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| **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 2013 |
| **Previous report:** | None |
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| **Location of project:** | Commercial site in Retford (Nottinghamshire), STC, Yorkshire, University of Warwick |
| **Industry representative:** | Mr Keith Mawer,<br>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

- SL567A (metalaxyl-M) remained the most effective treatment, though cavity spot control was only achieved in one of the two field experiments.
- Limex incorporated before sowing also gave control of cavity spot at one of the sites.
- The novel/experimental fungicide products were not effective at standard 'blight' rates and higher doses will be evaluated in 2013.

## 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 causal organism, *Pythium violae,* is able to utilise a wide range of crop and weed hosts. Whilst long rotations (e.g. one in six) benefit carrot production by reducing the risk of damage from various pests and pathogens, they are not very effective for preventing 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 to explain variation in disease development, weather conditions are outside growers' 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 and mode of action, the sustainability of this treatment is a major concern though fortunately, to date, resistance to metalaxyl-M has not been detected in the *P. violae* population. 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*) or downy mildew (e.g. *Plasmopara viticola* in vines) are candidates for cavity spot control. Screening of new products (of 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* were appraised during the growing season using quantitative PCR and methodology developed in FV 353. Measures of pathogen activity in relation to treatments were undertaken in collaboration with Dr D Barbara[1] and colleagues 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; and HGCA work on oilseed rape (RD-2007-3373). Calcium applications can be made immediately prior to sowing (e.g. as Limex or Perlka). 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. Also, it is known that *Pythium* spp. in general prefer an acid pH.

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 2 were:

1. To evaluate new fungicides and biological treatments with potential to control *Pythium* species in soil.
2. To establish optimum application rates and timings for the most promising new products.
3. To determine the contribution of pre-planting calcium applications for cavity spot control.

[1] Unfortunately, Dr Dez Barbara passed away during 2012 and he will be sadly missed by both the research community and the horticultural industry.

4. To determine the prevalence of enhanced degradation of metalaxyl-M in carrot growing areas.

## Summary of the project and main conclusions

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

In Year 1, cavity spot levels were low because of the dry spring conditions and no significant treatment differences in cavity spot incidence or yield were observed in the two field experiments. However, in 2012, in excess of 55% of roots were affected by disease at Retford and 64% at STC, which provided a severe test of the products.

The standard fungicide metalaxyl-M (SL567A) was the most effective fungicide at the Retford site where it gave 64% control. Disappointingly, none of the experimental fungicides applied at standard rates of application (for foliar disease) decreased soil-borne cavity spot incidence.

**Table 1:** Effects of novel fungicides, Limex and Perlka in comparison with SL567A on the incidence of cavity spot in 2012

| | Timing 1 | Timing 2 | Timing 3 | Cavity spot incidence (%) | |
|---|---|---|---|---|---|
| | Pre-drilling | 4–6 weeks after drilling | 4–6 weeks after Timing 2 | Retford | STC |
| 1 | Untreated | Untreated | Untreated | 55 | 65 |
| 2 | Standard | SL567A (1.3 L/ha) | - | 20 | 55 |
| 3 | | HDC F50 | - | 51 | 65 |
| 4 | | HDC F52 | | 55 | 78 |
| 5 | HDC F51 | - | - | 40 | 68 |
| 6 | | HDC F53 | | 47 | 55 |
| 7 | | SL567A (0.65 L/ha) | SL567A (0.65 L/ha) | 19 | 60 |
| 8 | | HDC F50 | HDC F50 | 53 | 63 |
| 9 | | HDC F52 | HDC F52 | 49 | 69 |
| 10 | HDC F51 | HDC F51 | | 43 | 62 |
| 11 | | HDC F53 | HDC F53 | 42 | 62 |
| 12 | Limex 5 t/ha | - | - | 48 | 68 |
| 13 | Limex 10 t/ha | - | - | 37 | 60 |
| 14 | Limex 15 t/ha | - | - | 34 | 60 |
| 15 | Perlka 400 kg/ha | - | - | 74 | 60 |
| 16 | HDC F125 | HDC F125 | HDC F125 2 | 51 | 49 |
| Fpr | - | - | - | <0.001 | 0.349 |

 

| | Timing 1 | Timing 2 | Timing 3 | Cavity spot incidence (%) | |
|---|---|---|---|---|---|
| | **Pre-drilling** | **4–6 weeks after drilling** | **4–6 weeks after Timing 2** | **Retford** | **STC** |
| SED | - | - | - | 9.5 | 9.28 |
| LSD | - | - | - | 19 | 18.64 |

At both sites, the calcium treatments (as Limex) showed trends for decreased cavity spot at the higher rates of application. At the Retford site, 15 t/ha of Limex was more effective than most of the foliar treatments apart from the SL567A control (Table 1). There were also significant effects on pH in the Limex treatments at the later assessments in both the STC and the Retford experiments, with a clearer rate effect at the later assessment. The higher Limex applications also increased available calcium. Perlka resulted in significantly higher cavity spot incidence than the untreated control at the Retford site.

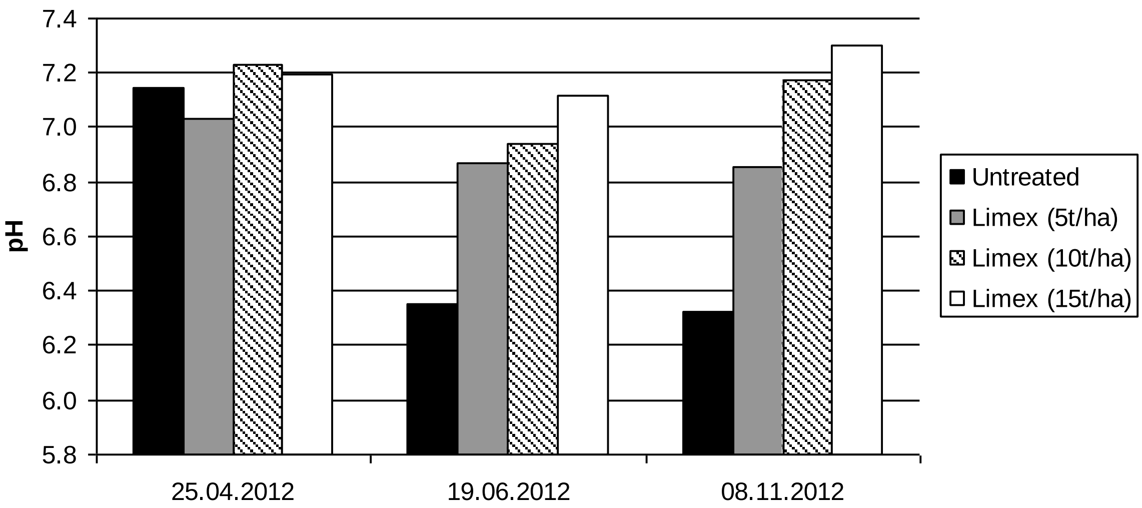


**Figure 1:** pH differences between treatments at the STC trial
25.04.2012: Fpr. 0.013; SED: 0.06; LSD: 0.12
19.06.2012: Fpr. 0.005; SED: 0.16; LSD: 0.09
08.11.2012: Fpr. <0.001; SED: 0.36; LSD: 0.20

 

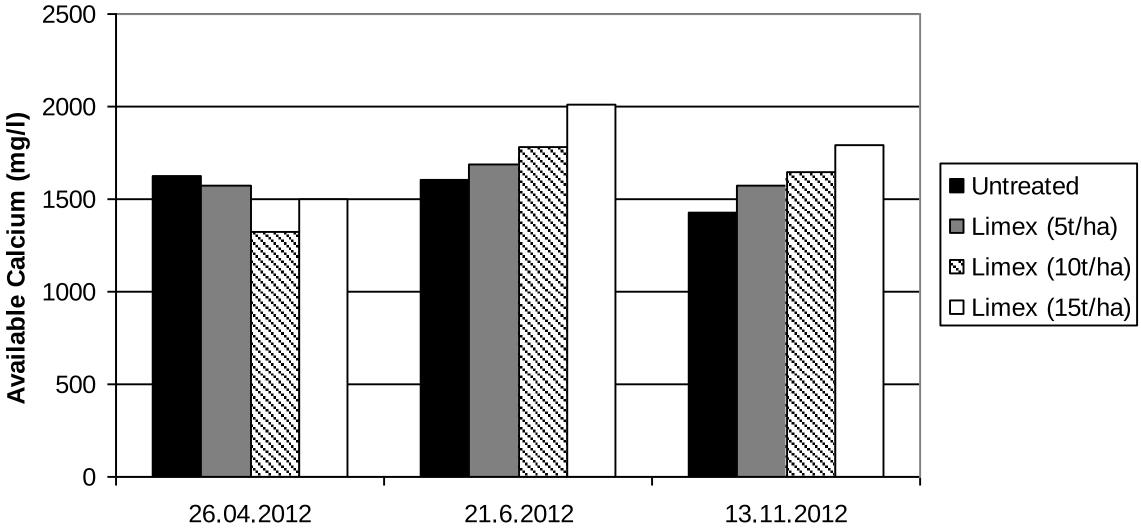


**Figure 2:** Available calcium at the STC site, in the untreated and Limex treatments
21.06.2012: Fpr: 0.541, SED: 208.4, LSD: 471.4
21.06.2012: Fpr: 0.005, SED: 86.3, LSD: 195.3
13.11.2012: Fpr: 0.243, SED: 165.8, LSD: 375.1

