide damage score 9 June	Vigour score 13 July	% Ground cover 13 July
1	Untreated	Untreated	Untreated	6.3	1.0	6.5	81.0
2		SL567A (1.3 L/ha)	-	5.8	1.0	6.3	78.3
3		HDC F50	-	6.0	1.0	6.5	87.8
4		HDC F52		5.8	1.0	6.3	88.5
5	HDC F51	-	-	6.0	2.0	6.3	80.3
6		HDC F53		5.3	2.3	5.5	70.3
7		SL567A (0.65 L/ha)	SL567A (0.65 L/ha)	4.8	2.0	6.0	75.8
8		HDC F50	HDC F50	6.3	1.0	6.8	89.8
9		HDC F52	HDC F52	6.0	1.0	5.8	80.5
10	HDC F51	HDC F51		4.3	1.3	5.0	74.0
11		HDC F53	HDC F53	4.8	2.8	4.5	64.0
12	Limex 5 t/ha	-	-	7.0	1.0	7.3	91.3
13	Limex 10 t/ha	-	-	6.8	2.3	6.8	82.5
14	Limex 15 t/ha	-	-	7.3	1.3	7.5	86.3
15	Perlka 250 kg/ha	-	-	7.0	1.0	7.3	87.5
			F Pr	NS (0.116)	NS (0.353)	NS (0.158)	NS (0.484)
			SED (42 df)	0.99	0.81	0.96	11.07
			LSD	2.00	1.64	1.95	22.33

Table 4. Crop vigour scores in August/September and yield assessments, Retford, Notts - 2011.

	Timing 1 Pre-drilling	Timing 2 4-6weeks after drilling	Timing 3 4-6 weeks after Timing 2	Vigour score 3 August	Vigour score 24 August	Vigour score 22 September	Yield (t/ha)
1	Untreated	Untreated	Untreated	7.8	7.6	7.3	68.6
2		SL567A (1.3 L/ha)	-	7.0	7.3	7.1	64.7
3		HDC F50	-	7.0	7.0	7.3	75.9
4		HDC F52		7.5	7.4	7.0	69.0
5	HDC F51	-	-	8.0	7.8	7.8	73.0
6		HDC F53		7.5	7.5	7.5	69.0
7		SL567A (0.65 L/ha)	SL567A (0.65 L/ha)	8.0	8.0	7.8	65.4
8		HDC F50	HDC F50	7.3	7.3	7.3	78.3
9		HDC F52	HDC F52	6.8	6.9	7.0	82.7
10	HDC F51	HDC F51		7.0	7.3	7.0	61.6
11		HDC F53	HDC F53	7.5	7.5	8.1	63.8
12	Limex 5 t/ha	-	-	8.0	7.6	7.4	74.0
13	Limex 10 t/ha	-	-	7.5	7.5	7.5	78.9
14	Limex 15 t/ha	-	-	7.5	7.4	7.3	85.2
15	Perlka 250 kg/ha	-	-	7.8	7.6	7.4	77.4
			F Pr	NS (0.294)	NS (0.497)	NS (0.500)	NS (0.491)
			SED (42 df)	0.510	0.412	0.458	10.28
			LSD	1.030	0.831	0.924	20.74
			CV (%)				20.0

There were no significant effects of treatments on yield (Table 4). The high rate of Limex gave the highest yield and there was a positive yield trend with increasing rates of Limex application. The yield trend was not associated with similar trends in crop vigour (Table 4).

Table 5. Incidence and severity of carrot scab at harvest, Retford, Notts - 2011.

