FV 5f Carrot: the biology and control of cavity spot

Conducted on behalf of
Horticulture Research International and ADAS

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PRACTICAL SECTION FOR GROWERS

The background to this project has been fully reviewed in the first year report of the project. It is accepted that current fungicidal control of cavity spot is under pressure partly because it is based only on the fungicide metalaxyl, and we have established that metalaxyl may be subject to rapid degradation in fields routinely used for carrot production. The priority for this project remains therefore to find alternative fungicide treatments, or effective treatments not based on synthesised fungicides.

Field trials have again been done at HRI Stockbridge House, and by ADAS in collaboration with a commercial grower. As a result of the first year findings of the project, the trials were based on comparisons of SL567 (metalaxyl-M) with Amistar, a range of experimental fungicides and calcium carbonate and calcium monocarbamide. While the experimental fungicides were used on a speculative basis, the calcium compounds were included because of evidence that calcium may encourage development of a soil microflora which is antagonistic to *Pythium violae*, the causal agent of cavity spot.

Variability in the cavity spot incidence previously seen at Stockbridge House was dealt with by increasing replication in the experiment. At the autumn harvest untreated carrots had 31 % carrots with cavities. SL567 applied alone, post-emergence, significantly reduced disease. This was also the case when the fungicide was applied with Amistar, calcium carbonate or calcium monocarbamide. None of the other fungicide treatments gave disease incidence significantly lower than the untreated controls, but one did apparently significantly increase disease. At this harvest the calcium compounds applied alone did not show beneficial effects.

At the second harvest in late winter, disease in the untreated controls had risen to 64 %, and that in the SL567 treatment was no longer significantly different. Amistar applied alone or with SL567 had significantly less cavity spot than the untreated control, as did calcium carbonate alone or with SL567. The latter treatment gave both the best reduction in percentage cavity spot and also reduced the number of lesions per root to one third of that in the untreated control.

In the ADAS trial held at a commercial site in Norfolk, cavity spot in the untreated controls at the autumn harvest was 23 %. Because of variability in the data, no treatment was significantly different from the control value. The second harvest was made in January, with the same result.

The preliminary screen of new molecules in pot tests at Wellesbourne included a Novartis compound (EC125; Twist) and three coded fungicides from Bayer (UK634, UK831, UK876). Although one of the latter had shown promise in laboratory tests for control of *P. violae*, none of them was equal to SL567 in the pot tests. The one with supposed activity has been included in a test in the current year at higher rates of application.

Pot trials with calcium compounds gave more hopeful results, with calcium carbonate at 12 t/ha giving the largest reductions in cavity spot when applied immediately before, or one month before drilling. Both the 6 and 9 t/ha rates gave good effects. From extremely high levels of percentage infection, the effective treatments reduced cavity spot to minuscule amounts, even though carrot cultivar Nanco is highly susceptible. The additional use of SL567 applied post emergence gave no additional benefits.

Results with calcium hydroxide were much more variable, and although one treatment was similar in effect to calcium carbonate, results indicate that the carbonate would be the choice for consistent effects.

Calcium monocarbamide showed a range of effects from nothing to statistically significant disease reductions. This again indicates less consistency than one might expect from the carbonate.

Although the calcium compounds did have marked effects on soil pH, it is now well established that the beneficial effects on cavity spot do not come directly from that. Soil is effectively conditioned by the treatments and an antagonistic microflora is built up. This is supported by the generally superior disease reduction for treatments applied a month before drilling. Growers may feel it is practically difficult to apply calcium some time before drilling, but there must be an equation balancing the odds of successful use of SL567 and potential disease reduction from the calcium compound, with that of potentially losing the crop.

Work on enhanced microbial degradation of metalaxyl and resistance to metalaxyl in *P. violae* was generally encouraging. Consistent with findings in all such previous work, there was no evidence that the isolates of *P. violae* tested showed any resistance to the fungicide.

In the first year of the project we demonstrated rapid degradation of metalaxyl in nine fields from the Eastern Counties where growers had found problems with cavity spot following the use of the fungicide for cavity spot control. This was seen as an extreme choice of fields, and indicated the need both for a wider survey and investigation of fields where growers had not necessarily had problems, or were happy that the fungicide had worked satisfactorily. The survey this year was therefore from the very north of Scotland, through Lancashire/Yorkshire to Lincolnshire/Nottinghamshire. A total of 26 fields were identified by growers as being of interest. Of those fields metalaxyl survived for most of the 84 day assessment period in 12. Rapid degradation in which most of the fungicide had disappeared by day 20 was seen only in three fields, while the remainder of fields showed loss over 28 - 63 days.