### *Tests for enhanced degradation of metalaxyl-M*

Soils from 25 commercial carrot crops and the two fungicide experiments were tested for enhanced degradation of metalaxyl-M. In 2012, none of the soils sampled showed very rapid degradation (half-life less than ten days) compared with 50% of samples from different fields in 2011. A total of nine soils had half-life values of between ten and thirteen days, and eleven soils had a half-life greater than 20 days. Metalaxyl-M treatments are likely to be more effective in soils with slower rates of degradation. The slower rates of degradation in 2012 may be due to effects on soil microbial populations in dry conditions that were evident up to the end of March 2012. The lack of cavity spot control at STC may be due to very wet conditions increasing the likelihood that the metalaxyl-M was washed out of the soil profile due to its high water solubility.

## Financial benefits

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

# SCIENCE SECTION

## Introduction

Carrot cavity spot is one of the most important diseases of carrots, causing UK losses of between £20 and £30 million according to Defra. In severe cases, growers have reported unmarketable crops of over 35%. Financial losses are particularly high when overwintered crops are lost. Current management of the disease relies on the use of partially resistant or tolerant varieties as well as 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 causal organism, *Pythium violae,* is able to utilise a wide range of crop and weed hosts. Whilst long rotations (e.g. one in six) 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 to explain variation in disease development, weather conditions are outside growers' 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. This shift in performance may relate to the poorer efficacy of the product due to enhanced degradation. 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*) and downy mildew (e.g. *Plasmopara viticola*) are candidates for cavity spot control. Screening of new products (mainly of 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 agrochemical 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 from methodology developed in FV 353. Measures of pathogen activity in relation to treatments were undertaken in collaboration with 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*); and HGCA work on oilseed rape (RD-2007-3373). Calcium applications can be made immediately prior to sowing (e.g. as Limex or Perlka). 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 tolerance or 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 was 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 or simply improve the level of control on the more resistant varieties through breeding and selection. 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 2 were:

1. To evaluate new fungicides and biological treatments with potential to control *Pythium* species in soil.
2. To establish optimum application rates and timings for the most promising new products.
3. To determine the contribution of pre-planting calcium applications for cavity spot control.
4. To determine the prevalence of enhanced degradation of metalaxyl-M in carrot growing areas.

## Materials and methods

### *Field experiments*

#### *1. Retford, Nottinghamshire*

This replicated field experiment, using a Chantenay variety for canning, was sown on 23 May 2012, seven days after soil treatments (Limex at three rates, Perlka and two of the coded products [as a high volume spray]) had been applied and incorporated. A cress test was done on soil from treatment HDC F125 and the untreated controls on 18 May to determine if it was safe to sow the carrots after this treatment. There were a total of sixteen treatments (Table 1) replicated four times in a randomised block design. Plots were a standard bed width (1.8 m) and 5 m in length, with the exception of treatments 5, 10 and 12–16 where soil incorporation was required for Limex, Perlka, HDC F51 and HDC F125. These soil incorporation plots were 10 m bed lengths with 2 m discards at each end to prevent movement of treatments into the next plot. Post-emergence treatments were applied on 11 June and 18 July. Soil samples were taken for routine soil analysis and pH and calcium tests, a metalaxyl-M degradation test and a *Pythium* soil test.

April and May were both very wet months with April 2012 having the highest rainfall since 1910. Therefore, conditions at drilling were very moist but not problematic as the trial was established on free draining sandy loam. The crop grew well in the wet conditions and regular assessments of crop vigour were made (1–9 score). Carrot samples were taken regularly (6 and 21 August, 6 September and 18 October from control plots) and examined for cavity spot.

Additional soil samples were taken from all the control plots and Limex treatments on 17 May, 19 June and 8 November for pH and extractable (= free) calcium analyses. Soil samples for *Pythium* tests were taken from control plots on 11 June and all plots on 6 August.

The final harvest on 14 November 2012 was delayed as long as possible to allow the highest possible level of cavity spot incidence. Harvest yields were based on a harvested area of 2 m x 1 m at the centre of the bed. Cavity spot assessments were done on 50 roots per plot. Site details are given in Appendix 3.

**Table 2.** Treatments for cavity spot control in 2012

| | **Timing 1**<br>**Pre-drilling** | **Timing 2**<br>**4–6 weeks after drilling** | **Timing 3**<br>**4–6 weeks after Timing 2** |
|---|---|---|---|
| 1 | Untreated | Untreated | Untreated |
| 2 | Standard | SL567A<br>(1.3 L/ha) | - |
| 3 | | HDC F50 | - |
| 4 | | HDC F52 | |
| 5 | HDC F51 | - | - |
| 6 | | HDC F53 | |
| 7 | | SL567A<br>(0.65 L/ha) | SL567A<br>(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 250 kg/ha | - | - |
| 16 | HDC F125 | HDC F125 | HDC F125 |

### *2. STC, Yorkshire*

This replicated field experiment was sown with a susceptible Nantes cultivar on 14 May 2012, after soil treatments (Limex at three rates, Perlka, HDC F51 and HDC F125) had been applied and incorporated on 24 April. Treatments were identical to those at Retford (Table 2) and post-emergence sprays were applied on 25 June and 2 August. Plot sizes were 10 m of bed length where incorporation of treatments (plus 2 m guard at each end) was required and 5 m 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.

As with the Nottinghamshire site, the trial established adequately and grew well throughout the growing season despite the low solar radiation levels. The wet weather continued until harvest, thus eliminating the need for irrigation. Regular assessments were made of any phytotoxicity symptoms and foliar disease. Carrot samples were taken from control plots on 4 September and 7 November to monitor progression of cavity spot.

Additional soil samples were taken from all the control plots and Limex treatments on 19 June and 8 November for pH and extractable (= free) calcium analyses. Soil samples for *Pythium* tests were taken from all plots on 5 October.

The final harvest was delayed as long as possible to allow the maximum possible cavity spot incidence. Harvest yields were based on a harvested area of 2 m x 2 rows at the centre of the bed. Cavity spot assessments were done on 100 roots per plot on 20–21 November 2012. Site details are given in Appendix 4.

### *3. Metalaxyl-M degradation*

**Sampling for Degradation Study 2012**

During the spring of 2012, representative soil samples of approximately 1 kg in weight were collected from each of 25 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. Ten 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 two batches. Batch 1 contained fourteen soils and Batch 2 contained thirteen soils. 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 an 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 SL567A (Syngenta) 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, 5, 11, 18 and 25 days after treatment 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 absorption 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*

**Overall**

This year (2012), levels of disease were considerably higher than those seen in 2011, with a cavity spot incidence of 55% in the untreated control. The site was classified as showing relatively rapid degradation of metalaxyl-M with a half-life of 12.6 days.

**Cavity spot**

Three treatments had significantly less cavity spot than the untreated control. The most effective was SL567A (metalaxyl-M) applied at 0.65 L/ha at both T2 and T3 timings. This had 19% of roots with cavity spot (65% control) whilst a single full rate of SL567A, (1.3 L/ha) at T2 timing was very similar with 20% cavity spot. But, in this case, just one 1.3 L/ha dose was applied at T2 (Table 3). There was a trend for decreased incidence of cavity spot with increasing rates of Limex, though only the highest rate Limex (15 t/ha) gave significant control. All treatments, except Perlka 400, showed a trend for lower cavity spot incidence than the untreated control. The increased incidence of cavity spot in the Perlka treatment was a significant effect. In contrast to the yield results, it was noted that increasing the Limex dose has a slight cavity spot reducing effect.

Only small numbers of cavity spot lesions were found on affected roots and disease severity data (percentage root area affected) showed similar effects to those identified for the incidence data. The Perlka treatment had a significantly greater area affected than the control (Table 3). The other treatments had no significant effects on the root area affected by cavity spot. The split dose of SL567A showed significantly fewer cavity spot lesions on affected roots than the untreated (Table 3).