	Timing 1 Pre-drilling	Timing 2 4-6 weeks after drilling	Timing 3 4-6 weeks after Timing 2	Mean % roots with scab	Mean % root area with scab
1	Untreated	Untreated	Untreated	1.3	0.01
2		SL567A (1.3 L/ha)	-	2.0	0.01
3		HDC F50	-	1.5	0.01
4		HDC F52		2.0	0.02
5	HDC F51	-	-	1.3	0.01
6		HDC F53		2.0	0.02
7		SL567A (0.65 L/ha)	SL567A (0.65 L/ha)	1.0	0.01
8		HDC F50	HDC F50	1.5	0.02
9		HDC F52	HDC F52	0.5	<0.01
10	HDC F51	HDC F51		1.0	0.01
11		HDC F53	HDC F53	2.5	0.10
12	Limex 5 t/ha	-	-	1.5	0.02
13	Limex 10 t/ha	-	-	2.5	0.02
14	Limex 15 t/ha	-	-	1.0	0.01
15	Perlka 250 kg/ha	-	-	1.0	0.011
			F Pr	NS (0.937)	NS (0.441)
			SED (42 df)	1.22	0.029
			LSD	2.46	0.060

There were only low levels of scab on the roots but no significant treatment differences (Table 5). This indicated no adverse effects of liming or other interactions with treatments.

Table 6. Soil pH and extractable calcium levels in Limex treatments, Retford, Notts -2011

	Timing 1 Pre-drilling	Mean pH			Extractable Calcium (mg/L)		
		5 May	21 June	2 November	5 May	21 June	2 November
1	Untreated	7.06	6.87	7.50	1009	956	1016
12	Limex 5 t/ha	6.97	6.97	7.49	945	991	1019
13	Limex 10 t/ha	7.05	7.03	7.43	871	935	943
14	Limex 15 t/ha	7.07	6.84	7.51	934	1020	925
	F Pr	NS (0.670)	NS (0.519)	NS (0.943)	NS (0.152)	NS (0.585)	NS (0.768)
	SED (9 df)	0.090	0.140	0.137	53.1	64.4	111.7
	LSD	0.203	0.317	0.309	120.1	145.6	252.6

There were no significant differences between the Limex treatments and the untreated control (Table 6). The differences in mean pH at the different assessment dates have been attributed to the influence of low soil moisture.

2. STC, Yorks

Table 7. Incidence and severity of cavity spot, STC - 2011

	Timing 1 Pre-drilling	Timing 2 4-6 weeks after drilling	Timing 3 4-6 weeks after Timing 2	% roots with cavity spot	Mean no. lesions per root	% root area affected	Yield (kg/ $2.7m^2$)
1	Untreated	Untreated	Untreated	9.3	1.0	0.23	22.7
2		SL567A (1.3 L/ha)	-	14.3	1.6	0.34	26.4
3		HDC F50	-	12.3	1.0	0.27	21.4
4		HDC F52		5.8	0.6	0.10	23.5
5	HDC F51	-	-	6.0	0.4	0.13	24.1
6		HDC F53		7.0	0.6	0.15	22.8
7		SL567A (0.65 L/ha)	SL567A (0.65 L/ha)	9.8	0.4	0.18	22.9
8		HDC F50	HDC F50	3.3	0.4	0.09	24.3
9		HDC F52	HDC F52	9.5	0.4	0.20	22.6
10	HDC F51	HDC F51		6.3	0.5	0.12	27.0
11		HDC F53	HDC F53	6.3	0.3	0.13	25.6
12	Limex 5 t/ha	-	-	13.5	1.4	0.70	20.7
13	Limex 10 t/ha	-	-	5.5	0.4	0.11	25.5
14	Limex 15 t/ha	-	-	6.5	0.8	0.18	27.2
15	Perlka 250 kg/ha	-	-	7.0	0.6	0.15	19.8
			F Pr	NS (0.174)	NS (0.094)	NS (0.344)	NS (0.174)
			SED (42 df)	3.744	0.42	0.202	3.74
			LSD	7.556	0.85	0.407	7.55

There were no significant treatment effects on cavity spot or yield at the STC site (Table 7). Cavity spot symptoms had appeared by 5 October when 34% of untreated roots had small cavity spots. There was little development later in season at the STC site despite harvest being delayed as long as possible to allow symptoms to develop. When assessed on 20 November, the incidence of cavity spot in untreated plots appeared to have decreased from 34% to 9.3%. This was attributed to sampling effects as much larger samples were taken at the November harvest. There were positive yield trends with increasing rates of Limex as noted at the Retford site. At both sites there was a trend for lower cavity spot at higher rates of Limex.