Of major importance was finding a field in Lancashire which had had regular application of metalaxyl adjacent to one which had never received the fungicide. The former showed medium degradation, while the metalaxyl was stable in the latter. By means of an experiment in which the non-degrading soil was spiked with degrading soil we were able to transfer the ability to degrade metalaxyl into the former soil. This supports the concept that degradation of metalaxyl is a feature which soils acquire, rather than having naturally, and the finding has obvious implications for future increase in incidence of degradation as growers move machinery between fields or wind blows soil.

- At the first (pre-strawing) harvest at Stockbridge House, three treatments showed significant control of cavity spot for each assessment parameter. They were SL567 applied alone, Amistar pre-drilling with SL567 port-emergence and calcium monocarbamide pre-drilling with SL567 post-emergence.

- The observation with Amistar is illogical because the active ingredient shows no effect on *P. violae* in the laboratory, but positive results in the field have been reported from Israel.

- By the post-strawing harvest percentage carrots with cavities was similar in the SL567 alone treatment as in the untreated control, but benefits were still obvious for mean number of cavities per root and mean disease severity score. The same was true at this harvest for Amistar applied alone and for calcium carbonate applied alone or with SL567.

- A similar range of treatments inexplicably gave no satisfactory control at either the autumn harvest or at a second harvest in January.

- By definition, none of the new, experimental materials showed control of cavity spot in either trial. This was also the case with these materials in pot trials at Wellesbourne.

- Work with calcium compounds in pot tests has identified calcium carbonate as both effective and consistent in reducing cavity spot, with calcium hydroxide also giving good disease control. The benefits were apparent for percentage roots with cavity spot and disease severity as measured by lesion number and size.

- In one trial the benefit from use of calcium carbonate was greater than that from SL567, and the effects have been shown to persist through a second crop after treatment. In this work we do not have a clear indicator of whether calcium compounds should be applied well in advance of drilling, but because the effect is based on stimulating an antagonistic soil microflora giving some time for conditioning would appear logical.

- In a survey of 26 fields covering the major carrot growing areas, enhanced microbial degradation of metalaxyl was again recorded, but to a lesser extent than found in the earlier survey of fields in the Eastern Counties. This is reasonable, as the present fields were a mix of those where problems with metalaxyl had not been recorded, or it had not been used significantly in recent years.

- It has been shown that immediately adjacent fields can have very different degradation characteristics, and that enhanced degradation of metalaxyl can be acquired by soil by addition of further soil with that ability. This has implications for management of machinery between fields and possible effects of soil blow. In the long term growers will require advance information on the degradation properties of fields.

EXPERIMENTAL SECTION

A. GENERAL INTRODUCTION

Cavity spot has been recognised and studied for 38 years, but for the first 22 years the cause of the disease was not known. Many theories were advanced, including calcium deficiency, damage by insect larvae, soil ammonification, damage by anaerobic bacteria and others. However, the disease was controlled in work in Norway by fungicides which specifically targeted Oomycete fungi. The latter include both *Pythium* and *Phytophthora* among the soil-borne pathogens, and it was a relatively quick job to isolate *Pythium* from cavities and complete Koch's Postulates by using the isolates to cause cavities on healthy carrots. Over the years it has become obvious that the slow-growing *Pythium violae* is causal in over a dozen counties worldwide and the even slower-growing *Pythium sulcatum* is causal in a smaller number of countries, particularly on low pH soils. It is now thought that very few other species of *Pythium* are involved primarily in causing cavity spot, although many other species may be isolated from old, dark lesions. This history has been covered in detail in the report of HDC FV 5e and is therefore not repeated here.

Because of the practical importance of work on enhanced microbial degradation of metalaxyl, and the scale of work required for a national survey, work on the biology of cavity spot pathogens was put in abeyance.

B. PART 1 – Field trial at HRI, Stockbridge House

Materials and methods

<u>Site</u>

Horticulture Research International, Stockbridge House, Cawood, Selby, North Yorkshire YO8 3TZ. The trial site being located in field L. This site is known to be infested with *Pythium violae,* the causal agent of carrot cavity spot, following intensive production of carrot on this field.

<u>Crop and Cultivar</u>

Carrot cv. Lagor

<u>Trial Design</u>

The trial comprised a randomised block with 12 treatments x 6 replicates. Each plot comprised a single bed (1.8 m X 8 m long) which was split into two 4 m long plots. The first half of each 4 m plot was used for sampling purposes during the course of the trial (see crop diary) with a harvest in autumn. The second half of the plot was strawed-down over winter with black polythene and straw and harvested in the spring.