 

**Table 3.** Incidence and severity of cavity spot at harvest, Retford site, 2012

| | Timing 1 | Timing 2 | Timing 3 | % roots with cavity spot | % root area (all carrots) | % root area (infected carrots) | Cavities per infected carrot |
|---|---|---|---|---|---|---|---|
| | **Pre-drilling** | **4–6 weeks after drilling** | **4–6 weeks after Timing 2** | | | | |
| 1 | Untreated | Untreated | Untreated | 55 | 0.39 | 1.4 | 2.4 |
| 2 | Standard | SL567A (1.3 L/ha) | - | 20 | 0.04 | 0.3 | 1.8 |
| 3 | | HDC F50 | - | 51 | 0.38 | 1.8 | 2.3 |
| 4 | | HDC F52 | | 55 | 0.31 | 1.1 | 2.3 |
| 5 | HDC F51 | - | - | 40 | 0.30 | 1.5 | 2.4 |
| 6 | | HDC F53 | | 47 | 0.50 | 2.4 | 2.3 |
| 7 | | SL567A (0.65 L/ha) | SL567A (0.65 L/ha) | 19 | 0.06 | 0.4 | 1.4 |
| 8 | | HDC F50 | HDC F50 | 53 | 0.52 | 2.1 | 2.3 |
| 9 | | HDC F52 | HDC F52 | 49 | 0.53 | 2.1 | 2.2 |
| 10 | HDC F51 | HDC F51 | | 43 | 0.24 | 1.1 | 2.5 |
| 11 | | HDC F53 | HDC F53 | 42 | 0.24 | 1.1 | 2.0 |
| 12 | Limex 5 t/ha | - | - | 48 | 0.38 | 1.6 | 2.4 |
| 13 | Limex 10 t/ha | - | - | 37 | 0.40 | 2.4 | 1.9 |
| 14 | Limex 15 t/ha | - | - | 34 | 0.219 | 1.2 | 1.9 |
| 15 | Perlka 400 kg/ha | - | - | 74 | 1.70 | 4.3 | 3.2 |
| 16 | HDC F125 | HDC F125 | HDC F125 | 51 | 0.75 | 3.1 | 2.6 |
| Fpr | - | - | - | <0.001 | <0.001 | 0.004 | 0.015 |
| SED (45df) | - | - | - | 9.5 | 0.283 | 0.8 | 0.4 |
| LSD | - | - | - | 19 | 0.570 | 1.7 | 0.7 |

**Treatment effects upon Cercospora leaf blight**

Other impacts of treatments included a significant increase in Cercospora leaf blight in the Perlka treatment. HDC F50 (Treatment 8) showed a trend for lower Cercospora leaf blight but this was not a significant effect (Table 4). The increase in foliar disease was associated with increased early lodging which was most apparent in the Perlka treated plots from August onwards. An assessment on 6 September 2012 showed lodging was quite severe in the Perlka plots (Table 4), but did not increase subsequently in the Perlka treatment. The later lodging assessment on the 18 October 2012 showed no significant treatment differences.

 

**Table 4.** Cercospora leaf blight and foliar lodging assessments, Retford site, 2012

| | Timing 1 | Timing 2 | Timing 3 | Cercospora % leaf area affected 18/10/2012 | Lodging % area 6/9/12 | Lodging % area 18/10/12 |
|---|---|---|---|---|---|---|
| | **Pre-drilling** | **4–6 weeks after drilling** | **4–6 weeks after Timing 2** | **-** | **-** | **-** |
| 1 | Untreated | Untreated | Untreated | 16 | 0.0 | 35.2 |
| 2 | Standard | SL567A (1.3 L/ha) | - | 19 | 2.5 | 56.2 |
| 3 | | HDC F50 | - | 21 | 0.0 | 33.2 |
| 4 | | HDC F52 | | 18 | 0.0 | 53.8 |
| 5 | HDC F51 | - | - | 16 | 1.3 | 37.5 |
| 6 | | HDC F53 | | 30 | 0.0 | 73.8 |
| 7 | | SL567A (0.65 L/ha) | SL567A (0.65 L/ha) | 33 | 4.3 | 66.2 |
| 8 | | HDC F50 | HDC F50 | 11 | 0.0 | 45.0 |
| 9 | | HDC F52 | HDC F52 | 19 | 0.3 | 51.8 |
| 10 | HDC F51 | HDC F51 | | 16 | 0.0 | 63.8 |
| 11 | | HDC F53 | HDC F53 | 31 | 0.0 | 48.8 |
| 12 | Limex 5 t/ha | - | - | 20 | 0.0 | 50.8 |
| 13 | Limex 10 t/ha | - | - | 21 | 0.5 | 78.8 |
| 14 | Limex 15 t/ha | - | - | 28 | 0.0 | 73.8 |
| 15 | Perlka 400 kg/ha | - | - | 64 | 59.0 | 57.5 |
| 16 | HDC F125 | HDC F125 | HDC F125 | 13 | 0.0 | 40.0 |
| Fpr | - | - | - | <0.001 | <0.001 | NS (0.098) |
| SED (45df) | - | - | - | 8.3 | 1.6 | 15.64 |
| LSD | - | - | - | 17 | 3.2 | 31.49 |

The vigour assessment on 6 August showed that Perlka, Limex 5 t/ha, Limex 10 t/ha and Limex 15 t/ha had increased leaf growth significantly (Table 5). At the October assessment, there were no significant differences in vigour between treatments (Table 5).

 

**Table 5.** Vigour scores for Retford site, 2012

| | Timing 1 | Timing 2 | Timing 3 | Vigour 6/8/12 | Vigour 18/10/12 |
|---|---|---|---|---|---|
| | Pre-drilling | 4–6 weeks after drilling | 4–6 weeks after Timing 2 | - | - |
| 1 | Untreated | Untreated | Untreated | 7.6 | 5.3 |
| 2 | Standard | SL567A (1.3 L/ha) | - | 8.0 | 5.5 |
| 3 | | HDC F50 | - | 7.9 | 5.3 |
| 4 | | HDC F52 | | 8.0 | 5.3 |
| 5 | HDC F51 | - | - | 7.8 | 5.5 |
| 6 | | HDC F53 | | 7.9 | 4.5 |
| 7 | | SL567A (0.65 L/ha) | SL567A (0.65 L/ha) | 7.9 | 5.0 |
| 8 | | HDC F50 | HDC F50 | 7.8 | 5.5 |
| 9 | | HDC F52 | HDC F52 | 7.8 | 5.5 |
| 10 | HDC F51 | HDC F51 | | 7.9 | 5.8 |
| 11 | | HDC F53 | HDC F53 | 8.0 | 5.3 |
| 12 | Limex 5 t/ha | - | - | 7.9 | 5.8 |
| 13 | Limex 10 t/ha | - | - | 8.1 | 5.3 |
| 14 | Limex 15 t/ha | - | - | 8.1 | 5.8 |
| 15 | Perlka 400 kg/ha | - | - | 9.0 | 4.8 |
| 16 | HDC F125 | HDC F125 | HDC F125 | 7.9 | 5.8 |
| Fpr | - | - | - | <0.001 | NS (0.60) |
| SED (45 df) | - | - | - | 0.1 | 0.5 |
| LSD | - | - | - | 0.3 | 1.1 |

**Pythium results**

*Pythium* results are based on presence or absence of *Pythium* DNA in extracts from soil samples. A score of 1 indicates that *Pythium* was detected in all four replicates whilst a score of 0.25 indicates *Pythium* was found in only one of the four replicates. No *Pythium* DNA was identified in samples taken on 11 June. At the 6 August assessment, *Pythium* DNA was identified in many of the plots and treatment differences approached significance (P=0.089) (Table 6). The greatest number of positive results were found in the untreated, HDC F50 (Tr3), HDC F53 (Tr6), Limex 15 t/ha and the HDC F125 treatments. The treatments that had the lowest levels of *Pythium* were single applications of SL567A (Tr2), HDC F52 (Tr4), and Limex 10 t/ha.