The two higher rates of Limex significantly increased soil pH in June by up to 0.7 pH units but effects were not significant in November (Table 8). Differences in the untreated pH between the two sampling dates are attributed to variation on soil moisture when samples were taken. The higher rates of Limex increased extractable calcium in samples taken in

June. Calcium levels were still higher in treated soils in November but differences were no longer significant (Table 8).

The absence of cavity spot control with SL567A suggests that the seasonal weather pattern may have affected fungicide performance as metalaxyl-M was degraded slowly by the soil at this site.

Table 8. Soil pH and extractable calcium levels in relation to Limex treatments, STC 2011

	Timing 1 Pre-drilling	Mean pH		Extractable Calcium (mg/L)		
		21 June	2 November	10 May	21 June	2 November
1	Untreated	6.15	6.97	1486	1778	1911
12	Limex 5 t/ha	6.48	7.34	1499	2009	2153
13	Limex 10 t/ha	6.75	7.46	1478	2301	2091
14	Limex 15 t/ha	6.85	7.21	1429	2323	2431
	F Pr	0.021	NS (0.223)	NS (0.76)	0.01	NS (0.239)
	SED (9 df)	0.155	0.182	55.6	113.3	191.8
	LSD	0.430	0.507	155.1	314.0	531.3

Metalaxyl degradation

Examples are given in Figure 1 ('fast' degrader) and Figure 2 ('slow' degrader). For 4 soils (11, 18, 19 and 28) the fit was very poor (as measured by R^2 values) so a linear fit was used.

The detailed results of soil tests will be presented in the associated HDC cavity spot project FV 373. Soil from 32 fields (including the two fungicide trial sites) was assessed for the persistence of metalaxyl-M in 2011. The half-life was less than the 10 days previously associated with control failure in 15 soils and greater than 20 days in 12 soils. The remaining 5 soils fell between 10 and 20 days.

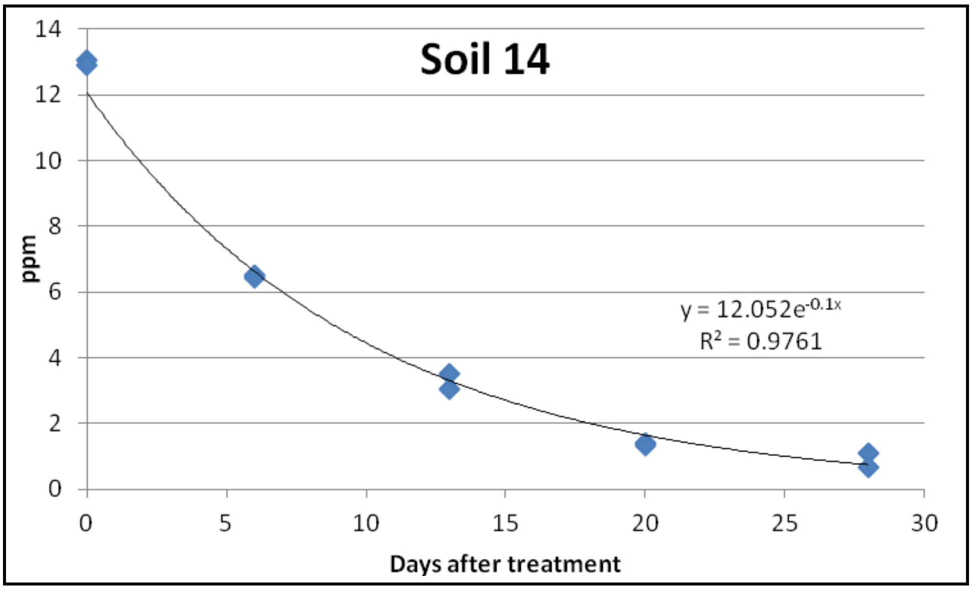

Figure 1. Example of plot of 'fast' degrading soil.