<u>Treatment List</u>

1. Untreated (water) control.
2. **SL567** (metalaxyl-M) (Novartis) at 1.3 l product/1000 l water/ha post-emergent.

3. **Amistar** (azoxystrobin) (Zeneca) at 6 l product/1000 l water/ha post-emergent.
4. **F279** (trifloxystrobin) (Novartis) 12 l product/1000 l water/ha post-emergent.
5. **RP10623A** (Rhone-Poulenc) at 3.6 l product/1000 l water/ha post-emergent.
6. **RH -117281** (Rohm & Haas) at 5 l product/1000 l water/ha post-emergent.
7. **UK634** (Bayer) 2.88 kg product/1000 l water/ha post-emergent.
8. **Amistar** (6 l) pre-drilling + **SL567** (1.3 l) post-emergent.
9. **Calcium carbonate** (10 t/ha) pre-drilling.
10. **Calcium monocarbamide** 300 l product/1000 l water/ha pre-drilling.
11. **Calcium carbonate** (10 t/ha) pre-drilling + **SL567** (1.3 l/ha) post-emergent.
12. **Calcium monocarbamide** 300 l product/1000 l water/ha pre-drilling + **SL567** (1.3 l/ha) post-emergent.

Treatment Application

The calcium treatments (carbonate and monocarbamide) were all applied pre-drilling. Calcium carbonate was incorporated into the top 20 cm of soil while calcium monocarbamide was applied to the soil surface prior to drilling with the drill giving slight incorporation. The fungicide treatments were applied overhead at early post-emergence when the seedlings were between the cotyledon and first true leaf stage (3-5 weeks after drilling) using an Oxford Precision sprayer (E-Bar Engineering) with boom attachment modified to operate with compressed air at a pressure of 2.5 bars.

Assessments

All assessments following emergence to the autumn harvest period were performed on the first half of each plot. The spring harvest was performed on the second half of the plot.

a) **Plant measurements to determine key growth stages.** To determine key growth stages at each site 10 carrot plants were selected randomly from guard rows and measurements of root length/diameter (widest point) and leaf number were taken from emergence onwards. The first sample was taken at the time of the post-emergent spray application. Subsequent samples were taken at approximately 2 week intervals until pencil stage and then at monthly intervals thereafter. Early seedling samples were photocopied to provide a record of growth stages (Appendix Table 1).

b) **Sample harvest for *P.violae* assessment by Dr G White**. At three intervals of approximately two weeks commencing from emergence onwards and at four weekly intervals thereafter until cavity spot symptoms were first observed, a sample of 20 carrots was randomly harvested from the Treatment 1 - untreated plots (each replicate) and from Treatment 2 - SL567 post-emergent (each replicate). The roots were sent unwashed to Dr G White for assessment of the presence of *P.violae*. The seedlings were kept cool while in transit.

c) **Sample harvest dates for in-crop cavity spot assessment**. From the pencil stage onwards and then at 4 weekly intervals a sample of 25 roots was selected randomly from each of the untreated plots, washed and scored for the number and severity of cavity spot lesions using the NIAB Provisional Key.

d) **Major harvests and cavity spot assessment.** In the autumn and spring the carrots from 2 m X 2 m centre rows of each plot were lifted, washed and weighed. A random 50 root sample was selected from the harvested carrots from each plot and a full detailed assessment of cavity spot including the number of lesions/root and percentage area affected was recorded using the NIAB Provisional Key. This schedule is based on 6 categories of severity:
   0 = no cavity spot lesions visible,
   1 = low disease levels with zero to 0.3 % of the root surface showing cavities,
   2 = 0.4 to 1.5 % of the root surface showing cavities,
   3 = 1.6 % to 3.0 % of the root surface showing cavities,
   4 = 3.1 % to 10.0 % of the root surface showing cavities,
   5 = over 10.0 % of the root surface with cavities.
   Roots that fall into categories 3 to 5 are classed as unmarketable.

Crop Diary

Sowing Date: 19 May 1999

Treatment application Schedule:

Calcium Carbonate incorporation – 14 May 99
Pre-Drilling – 19 May 1999
Post-emergent – 15 June 1999

Assessment Dates			
Assessment Number	**Sample Harvests for *P.violae* Assessment by Dr G White**	**Sample Harvest Dates for In-Crop Cavity Spot Assessment**	**Major Harvest Dates**
1	21 June 99	19 July 99	First harvest (pre-strawing) 21 October 99
2	5 July 99	16 August 99	Second harvest (post-strawing) 29 February 2000
3	17 July 99	13 September 99	

Statistical Analysis

A statistical analysis of variance was performed on raw data using a Genstat 5 programme.