 

**Table 6.** Pythium DNA results Retford site, 2012

| Tr. | Timing 1<br>Pre-drilling | Timing 2<br>4–6 weeks after drilling | Timing 3<br>4–6 weeks after Timing 2 | -<br>Pythium score |
|---|---|---|---|---|
| 1 | Untreated | Untreated | Untreated | 1.00 |
| 2 | Standard | SL567A (1.3 L/ha) | - | 0.25 |
| 3 | | HDC F50 | - | 1.00 |
| 4 | | HDC F52 | | 0.25 |
| 5 | HDC F51 | - | - | 0.75 |
| 6 | | HDC F53 | | 1.00 |
| 7 | | SL567A (0.65 L/ha) | SL567A (0.65 L/ha) | 0.75 |
| 8 | | HDC F50 | HDC F50 | 0.75 |
| 9 | | HDC F52 | HDC F52 | 0.75 |
| 10 | HDC F51 | HDC F51 | | 0.75 |
| 11 | | HDC F53 | HDC F53 | 0.75 |
| 12 | Limex 5 t/ha | - | - | 0.50 |
| 13 | Limex 10 t/ha | - | - | 0.25 |
| 14 | Limex 15 t/ha | - | - | 1.00 |
| 15 | Perlka 400 kg/ha | - | - | 0.50 |
| 16 | HDC F125 | HDC F125 | HDC F125 | 1.00 |
| Fpr | - | - | - | 0.089 |
| SED (45df) | - | - | - | 0.302 |
| LSD | - | - | - | 0.608 |

*Yield*

There were no significant effects on yield (Table 7). The highest yield was recorded in the lowest rate Limex (5 t/ha).

**Table 7.** Yield at the Nottinghamshire site

| | Timing 1 | Timing 2 | Timing 3 | Plot yield ($kg/m^2$) | Marketable yield (t/ha) |
|---|---|---|---|---|---|
| | Pre-drilling | 4–6 weeks after drilling | 4–6 weeks after Timing 2 | - | |
| 1 | Untreated | Untreated | Untreated | 9.8 | 97 |
| 2 | Standard | SL567A (1.3 L/ha) | - | 10.0 | 101 |
| 3 | | HDC F50 | - | 9.5 | 94 |
| 4 | | HDC F52 | | 9.2 | 92 |
| 5 | HDC F51 | - | - | 9.7 | 96 |
| 6 | | HDC F53 | | 9.7 | 97 |
| 7 | | SL567A (0.65 L/ha) | SL567A (0.65 L/ha) | 10.0 | 100 |
| 8 | | HDC F50 | HDC F50 | 10.0 | 102 |
| 9 | | HDC F52 | HDC F52 | 9.8 | 97 |
| 10 | HDC F51 | HDC F51 | | 9.9 | 98 |
| 11 | | HDC F53 | HDC F53 | 10.0 | 100 |
| 12 | Limex 5 t/ha | - | - | 11.0 | 105 |
| 13 | Limex 10 t/ha | - | - | 9.5 | 95 |
| 14 | Limex 15 t/ha | - | - | 9.0 | 90 |
| 15 | Perlka 400 kg/ha | - | - | 9.5 | 94 |
| 16 | HDC F125 | HDC F125 | HDC F125 | 9.7 | 96 |
| Fpr | - | - | - | NS (0.90) | NS (0.90) |
| SED | - | - | - | 0.8 | 7.7 |
| LSD | - | - | - | 1.5 | 15 |

**HDC F125 effects on germination**

Seeds from two species of cress were used in a 'cress test' to determine if there was satisfactory germination after the application of HDC F125. This was to ensure that treated areas did not impact on seed germination. The cress test was done two days after treatment and showed 100% germination of garden cress (*Lepidium sativum)* in both treated and untreated soil after three days. However, land cress (*Barbarea vena)* showed a large difference indicating treatment effects, with the untreated having 77% germination and the treated just 4%.

The plots were sown seven days after soil treatment incorporation and no significant effects were found in the crop subsequently. Plant counts done on both the untreated and the HDC F125 treatment on the 6 August 2012 showed no significant differences, though the treated had a lower plant count, this was only 5% lower (52 plants/$m^2$) than the untreated control (900 plants/$m^2$).

**In season disease progress**

Samples were taken from the untreated control plots to monitor disease progress at the Retford site. At the first assessment (13 August) cavity spot incidence was just 0.5% in the untreated controls. At the second assessment on 21 August 5% of roots were affected and the incidence had increased to 8% (by 7 September) in the untreated. By 18 October, the incidence had increased dramatically to 46.5%, with average severity being 1.6% area affected. Further development was limited and 55% of roots were affected at harvest on 14 November.

**pH results**

A series of three pH analyses were conducted on the three Limex treatments in order to quantify the treatment effects on soil acidity. There were no significant pH differences pre-drilling (P=0.50) between any of the treatments (pH range 7.16–7.33). Post drilling on 19 June, there still was no significance between treatments (P=0.15), although the pH was higher than the untreated after all the Limex treatments. The pre-harvest pH results were significantly different (P=0.03), with Limex at 10 t/ha showing a significantly higher pH than the untreated (Fig. 3).

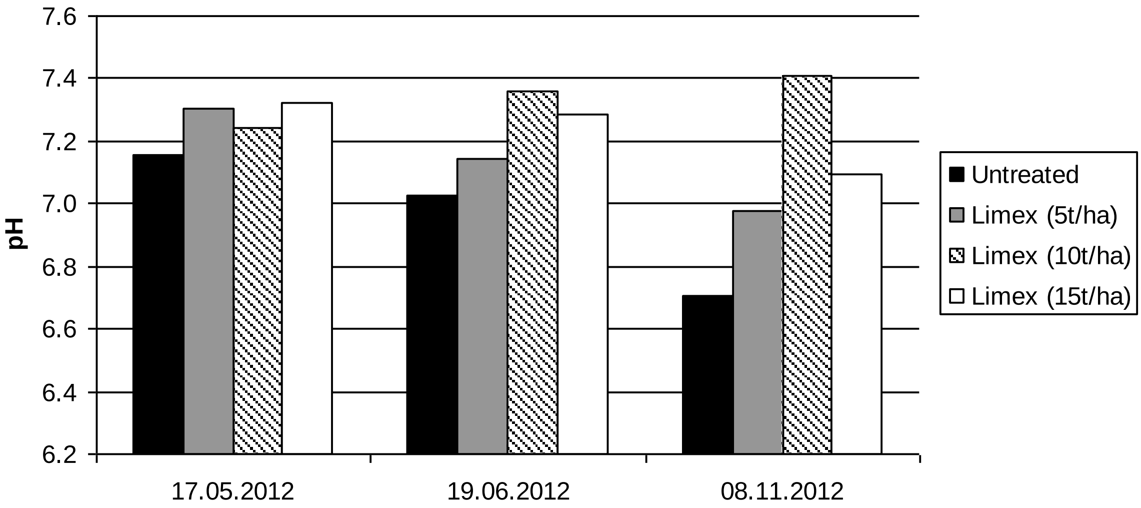


**Figure 3.** pH samples taken from the Limex and untreated plots at the Retford Site
17.05.2012: Fpr. 0.50 (NS); SED: 0.11; LSD: 0.26
19.06.2012: Fpr. 0.15 (NS); SED: 0.14; LSD: 0.32
08.11.2012: Fpr. 0.03; SED: 0.19; LSD: 0.43

**Available calcium**

Available calcium was increased by all the Limex treatments at the three sampling times (Fig. 4). There was no significant difference between treatments at the first sampling date in May, however there were significant differences at the later assessment in June, with the untreated having significantly less available calcium than Limex treatments at 10 t/ha and the 15 t/ha. There were no significant differences between treatments at the November assessment.

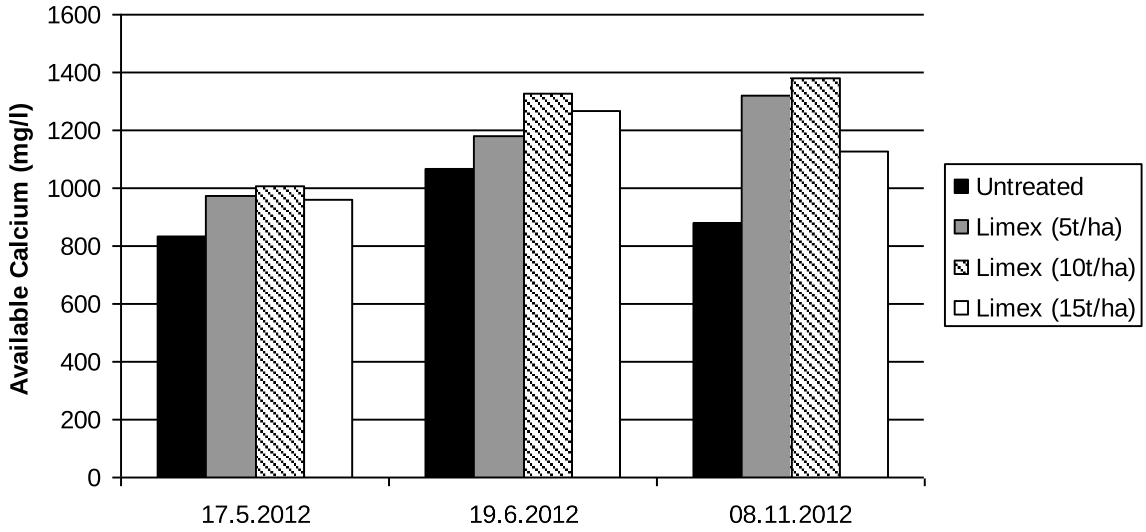


**Figure 4.** Available calcium, at two assessment dates, for the untreated control and the Limex treatments.
17/5/12: FPr 0.205, SED 78.4, LSD 177.3
19/6/12: Fpr 0.041, SED 81.3, LSD 187.5
08/11/12: Fpr 0.243 (NS), SED 165.8, LSD 375.1

**Total calcium**

Total calcium levels were greater in the Limex treatments than the untreated at the end of the season, but the differences were not significant at the Retford site (Fig. 5).