Half-lives were plotted against the measured soil pH (Figure 3) and soil organic content (Figure 4) values. There is some evidence of correlation between half-life and pH with half-life appearing to diminish with increasing pH. The effect of organic matter was weaker. Two highly organic soils showed slow degradation (Figure 4). However, this is a speculative relationship without previous cropping and metalaxyl-M usage histories.

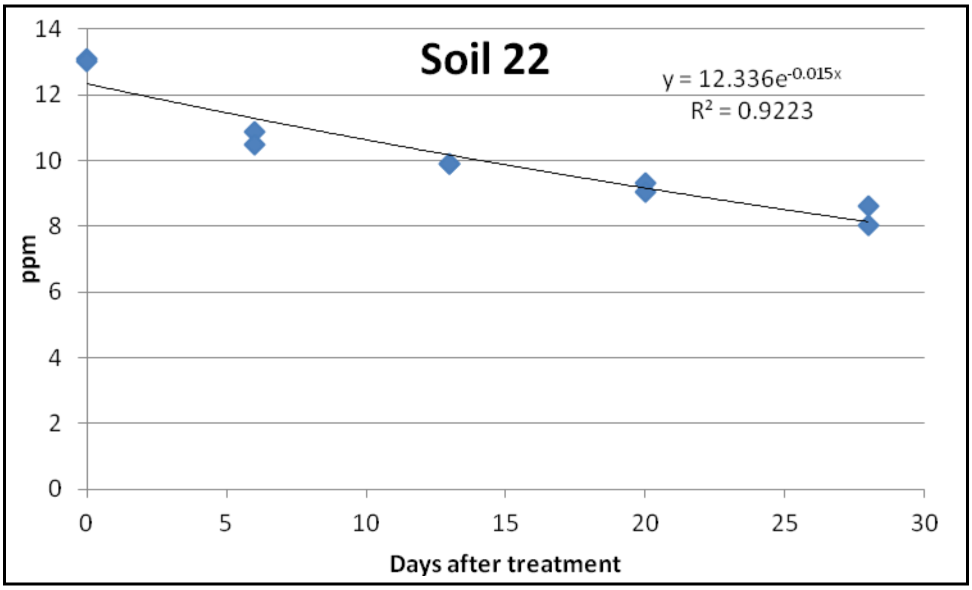

Figure 2. Example of plot of 'slow' degrading soil.

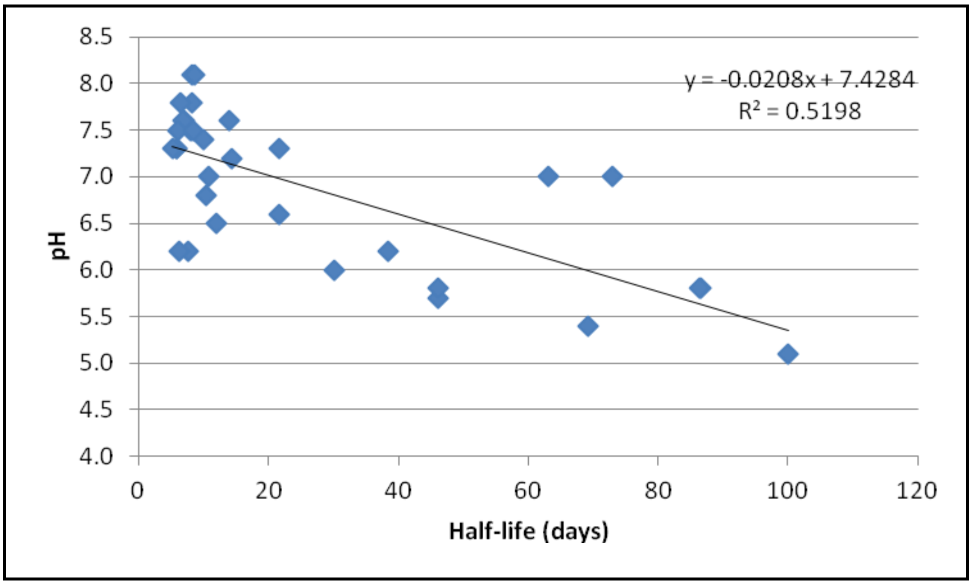

Figure 3. Relationship between soil pH and metalaxyl-M half-life (soils sampled and tested in 2011)