Within the tables of results are comments on the significance of data, these comments are based on the comparison between the treatments (Significance Treated). The notation of significance in the tables is based on the following:-

NS = Result not significant
* = Significant result (P at 5 %)
** = Highly significant result (P at 1 %)
*** = Very highly significant result (P at 0.1 %)

Official Recognition at HRI, Stockbridge House

The study described was undertaken in compliance with the guidelines for Official Recognition of Efficacy Testing Organisations in accordance with EPPO guidelines.
Certificate No. ORETO 020,
Date of Issue: 13 January 1998,
Expiry Date: 31 December 2002.

Results and discussion

During the growing season the incidence (percentage infection), mean number of lesions per root and severity of cavity spot was assessed in the six untreated control plots. The results of these pre-harvest assessments are displayed in Appendix Table 2. The results show that cavity spot was recorded in each of the untreated control plots with low levels of infection at the first assessment on 19 July with the incidence of cavity spot increasing dramatically in the weeks between 16 August and 13 September.

There was some variability in the levels of infection between the six plots. This variability, however, was less extreme than was seen in the previous years trial (1998) where infection levels between plots varied between 16 % and 82 % compared to a variation of between 12 % and 26 % in this years study. This reduction in variability in levels of infection in this year's study is considered to be due to the increase in replicates from 4 to 6.

The results for percentage roots infected with cavity spot (Table 1) from the first (autumn) harvest show that Treatments 2 (SL 567 post-emergent), 8 (Amistar pre-drilling/SL567 post-emergent), 11 (calcium carbonate pre-drilling/SL567 post-emergent) and 12 (calcium monocarbamide pre-drilling/SL567 post-emergent) all gave significant control of cavity spot compared with the untreated control. Treatment 8 (Amistar pre-drilling/SL567 post-emergent) had the lowest percentage of carrots with cavities but this result was not significantly different to Treatments 2, 11, and 12.

All other fungicide treatments were not significantly different to the untreated control with Treatment 5 (RP10623A post-emergent) more severely affected than the untreated control.

The results for the second (late winter) harvest show an increase in the incidence of infection in Treatment 2 (SL 567 post-emergent) with the percentage infection not being significantly different to the untreated control. The disease control shown by Treatments 8 (Amistar pre-drilling/SL567 post-emergent), 9 and 11 (calcium carbonate alone pre-drilling or with SL567 post-emergent) shown in the first harvest results were maintained to the second harvest. Treatment 11 showed the best disease control at this time. The result for Treatments 11 (calcium carbonate pre-drilling/SL567 post-emergent) is significantly better than Treatment 2 where SL567 was applied alone as a post-emergent application.

Table 2 shows the results for the mean number of cavity spot lesions per root. Treatments 2 (SL567 post-emergent), 8 (Amistar pre-drilling/SL567 post-emergent) and 12 (calcium monocarbamide pre-drilling/SL567 post-emergent) showed a significant reduction in the number of cavity spot lesions compared to the untreated control at the first harvest. As with the results for percentage roots infected, all other fungicide treatments were not significantly different to the untreated control with the exception of Treatment 5 (RP10623A post-emergent) which had significantly more lesions per root than the untreated control.

At the second (late winter) harvest there was an increase in the mean number of lesions per root in the untreated control plots. At this assessment Treatments 2, 8 and 12 again showed a reduction in lesion number compared to the untreated control with Treatments 3 (Amistar post-emergent), 9 (calcium carbonate pre-drilling) and 11 (calcium carbonate pre- drilling/SL567 post-emergent) also showing a reduction in lesion number at this time. Treatment 11 (calcium carbonate pre-drilling/SL567 post-emergent) gave the lowest number of lesions at this post-strawing assessment.

The results for mean disease severity (Table 3) shows that Treatments 2 (SL 567 post-emergent), 8 (Amistar pre-drilling/SL567 post-emergent) and 12 (calcium monocarbamide pre-drilling/SL567 post-emergent) showed a significant reduction in cavity spot disease severity compared to the untreated control. The reduction in disease severity was also seen at the final (post-strawing) harvest when these 3 treatments again reduced disease severity. At the final harvest Treatments 3 (Amistar post-emergent), 9 (calcium carbonate pre-drill) and 11 (calcium carbonate pre-drilling/SL567 post-emergent) also significantly reduced disease severity at this assessment.

There were no significant differences between treatments for mean weight (yield/tonnes per hectare) (Table 4).

A total of 304 attempts at isolation were made from roots submitted to Wellesbourne. *P. violae* was not isolated at any time, either from asymptomatic periderm or from cavities. Species of *Pythium* which were isolated were those commonly associated with carrots, but not considered to be primary causes of cavity spot.