**Weather**

The site experienced a dry winter and was under threat of drought until there was above average rainfall in April. May had limited rainfall after sowing but there was frequent rain in June, July, mid to late August, September and October. The two weeks after the T1 and drilling saw some rainfall, with over 6 mm being recorded and warm soil temperatures, over 17°C on average. June was the wettest month, with nearly 129 mm being recorded, with above average rainfall being found for the rest of the summer and the autumn. Disease development is strongly influenced by soil moisture, so the wetter conditions seen this year have resulted in high levels of disease.

 

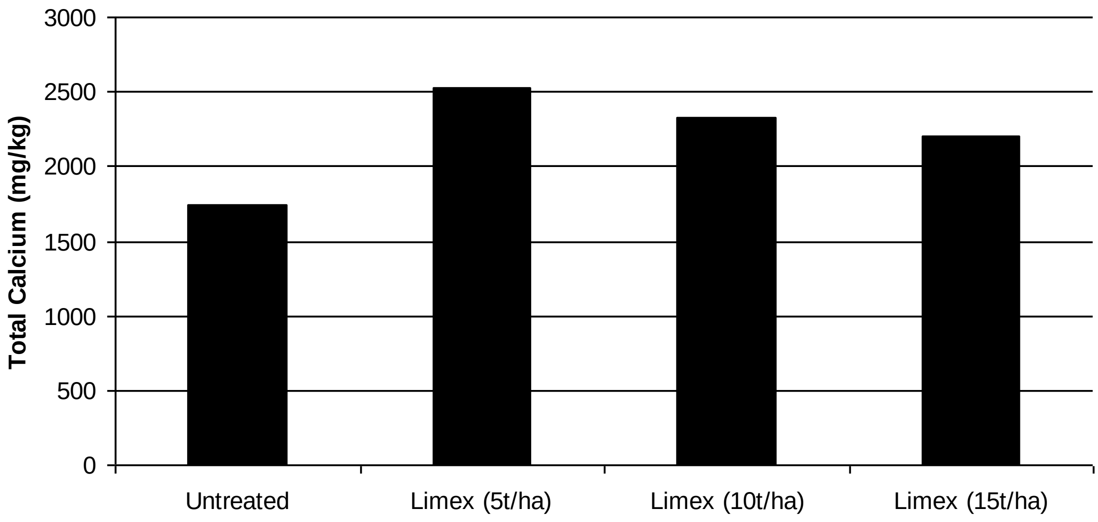


**Figure 5.** Total calcium for the untreated control and the Limex treatments, Retford site 08 November 2012.
Fpr 0.346 (NS), SED 420.1, LSD 950.4

### *2. STC, Yorkshire*

**Overall**

As with the Nottingham trial, levels of disease were considerably higher than seen in 2011, with cavity spot incidence of 64.8% in the untreated at harvest on 20 November. Cavity spot incidence was present on 40% of untreated roots on 4 September and 54% of roots on 7 November. The site was classified as being relatively slow for degradation of metalaxyl-M with a half-life of 26.3 days.

**Cavity spot**

No significant treatment effects upon cavity spot incidence were detected (P=0.349). Only three of the treatments showed cavity spot incidence that was at least 10% lower than the untreated. These were full dose SL567A, HDC F53 and HDC F125 (Table 8). There were trends for the increasing rates of Limex to decrease cavity spot severity. This was partly due to carrots in the higher rate treatments having fewer cavity spot lesions per root (Table 8). Soil moisture levels were very high at this site because of the high water table. Cavity spot may therefore have developed and proliferated in response to the very wet conditions with late infection masking any early control that may have been achieved.

 

**Table 8.** Cavity spot incidence and severity, STC 2012

| | Timing 1 | Timing 2 | Timing 3 | % roots with cavity spot | % root area affected (all carrots) | % root area affected (infected carrots) | Cavities per infected carrot |
|---|---|---|---|---|---|---|---|
| | **Pre-drilling** | **4–6 weeks after drilling** | **4–6 weeks after Timing 2** | | | | |
| 1 | Untreated | Untreated | Untreated | 65 | 4.69 | 7.0 | 4.8 |
| 2 | Standard | SL567A (1.3 L/ha) | - | 55 | 4.06 | 7.3 | 4.7 |
| 3 | | HDC F50 | - | 65 | 4.88 | 7.5 | 5.8 |
| 4 | | HDC F52 | | 78 | 6.92 | 8.7 | 6.1 |
| 5 | HDC F51 | - | - | 68 | 6.44 | 9.4 | 5.9 |
| 6 | | HDC F53 | | 55 | 4.03 | 6.4 | 4.8 |
| 7 | | SL567A (0.65 L/ha) | SL567A (0.65 L/ha) | 60 | 4.81 | 7.6 | 5.3 |
| 8 | | HDC F50 | HDC F50 | 63 | 4.67 | 7.1 | 5.7 |
| 9 | | HDC F52 | HDC F52 | 69 | 5.46 | 7.6 | 5.2 |
| 10 | HDC F51 | HDC F51 | | 62 | 4.77 | 8.1 | 5.2 |
| 11 | | HDC F53 | HDC F53 | 62 | 3.45 | 5.6 | 4.9 |
| 12 | Limex 5 t/ha | - | - | 68 | 5.70 | 8.1 | 5.5 |
| 13 | Limex 10 t/ha | - | - | 60 | 4.32 | 7.3 | 4.4 |
| 14 | Limex 15 t/ha | - | - | 60 | 2.16 | 3.6 | 3.5 |
| 15 | Perlka 400 kg/ha | - | - | 57 | 3.87 | 6.9 | 5.3 |
| 16 | HDC F125 | HDC F125 | HDC F125 | 49 | 2.40 | 5.3 | 4.2 |
| Fpr | - | - | - | NS (0.349) | NS (0.412) | NS (0.676) | NS (0.206) |
| SED | min.rep<br>max–min* | - | - | 9.28<br>8.03 | 1.74<br>1.507 | 2.201<br>1.906 | 0.831<br>0.72 |
| LSD | min.rep<br>max–min* | - | - | 18.64<br>16.14 | 3.496<br>3.028 | 4.423<br>3.831 | 1.67<br>1.447 |

* Max–min values are for untreated vs treatment comparisons

**Yield**

There were no significant yield differences between treatments (Table 9). Seven treatments showed lower yields than the untreated control. The highest yield (8.6 kg/m$^2$) was in the HDC F125 treatment at 6.98 kg/m$^2$, and there were positive trends with SL57A, HDC F53 and Limex (10 t/ha) (Table 9).

 

**Table 9.** Plot yields at STC, 2012

| | Timing 1 | Timing 2 | Timing 3 | Yield (kg/m$^2$) |
|---|---|---|---|---|
| | Pre-drilling | 4–6 weeks after drilling | 4–6 weeks after Timing 2 | |
| 1 | Untreated | Untreated | Untreated | 7.9 |
| 2 | Standard | SL567A (1.3 L/ha) | - | 8.3 |
| 3 | | HDC F50 | - | 7.0 |
| 4 | | HDC F52 | | 7.8 |
| 5 | HDC F51 | - | - | 7.6 |
| 6 | | HDC F53 | | 7.0 |
| 7 | | SL567A (0.65 L/ha) | SL567A (0.65 L/ha) | 8.2 |
| 8 | | HDC F50 | HDC F50 | 8.0 |
| 9 | | HDC F52 | HDC F52 | 7.5 |
| 10 | HDC F51 | HDC F51 | | 8.0 |
| 11 | | HDC F53 | HDC F53 | 8.5 |
| 12 | Limex 5 t/ha | - | - | 7.9 |
| 13 | Limex 10 t/ha | - | - | 8.4 |
| 14 | Limex 15 t/ha | - | - | 7.6 |
| 15 | Perlka 400 kg/ha | - | - | 7.2 |
| 16 | HDC F125 | HDC F125 | HDC F125 | 8.6 |
| Fpr | - | - | - | NS (0.239) |
| SED | min.rep<br>max–min* | - | - | 1.229<br>1.064 |
| LSD | min.rep<br>max–min* | - | - | 2.47<br>2.14 |

*Max-min values are for untreated v treatment comparisons

**pH results**

The soil pH analyses were done on 24 April (pre-drilling), 19 June (post-drilling) and 8 November (pre-harvest) on the three Limex treatments and untreated controls in order to quantify the treatment effects on soil acidity. At all three sample timings, significant differences were identified between treatments, with the differences becoming more marked at the later samplings. At the post-drilling and pre-harvest samples significant differences were found between the untreated and all the Limex treatments (Figure 6). At the post-drilling timing, there were no differences between the individual Limex treatments. However at the pre-harvest sample, there was a significant difference between the 5 t/ha and the 10 t/ha rates of application. The differences in the untreated soil pH between samples may be due to variations in soil moisture (ideally soils should be moist when sampled but the soil was very wet at this site later in the season).