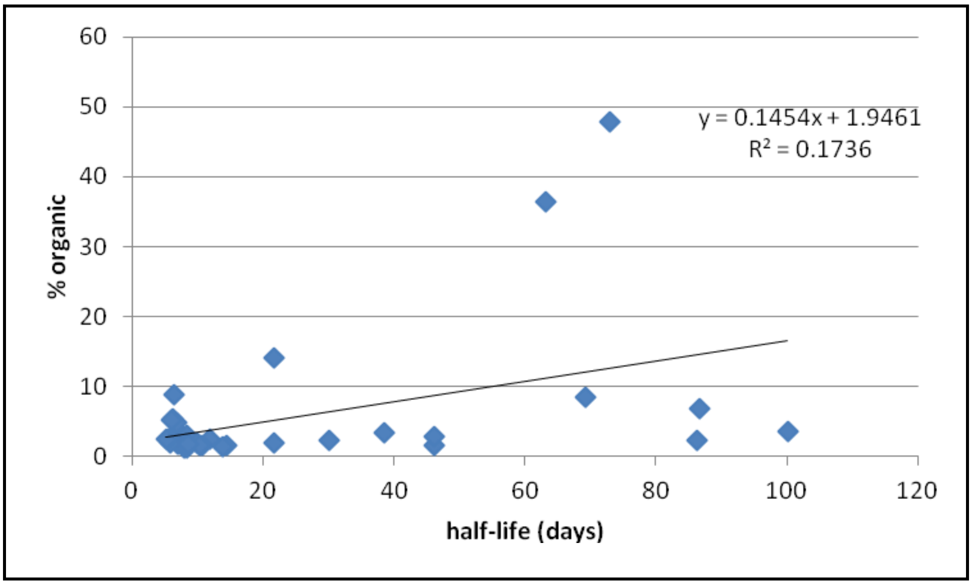

Figure 4. Relationship between Soil organic content and metalaxyl-M half-life (soils sampled and tested in 2011)

Discussion

Whilst there was significant rainfall close to drilling, generally 2011 was a dry season and this limited cavity spot development. During the season the soil was very dry around the roots and soil tests for *Pythium* failed to detect the presence of the pathogen. This profile is consistent with recent progress on understanding water requirements for cavity spot development (HDC project FV 353). Clearly there was some *Pythium violae* at the STC site as cavity spot affected about 10% of roots. However, the absence of control, particularly with SL567A, suggests that soil moisture may have affected fungicide performance as the soil was classified as a slow degrading type. Water is required for *Pythium* activity and fungicides are thought to be more effective if the pathogen is growing. A second requirement is the impact of water on fungicide movement within the soil profile and within plants. Metalaxyl-M is highly soluble and restricted movement during the key stage for control (within 10 weeks of sowing) may have affected performance in 2011. Whilst cavity spot levels were low generally in 2011, growers need to interpret disease control efficacy cautiously as poor control may not be due to enhanced degradation in soil.

A previous study (Kenny et al, 2001) associated a half-life of metalaxyl (i.e. prior to the release of metalaxyl-M) of less than 10 days in laboratory tests with failure to control cavity spot in carrots. All of the soils in their study where control had failed had previously been treated with metalaxyl. In this study, metalaxyl-M half-life was less than 10 days in 15 soils (almost half the fields sampled). It is probably reasonable to assume that metalaxyl-M may not always provide adequate control of cavity spot in these soils. In 12 soils the half-life was greater than 20 days and it is equally reasonable to assume that metalaxyl-M should have been effective in these soils. The remaining 5 soils gave a half-life which fell between 10 and 20 days. Weather conditions can play a big part in pesticide degradation with rates increasing with soil moisture content and temperature. So very dry or cold conditions are likely to increase persistence and very wet or warm conditions are likely to have the reverse effect.