Table 1: Mean Percentage of Carrots with Cavity Spot Infection at Two Harvest Dates

% Carrots Infected with Cavity Spot [a]			
Number	**Treatment**	**First harvest**	**Second harvest**
1	Untreated (water) control.	31.9	64.1
2	**SL567** (metalaxyl)	12.7	53.7
3	**Amistar** (azoxystrobin)	24.2	45.6
4	**F279** (trifloxystrobin)	30.6	59.5
5	**RP10623A** (experimental product) (Rhone-Poulenc)	47.1	63.7
6	**RH -117281** (experimental product) (Rohm & Haas)	34.3	57.1
7	**UK634** (experimental product) (Bayer)	38.8	62.2
8	**Amistar** (6 l) pre-drilling + **SL567** (1.3 l) post-emergent.	10.8	43.6
9	**Calcium carbonate** (10 tonnes/ha) pre-drilling.	27.3	46.7
10	**Calcium monocarbamide** at a rate of 300 l/product 1000 l water/ha pre-drilling.	39.0	60.5
11	**Calcium carbonate** (10 t/ha) pre-drilling + **SL567** (1.3 l/ha) post-emergent.	19.2	34.3
12	**Calcium monocarbamide** at a rate of 300 l/product 1000 l water/ha pre-drilling + **SL567** (1.3 l/ha) post-emergent.	13.3	59.7
Significance Treated		***	***
LSD 5% (60df)		12.52	13.06

[a] The results for % roots infected have been angle transformed.

Table 2: Mean number of Cavity Spot Lesions per Root at Two Harvest Dates

Mean Number of Cavity Spot Lesions per Root			
Number	**Treatment**	**First harvest**	**Second harvest**
1	Untreated (water) control.	2.64	4.08
2	**SL567** (metalaxyl)	1.08	2.50
3	**Amistar** (azoxystrobin)	2.24	2.35
4	**F279** (trifloxystrobin)	3.09	3.97
5	**RP10623A** (experimental product) (Rhone-Poulenc)	4.82	4.27
6	**RH -117281** (experimental product) (Rohm & Haas)	3.29	3.71
7	**UK634** (experimental product) (Bayer)	3.64	3.41
8	**Amistar** (6 l) pre-drilling + **SL567** (1.3 l) post-emergent.	1.21	2.31
9	**Calcium carbonate** (10 tonnes/ha) pre-drilling.	2.20	2.36
10	**Calcium monocarbamide** at a rate of 300 l/product 1000 l water/ha pre-drilling.	3.36	3.76
11	**Calcium carbonate** (10 t/ha) pre-drilling + **SL567** (1.3 l/ha) post-emergent.	2.15	1.84
12	**Calcium monocarbamide** at a rate of 300 l/product 1000 l water/ha pre-drilling + **SL567** (1.3 l/ha) post-emergent.	1.07	2.85
Significance Treated		**	***
LSD 5% (60 df)		1.23	1.21

Table 3: Mean Cavity Spot Disease Severity Score at Two Harvest Dates
(0-5 Disease Severity Category)

Mean Disease Severity Score			
Number	**Treatment**	**First harvest**	**Second harvest**
1	Untreated (water) control.	2.55	2.26
2	**SL567** (metalaxyl)	1.37	1.71
3	**Amistar** (azoxystrobin)	2.10	1.63
4	**F279** (trifloxystrobin)	2.05	2.30
5	**RP10623A** (experimental product) (Rhone-Poulenc)	2.96	2.08
6	**RH -117281** (experimental product) (Rohm & Haas)	2.29	1.85
7	**UK634** (experimental product) (Bayer)	2.64	2.13
8	**Amistar** (6 l) pre-drilling + **SL567** (1.3 l) post-emergent.	1.19	1.75
9	**Calcium carbonate** (10 tonnes/ha) pre-drilling.	1.65	1.57
10	**Calcium monocarbamide** at a rate of 300 l/product 1000 l water/ha pre-drilling.	2.38	1.99
11	**Calcium carbonate** (10 t/ha) pre-drilling + **SL567** (1.3 l/ha) post-emergent.	2.49	1.78
12	**Calcium monocarbamide** at a rate of 300 l/product 1000 l water/ha pre-drilling + **SL567** (1.3 l/ha) post-emergent.	1.31	1.77
Significance Treated		**	**
LSD 5% (60df)		0.91	0.4

Table 4: Mean weight of Harvested Carrots from 2x2m Rows at Two Harvest Dates
Yield – Tonnes per Hectare