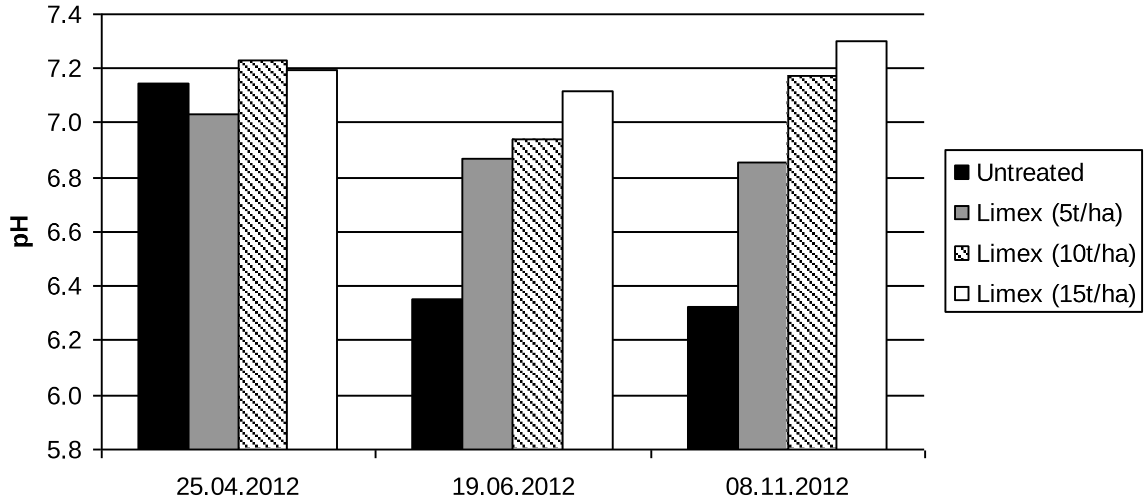


**Figure 6.** pH differences between treatments at the STC trial
25.04.2012: Fpr. 0.013; SED: 0.06; LSD: 0.12
19.06.2012: Fpr. 0.005; SED: 0.16; LSD: 0.09
08.11.2012: Fpr. <0.001; SED: 0.36; LSD: 0.20

### Free calcium

Available calcium was consistently higher where Limex treatments had been applied but the differences were not significant (Figure 77).

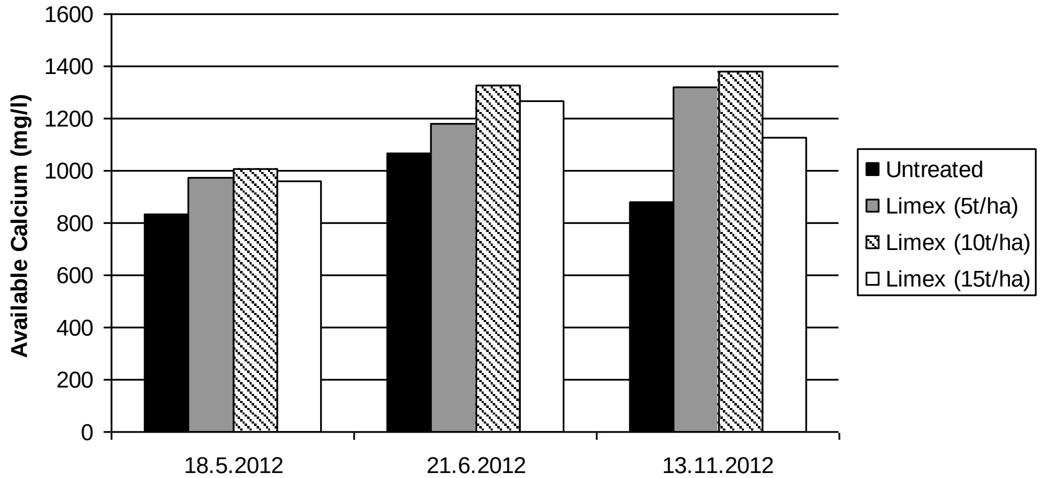


**Figure 7.** Available calcium at the STC site, in the Untreated, Limex 5 t/ha, Limex 10 t/ha and Limex 15 t/ha
18.05.2012: Fpr: 0.205 (NS), SED: 78.4, LSD: 177.3
21.06.2012: Fpr: 0.083 (NS), SED: 89.2, LSD: 201.8
13.11.2012: Fpr: 0.075 (NS), SED: 178.3, LSD: 403.4

 

**Total calcium**

Total calcium levels were significantly different between treatments at the STC site, with the 15 t/ha Limex dose producing significantly greater calcium levels compared to the other treatments (Figure 88).

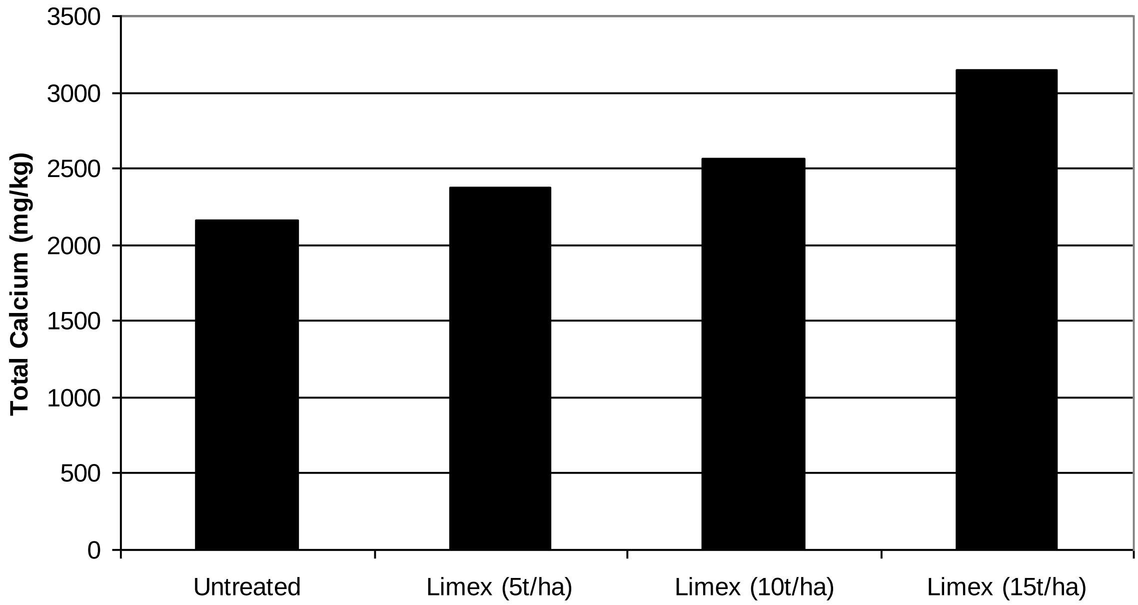


**Figure 8.** Total calcium in the untreated and Limex treatments at the STC site 8 November 2012.
Fpr: 0.003, SED: 188.8, LSD: 427.2

## *3. Metalaxyl-M degradation*

**Metalaxyl half-life**

Half-lives of metalaxyl-M degradation were measured at various sites, with a range of degradation rates being identified. Soil sample 17 (Figure 9) is an example of a fast degrading soil with a half-life of 12.5 days. In contrast, Figure 10 shows an example of a slow degrading soil with a half-life of over 90 days.

Soils from 25 commercial carrot crops and the two fungicide experiments were tested for enhanced degradation of metalaxyl-M. This year none of the soils sampled showed very rapid degradation (half-life less than ten days) compared with 50% of samples in 2011. A total of nine soils had half-life values of between ten and thirteen days, and eleven soils had a half-life greater than twenty days. Metalaxyl-M treatments are likely to be more effective in soils with slower rates of degradation. The slower rates of degradation in 2012 may be due to effects on soil microbial populations in dry conditions that were evident up to the end of March 2012.