There may well be spatial variation in metalaxyl-M degradation within fields. The complexity of this, and indeed variation in the occurrence of cavity spot, is not well defined. As degradation is caused by soil microbes, these could show patchy distributions which demand detailed sampling procedures. Where there is variation in soil type sampling requirements may need to be adjusted. Further work on sampling may be required to define optimized sampling protocols.

Soil tests for metalaxyl-M degradation will be done on a similar number of fields in 2012 and this will allow growers to review where enhanced degradation might be affecting fungicide performance. Soil testing may be required as new fields come into production. Note where soils are sampled for pH and nutrient analyses, they should be sampled early in the year whilst soils are still moist.

The use of calcium treatments just before sowing has shown some promising trends for decreasing cavity spot incidence and improving yield. The impact of these treatments may be different when soil moisture levels are higher during the growing season. There were effects on soil pH and extractable calcium and these could well influence microbial activity in the soil - ideally to the benefit of the carrot crop. There was no indication that carrot scab was aggravated by calcium treatment. Increased risk of common scab after using calcium treatments (lime) has been a concern for growers growing potatoes in a carrot rotation.

The new treatments in the field experiments included both fungicides and biological products. These were safe on the crop and treatments will be repeated in 2012.

Conclusions

- The dry spring in 2012 restricted the development of cavity spot in crops.
- No significant control of cavity spot was demonstrated in field experiments. Fungicide performance may have been impaired by the prevailing dry conditions.
- Almost half the soils from 32 carrot fields showed fast degradation of metalaxyl-M. At these sites the half life of metalaxyl-M was less than 10 days and this could affect the efficacy of cavity spot control.
- There were trends suggesting that calcium treatments may be able to contribute to cavity spot control and improve yields.
- Support for the findings from Year 1 is being progressed with further experimentation in Year 2.
- Rapid degradation of metalaxyl–M in soil could adversely affect cavity spot control.in carrots.
- SL567A should be applied to moist soil post-emergence (1-2 leaf stage) not later than 6 weeks after sowing.

Knowledge and Technology Transfer

The UK Onion and Carrot Conference, Peterborough 17 November 2011 – review paper on carrot cavity spot presented (PG).

HDC News Field vegetables review April 2012 New projects p. 4.

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Appendices

Appendix 1. Weather conditions at spraying Retford, Notts 2011

Target date (Timing)	Actual Date	Growth Stage	Weather (recorded at time of application)
Timing 1 Pre- drilling	05/05/11	Pre-em	Start: Air temp 20.3 ºC, RH% 50.5, wind SE 11.2 kph Finish: Air temp 18.3 ºC, RH% 45.9, wind SE 9.6 kph Sun and hazy cloud during spraying Soil dry on surface. Very slight drift
Timing 2 4-6 weeks after Timing 1 spray	09/06/11	10-12 Mean 11	Start: Air temp 16.3 ºC, RH% 48.1, wind NW 6.9 kph Finish: Air temp 15.3 ºC, RH% 44.8, wind NW 7.1 kph Sun and cloudy during spraying Soil dry on surface. Damp at 10mm Very slight drift
Timing 3 4-6 weeks after Timing 2 spray	13/07/11	13-16 Mean 14	Start: Air temp 16.1 ºC, RH% 59.8, wind NE 5.0 kph Finish: Air temp 16.9 ºC, RH% 60.3, wind NE 3.9 kph Cloudy during spraying Soil dry on surface and to 9 10cm depth Very slight drift

Sprayer: OPS sprayer with 2m boom and 110-03 nozzles operated at 2 bars pressure and applying fungicides in 1000 litres water/ha