Weight of harvested carrots			
Number	**Treatment**	**First harvest**	**Second harvest**
1	Untreated (water) control.	77.7	84.4
2	**SL567** (metalaxyl)	80.3	90.8
3	**Amistar** (azoxystrobin)	72.4	84.0
4	**F279** (trifloxystrobin)	71.3	73.7
5	**RP10623A** (experimental product) (Rhone-Poulenc)	71.6	89.4
6	**RH -117281** (experimental product) (Rohm & Haas)	73.1	85.7
7	**UK634** (experimental product) (Bayer)	70.9	80.9
8	**Amistar** (6 l) pre-drilling + **SL567** (1.3 l) post-emergent.	72.1	86.3
9	**Calcium carbonate** (10 tonnes/ha) pre-drilling.	73.1	80.6
10	**Calcium monocarbamide** at a rate of 300 l/product 1000 l water/ha pre-drilling.	72.4	73.9
11	**Calcium carbonate** (10 t/ha) pre-drilling + **SL567** (1.3 l/ha) post-emergent.	77.5	79.3
12	**Calcium monocarbamide** at a rate of 300 l/product 1000 l water/ha pre-drilling + **SL567** (1.3 l/ha) post-emergent.	72.1	83.7
Significance Treated		NS	NS
LSD 5% (60df)		10.26	12.36

Conclusions

- *Pythium* infection established effectively across the trial site causing cavity spot infection in all of the untreated control plots. Cavity spot lesions were visible on the carrot roots three months before the first (pre-strawing) harvest which was on 21 October 1999.

- Treatments 2 (SL567 post-emergent), 8 (Amistar pre-drilling/SL567 post-emergent) and 12 (calcium monocarbamide pre-drilling/SL567 post-emergent) all showed improved control of cavity spot for each of the assessment parameters at the first (pre-strawing) harvesting.

- For each of the parameters of disease assessment (incidence, lesion number and severity) Treatment 11 (calcium carbonate/SL567 post-emergent) showed an initially poor level of disease control in the first harvest but much improved at the second (post strawing) harvest. The results for disease incidence were significantly better than SL567 applied alone indicating that the addition of calcium carbonate improved long-term control of cavity spot in this instance.

- Experimental products – F279, RP10623A, RH- 17281 and UK634 did not show any activity in controlling cavity spot throughout the trial period.

- Calcium carbonate applied alone as a pre-drilling incorporation did not show any control of cavity spot in the first harvest but significantly reduced cavity spot infection for each of the assessment parameters at the second (post-strawing) harvest.

- There were no differences between any of the treatments in the final yield of carrots at both the autumn (pre-strawing) and late winter (post-strawing) harvests.

B. PART II – Field trial run by ADAS at a commercial site

Materials and methods

Trial design

The trial consisted of a randomised block design, comprising 13 treatments and 4 replicates. Each plot consisted of a single bed 1.8 m wide by 10 m long. The plots were split into two 5 m lengths, one 5 m length was used for the routine sampling and the other was used for yield determinations and harvest assessments. Cultivar Lagor was sown on 21 May at 1.63 million seeds /ha to give a population of 70-75 plants per metre row on a four row bed.

Treatments

The experiment was located in a commercial crop of carrots and received standard agrochemical treatments apart from fungicides. The trial was not strawed down over winter and frost damage to the roots was limited. The treatments were applied pre-emergence, or at the first true leaf (Table 5).

Table 5. Treatments, rates and dates of application, Norfolk 1999.

Treatment number	Treatment
1	Untreated (water) control at 1000 l/ha pre-emergence (within 7-14 days of drilling)
2	SL567 (metalaxyl-M) at 1.3 l product/1000 l water/ha post-emergent
3	Amistar (azoxystrobin) at 6 l product/1000 l water/ha post-emergent
4	F279 (trifloxystrobin) 12 l product/1000 l water/ha post-emergent
5	RP10623A (experimental product) at 3.6 l product/1000 l water/ha post-emergent
6	RH-117281 (experimental product) at 5 l product/1000 l water/ha post-emergent
7	UK634 (experimental product) at 2.99 kg product/1000 l water/ha post-emergent
8	UK831 (experimental product) at 16 l product/1000 l water/ha post-emergent
9	Amistar (61) pre-drilling + SL567 (1.3 l) post-emergent
10	Calcium carbonate (10 t/ha) pre-drilling
11	Calcium monocarbamide at 300 l product/1000 l water/ha pre-drilling
12	Calcium carbonate (10 t/ha) pre-drilling +SL567 (1.3 l/ha) post-emergent)
13	Calcium monocarbamide at 300 l product/1000 l water/ha pre-drilling + SL567 (1.3 l/ha) post-emergent

The calcium treatments were applied by hand and incorporated into the soil by a bed-former on 18.5.99

Treatments were applied using an Oxford precision sprayer with a 2 m boom attachment and Lurmark F110 02 nozzles operated at 2 bar pressure on 21.5.99 (pre-emergence) and 22.6.99 (post emergence) in 1000 l of water per ha. Conditions at spraying were warm and dry with a wind speed of 7.5 kph.