 

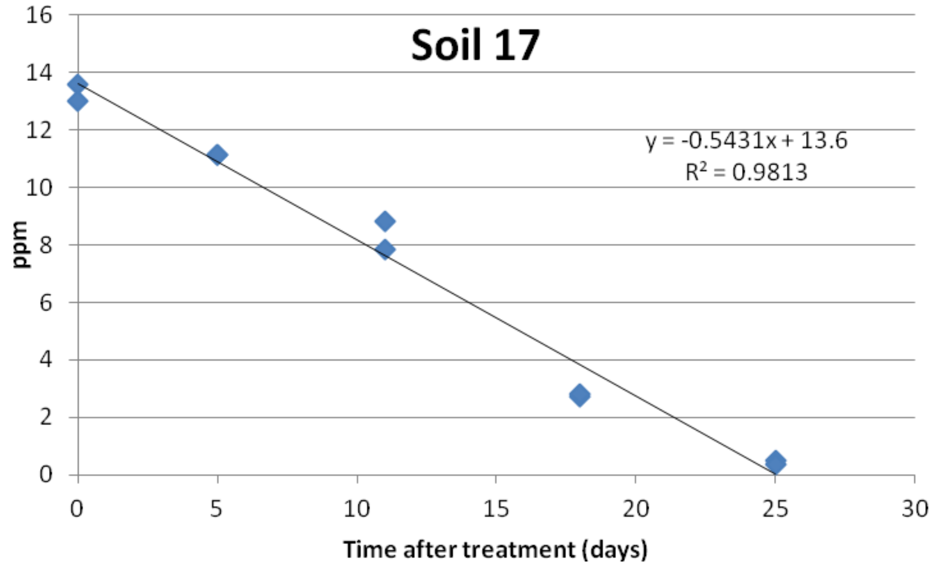

**Figure 9.** Example of plot of 'fast' degrading soil for metalaxyl-M

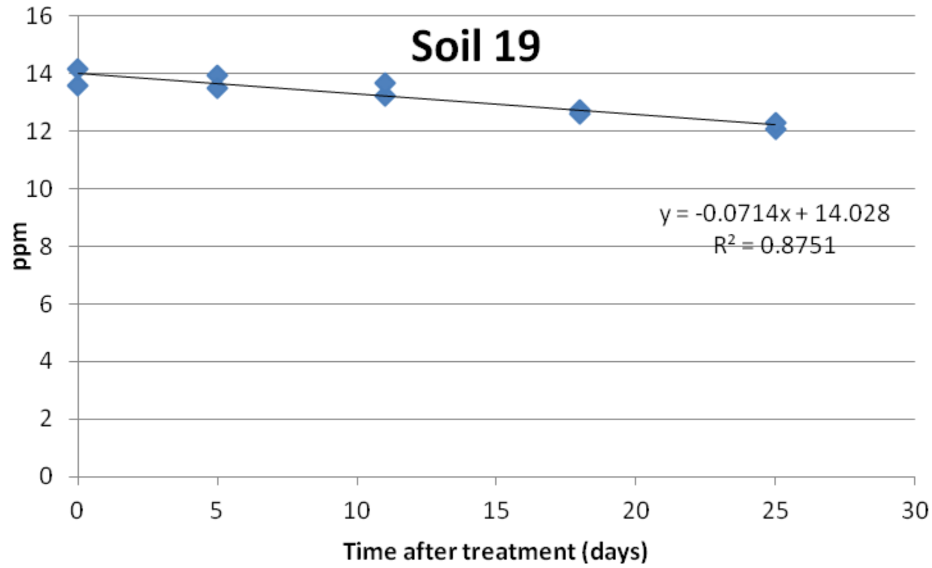

**Figure 10.** Example of plot of 'slow' degrading soil for metalaxyl-M

Half-lives were plotted against the measured soil pH (Figure 611) and soil organic content (Figure 72) values. There is a weak correlation between half-life and pH with half-life appearing to increase with increasing pH. However, this is a tentative relationship that requires examination of other site factors such as previous cropping and metalaxyl-M usage histories. There is little evidence of any correlation between organic content and half-life.

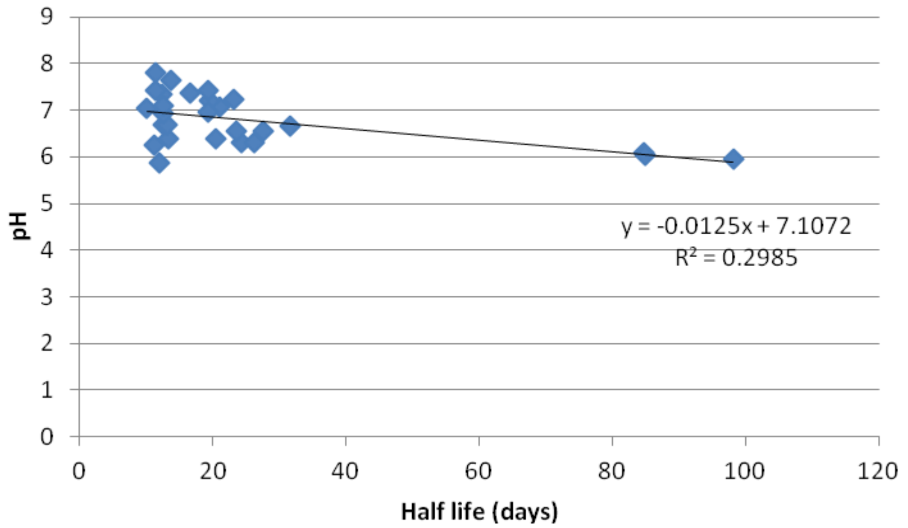


**Figure 6.** Soil pH vs metalaxyl-M half-life

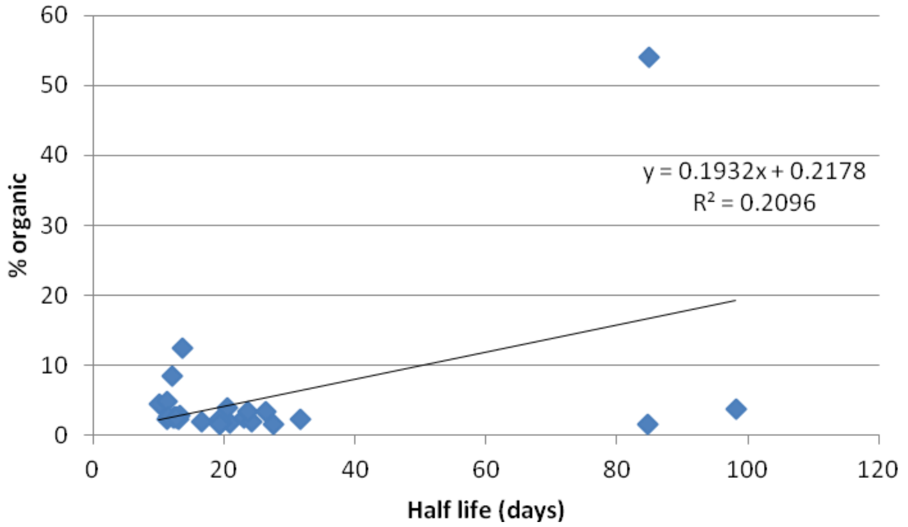


**Figure 72.** Soil organic content vs metalaxyl-M half-life

## Discussion

Climatically, the 2012 growing season was part of an unusual year with a dry spring and threatening drought until high rainfall arrived in April, and then above average rainfall through to harvest. Sunlight was notably lower than average in late spring, decreasing yields of both arable and horticultural crops. Both trials established well and went on to achieve reasonable yields. Cavity spot levels were as high as might be anticipated in the prevailing moist conditions (ref HDC project FV 353), and should have allowed good comparison of test products.

Metalaxyl-M gave the best cavity spot control at the Retford site in Nottinghamshire, despite soil at this site showing quite rapid degradation rates in laboratory tests (Davison & McKay, 1999). This could well have been a consequence of the extreme weather patterns influencing the soil microflora and pathogens at the site. The slightly extended half-life times observed in 2012 compared with 2011 could be the result of adverse effects of drought conditions on the soil organisms that degrade metalaxyl-M. In addition *P. violae* populations might also have declined in dry conditions and taken more time than usual to become active within the carrot crop. Actively growing *P. violae* is considered important if metalaxyl-M is going to be effective (see HDC project FV 353). Fungicides often require moisture to move within the soil profile and within plants. Metalaxyl-M is highly soluble and moist conditions (within ten weeks of sowing) may positively affect performance.