Appendix 2. Weather conditions at spraying STC, North Yorkshire 2011

Target date (Timing)	Actual Date	Growth Stage	Weather (recorded at time of application)
Timing 1 Pre- drilling	10/05/11- 11/05/11	Pre-em	Sunny with scattered cloud. Soil dry on surface. Gentle breeze Very slight drift
Timing 2 4-6 weeks after Timing 1 spray	15/06/11	11 1st true leaf	Soil damp on surface. Crop dry Light breeze, minimal drift Very light shower after spraying
Timing 3 4-6 weeks after Timing 2 spray	22/07/11	15-16 5-6 true leaves. 50-60% crop cover	Sunny spells during spraying, warmer following application. Soil damp on surface, crop dry. Light breeze, minimal drift

Sprayer: OPS sprayer with 2m boom and 110-03 nozzles operated at 2 bars pressure and applying fungicides in 1000 litres water/ha

Appendix 3. Site details Retford, Notts 2011

Site:	Babworth, nr Retford, Notts		
Field name/ GRef:	SK 668 777		
Soil texture:	Loamy sand		
Drainage:	Good		
Previous cropping:	2010 Spring barley	2009 Onions	2008 Sugar beet
Soil analysis:	pH 6.9		
(May 2010)	ADAS Indices – P 44.2 mg/l (3), K 134 mg/l (2-), Mg 140 mg /l (3) 1.9 % organic matter		
Crop: Carrots	Cultivar	: Chantenay variety	
	Sowing date	: 5 May 2011	
	Seed rate	: 7.4 kg/ha	
Cover crop	Spring barley cv. Tipple	50 kg/ha seed rate	Sown 5 May 2011
Irrigation	(not on trial)	13 July 2011	
	12 mm water	2 August 2011	
Fertilisers	Ammonium nitrate	87 kg/ha	14 June 2011
	Bittersalz	5 kg/ha	10 August 2011
Fungicides (to farm crop)	Clayton Tine	1.3 l/ha	8 June 2011
Herbicides	Cleancrop Hoedown	4.0 l/ha	23/ September 2010
	Afalon	0.67 l/ha	28 April 2011
	Stomp Aqua	2.9 l/ha	28 April 2011
	Afalon	0.67 l/ha	06 May2011
	Stomp Aqua	2.9 l/ha	06 May 2011
	Falcon	0.7 l/ha	01 June 2011
	Datura	1.0 l/ha	03 June 2011
	Afalon	0.55 l/ha	1 July 2011
	Shotput	0.5 kg/ha	1 July 2011
Insecticides	Dovetail	1.5 l/ha	01 July 2011
	Hallmark with Zeon Technology	0.15 l/ha	20 July 2011
	Hallmark with Zeon Technology	0.15 l/ha	02 August 2011
	Hallmark with Zeon Technology	0.15 l/ha	10 August 2011
Harvest (farm)			22 September 2011
Harvest trial plots			23 November & 1 December2011

Appendix 4. Site details Stockbridge Technology Centre 2011

Site:	Field H1, Stockbridge Technology Centre, Cawood, YO8 3TZ		
Field name/ GRef:	SE561366		
Soil texture:	Sandy loam		
Drainage:	good		
Previous cropping:	2010	2009	2008
Soil analysis:	pH 6.97		
Crop: Carrots	Cultivar	: Maestro	
	Sowing date	: 12 May 2011	
	Seed rate	: 180-200/m^2	
Irrigation			
Fertilisers	Muriate of Potash	291kg/ha (175kg/ha K)	21 April 2011
	Nitram	289 kg/ha (100kg/ha N)	30 May 2011
Herbicides	Linuron	1.2l/ha (in 600l/ha water)	04 May 2011
Insecticides	Biscaya	0.4l/ha (in 200l/ha water)	28 May 2011
	Biscaya	0.4l/ha (in 200l/ha water)	20 June 2011
	Hallmark Zeon	150ml in 200l/ha water	27 July 2011
	Hallmark Zeon	150ml in 200l/ha water	08 August 2011
Harvest trial plots			20-21 November 2011