Assessments:

Regular samples were taken and submitted to HRI Wellesbourne for testing.
At each site visit (see Table 6), a sample of 50 carrots was taken and the number of leaves and root diameter was measured on 10 plants from emergence onwards. During the early stages of crop development, these seedlings were photocopied to enable key growth stages to be determined (Fig 1 and Appendix Tables 3 and 4).

From the pencil stage (roots 8-10mm diam), 50 root samples from the control (untreated) plots were washed and assessed for the number of lesions/root and the overall severity of infection and sent to HRI Wellesbourne. A total of 100 untreated roots were examined for cavity spot.

The first harvest was taken on 4 November 1999. A 2 m row length was lifted from the centre 2 rows. The carrots were weighed and counted and a 100 root sample was taken and washed and assessed for disease, pest damage and other parameters. Root weights and numbers were assessed first and roots were cold stored until assessments were completed. The second harvest was taken on 11 January when assessments were repeated as described for the first harvest.

Cavity spot lesions were counted and the % root area affected recorded for each root. 'Old' cavity spot lesions (which were open lesions with corky strands) and 'new' lesions (which showed intact periderm and a water-soaked surface) were distinguished and recorded separately. The absolute % area values were converted to the NIAB disease index for subsequent analyses.

Full site details are given in Appendix Table 5.

Table 6. Sampling and assessment records, Norfolk 1999.

Date	Sample details	Sent to HRI
21 May	Crop sown	
22 June	50 plants	Yes
6 July	50 plants	Yes
20 July	50 plants	Yes
6 August	50 plants	Yes
1 September	50 plants	Yes
5 October	50 plants	Yes
4 November	Full harvest, assessment on 10 November	No
11 January	Full harvest, assessment on 19 January	No

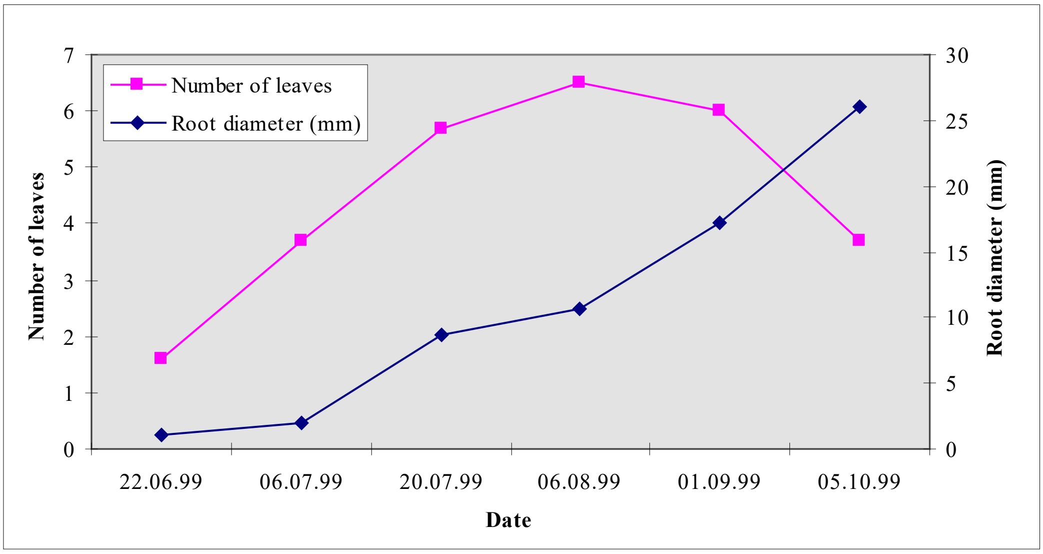

Figure 1: Means from growth assessments (see appendix for full data set)

Results

The trial plots established well and a slight growth check was noticed in carrot seedlings and on volunteer potatoes in plots treated with UK831, but the plants had grown away from the check by 9 August. Leaf development is summarised in Figure 1.

Cavity spot was first detected on 1 September when 1 % roots were affected. On 5 October, 11 % roots had cavity spot, all in NIAB category I. Subsequently cavity spot continued to increase, affecting 23 % roots at the first harvest on 4 November (Table 8) and 38 % at the second harvest on 11 January (Table 12).