Metalaxyl-M degradation samples were taken from soils at the field experiment sites, as well as from various commercial fields. A previous study (Kenny *et al*, 2001) associated a half-life of metalaxyl of less than ten days in laboratory tests with failure to control cavity spot in carrots, with the longer half-life indicating a better chance of control. In the samples taken in 2012, metalaxyl-M half-life was not less than ten days in any soils, but was between ten and thirteen days in nine soils. It is reasonable to assume that metalaxyl-M was likely to provide partial control of cavity spot in these soils with rapid degradation. In eleven soils the half-life was greater than twenty days (greater than 80 days in three of these soils) and it is equally reasonable to assume that metalaxyl-M should have been rather more effective in these soils.

Weather conditions can play a big part in pesticide degradation with rates increasing with soil moisture content and temperature, with very wet soils likely to decrease metalaxyl-M persistence. Soils were very wet at the STC site and this may therefore explain the lack of control compared with the Retford site that was on a lighter soil type. Soil moisture extremes may therefore be more influential for fungicide performance than differences in rates of metalaxyl-M degradation given that the Retford site had a lower half-life (12.6 days) and the STC site having the highest half-life (26.3 days).

Cavity spot did not affect commercial crops until very late in the autumn or until early in 2013 and in general disease levels in commercial crops were below average unusually. The high rainfall might have been expected to give high risk conditions for cavity spot. However, the impact of the previous dry weather in 2011 and up to the end of March may have contributed to improved persistence of metalaxyl-M (longer half-life) and decreased inoculum of *P.violae* surviving on plant hosts in previous crops. Varieties with partial resistance to cavity spot are used for most commercial crops and cavity spot levels are therefore likely to be lower than in the experiments using susceptible varieties.

The new products in these experiments applied at manufacturers recommended rates for 'blight' control in potato did not give control of cavity spot in carrots. The rate of metalaxyl-M for cavity spot control is eight times the foliar application rate for late blight control. Further testing of the new products at higher rates is proposed for 2013.

The use of Limex (calcium) treatments just before sowing in 2011 showed some promising trends, and in the 2012 experiments similar patterns were seen again. Limex gave promising trends at both sites compared to most foliar treatments, with a dose responses being identified between 5 t/ha, 10 t/ha and 15 t/ha. It is thought that this effect was caused by the Limex treatments increasing both the total calcium and the available calcium levels in the soils. Also, the Limex treatments had an effect of increasing the pH levels, particularly later in the season, compared to the untreated control. The effects on soil pH and extractable calcium could well influence microbial activity in the soil, and detrimentally effect cavity spot pathogens to the benefit of the carrot crop.

At the Retford site, Perlka was identified as causing detrimental effects to the carrot crop, and offered little effect at the STC site. There are claims that this compound may have bio-control properties through stimulation of soil microbes that interact antagonistically with more pathogenic soil pathogens. However, in this project, plots receiving Perlka had high levels of both cavity spot and Cercospora leaf blight. The latter was associated with early lodging of the carrot foliage and reflects the higher levels (19.8%) of nitrogen within Perlka.

A *Pythium* DNA test was completed at both Retford and at the STC sites at time of the post-emergence treatment again in August/early September. *Pythium* was only detected at the

Retford site, which was disappointing given the high levels of cavity spot at the STC site. The technique may need to be improved and made quantitative if it is to offer growers guidance on cavity spot risk.

## Conclusions

- The wet season in 2012 allowed the development of high levels of cavity spot in crops at the experimental sites.

- Significant control of cavity spot was demonstrated with metalaxyl-M and Limex in field experiments at Retford, but very wet soil conditions may explain the lack of control at the STC site.

- Metalaxyl-M degradation rates were rather slower than in 2011 and suggested the dry conditions up to March 2012 may have adversely affected the activity of the soil organisms involved in degradation.

- There were trends suggesting that calcium treatments may be able to contribute to cavity spot control, which were consistent with results from 2011.

- None of the new products, at standard rates of application, gave control of cavity spot and further work will be done using higher rates following further discussion with the manufacturers.

## Knowledge and technology transfer

Work from the project was discussed during the Carrot Growers' meeting at STC on 21 March 2013 and BCGA special cavity spot meeting on 6 June 2013.

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## Appendices

**Appendix 1.** Weather conditions at spraying Retford, Nottinghamshire, 2012

| **Target date (Timing)** | **Actual Date** | **Growth Stage** | **Weather (recorded at time of application)** |
|---|---|---|---|
| Timing 1<br>Pre-drilling | 15/05/12 | Pre-em | Temp: 14–15.2°C<br>RH: 45.9-46.9%<br>Wind Speed: 4.6–5.6 kph<br>Sun and hazy cloud<br>Very slight drift |
| Timing 2<br>4–6 weeks after Timing 1 spray | 11/06/12 | 10–12<br>Mean 11 | Temp: 12.9–13.2°C<br>RH: 75.4–79.8%<br>Wind Speed 3.2–7.8 kph<br>Cloudy and Dry<br>Slight Drift |
| Timing 3<br>4–6 weeks after Timing 2 spray | 18/07/12 | 13–16<br>Mean 14 | Temp: 19–19.1°C<br>RH: 75–77%<br>Wind Speed: 6.6–6.9 kph<br>Cloudy<br>Slight Drift |

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

**Appendix 2.** Weather conditions at spraying STC, North Yorkshire 2012

| Target date (Timing) | Actual Date | Growth Stage | Weather (recorded at time of application) |
|---|---|---|---|
| Timing 1 Pre-drilling | 24/4/12 | Pre-em | Mild with sunny spells. Max temp 11.9°C. Light breeze, slight drift. Ground damp. |
| Timing 2 4–6 weeks after Timing 1 spray | 15/06/11 | 12 (2nd TL) | Overcast at application, followed by sunny spells. Max temp 18.3°C. Crop dry, ground damp, light air with no drift. |
| Timing 3 4–6 weeks after Timing 2 spray | 02/08/12 | 16 (6TL) | Sunny spells, max temp 21.0°C, light air, no drift. Ground and crop dry. Overcast and light showers following application, min temp 11.8°C |

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

**Appendix 3.** Site details Retford, Notts 2012

| | | | |
|---|---|---|---|
| Site: | Babworth, nr Retford, Notts | | |
| Field name/ GRef: | Front of Grindles? / 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)<br>1.9% organic matter | | |
| Crop: Carrots | Cultivar | : Chantenay variety | |
| | Sowing date | : 23 May 2011 | |
| | Seed rate | : 7.4 kg/ha | |
| Cover crop | Spring barley cv. Tipple (Cover Crop) | 50 kg/ha seed rate | Sown 10 May 2012 |
| Irrigation | Nil Completed | | |
| Fertilisers | K-salt | 650 kg/ha | 13 Feb 2012 |
| | Ammonium nitrate | 115 kg/ha | 27 June 2012 |
| | Boron Liquid | 1 L/ha | 25 July 2012 |
| | Bittersalz | 5 kg/ha | 8 August 2012 |
| | Copper (Liquid) | 1 L/ha | 21 August 2012 |
| Fungicides (to farm crop) | | | |
| Herbicides | | | |
| Insecticides | | | |
| Harvest (farm) | | | 22 October–15 November 2012 |
| Harvest trial plots | | | 14 November 2012 |

**Appendix 4.** Site details Stockbridge Technology Centre 2012

| | | | |
|---|---|---|---|
| Site: | Field H1, Stockbridge Technology Centre, Cawood, YO8 3TZ | | |
| Field name/ GRef: | SE561366 | | |
| Soil texture: | Sandy loam | | |
| Drainage: | Good, though flooded in 2012 due to high water table | | |
| Previous cropping: | 2011 Spring barley | 2010 Winter Wheat | 2009 Winter Wheat |
| Soil analysis: | pH 7.1 | | |
| Crop: Carrots | Cultivar | : Nantes-type, confidential | |
| | Sowing date | : 14 May 2012 | |
| | Seed rate | : 200/m$^2$ | |
| Irrigation | None | | |
| Fertilisers | Muriate of Potash 60% | 291 kg/ha (175 kg/ha K) | 1 May 2012 |
| | Nitram | 232 kg/ha (80 kg/ha N) | 27 June 2012 |
| Herbicides | Linuron | 1.2 L in 600 L water/ha | 16 May 2012 |
| Insecticides | Biscaya | 0.4 L in 200 L water/ha | 20 June 2012 |
| | Biscaya | 0.4L in 200 L water/ha | 8 July 2012 |
| | Hallmark Zeon | 150 ml/200 L water/ha | 29 July 2012 |
| | Hallmark Zeon | 150 ml/200 L water/ha | 12 August 2012 |
| Harvest trial plots | | | 20 November 2012 |

 