P. violae was first isolated from carrots on 1 September when a sample of 35 cavities yielded 15 isolates of the fungus. On 5 October 45 cavities produced 7 isolates of *P. violae.* As with the Stockbridge House sampling, other *Pythium* species isolated were ones commonly associated with carrots, but not regarded as primary causes of cavity spot.

First Harvest

There were no significant differences between treatments for old, new or total cavity spot incidence and severity. However, data was skewed and further analysis combined with the Stockbridge House data may reveal differences. It was noticeable that the incidence of cavity spot was generally lower in treated than in untreated plots, particularly in NIAB category 2 (Tables 7 and 8). The severity of cavity spot, however, was generally higher in treated than untreated plots (Table 7).

There were no differences in yield or root numbers between treatments (Table 9). Interestingly, all yields except calcium carbonate applied pre-drilling were higher than the untreated. The combination of calcium carbonate + SL567 had fewer misshapen roots than the untreated (Table 9). The difference in small roots, fanged root, carrot fly damage and violet root rot were not significant. Scab affected 5% roots in the controls and differences between treatments were significant (P = 0.05) with F279 and UK831 showing a higher incidence of scab than SL567 alone or following calcium monocarbamide (Table 10).

Second harvest

There was an increase in old cavity spot lesions and in new lesions compared with the first harvest ten weeks earlier (Table 11). There were no treatment differences per incidence, lesion number and lesion severity (area) of either new, old or total lesion scores. There were some lesions in NIAB category 3 and 4 which accounted for the higher incidence than that derived by adding NIAB category 1 and NIAB category 2 columns in Table 12.

All treatments had higher root numbers and higher yield than the untreated, but differences were not significant (Table 13). There were no differences between treatments for small, misshapen, fanged, carrot fly damage or violet root rot. The incidence of scab differed from that at the first assessment in many of the treatments though F279 and UK831 were still among the worst affected treatments. At the second harvest however, differences were not significant (Table 14).

Comparison of first and second harvest data is presented in Figs.2-4. Treatments 6 (RH-117281) and 7 (UK634) showed the smallest differences between the two harvests for total numbers of roots affected. The largest increase in total cavity spot (Fig.4) occurred in treatments 9 (Amistar followed by SL567) and 13 (Calcium monocarbamide followed by SL567).

Discussion and conclusions

A range of novel fungicides, the standard metalaxyl (SL567) and various calcium treatments, all failed to give satisfactory control of cavity spot.

High rainfall early in the season may have contributed to poor control if metalaxyl was leached through the soil profile. A split dose approach with SL567 should be considered to reduce the risk of leaching soon after drilling. Similarly early post-emergence application would be preferable to pre-emergence timing. Enhanced degradation of metalaxyl at this site may be a further factor and soil tests are in progress to quantify it. Again split dose treatments may be beneficial where enhanced degradation is present and these should be evaluated further.

The calcium treatments were incorporated only 3 days before sowing and this may have been too short a period to stimulate the soil microflora and suppress cavity spot. A longer interval between incorporation and sowing should be considered though in practical terms this would be difficult to exploit. Growers often only access carrot fields a few days before sowing to de-stone and prepare the beds and a separate operation to apply calcium would be an additional burden logistically.

The failure to control cavity spot with new fungicides is disappointing. The properties of these materials may well indicate limited potential for cavity spot control, notably short persistence in soil, low water solubility and limited systemic activity compared with metalaxyl. Products with a half life in soil of a week or more would merit further investigation as soil applications.

The degree of cavity spot control now expected from fungicides is much lower than in previous work. Older fungicides or mixtures should therefore be re-considered within the project; an obvious example being propamocarb.

Table 7: Incidence and severity of old and new cavity spot lesions at first harvest in Norfolk, 4 November 1999.

Treatment Number	Treatment	Mean % roots affected (new lesions)	Mean number of new lesions /100 roots	Mean % root area affected (new lesions)	Mean % roots affected (old lesions)	Mean numbers of old lesion /100 roots	Mean % root area affected (old lesions)
1	Untreated	5.00	11.50	0.176	19.3	50.0	0.364
2	Post-emergent SL567	3.50	5.00	0.213	15.3	34.5	1.025
3	Post-emergent Amistar	2.25	2.70	0.086	22.3	54.5	1.091
4	Post-emergent F279	3.25	4.20	0.119	13.3	37.2	0.219
5	Post-emergent RP10623A	0.75	0.80	0.075	13.3	37.0	1.085
6	Post-emergent RH-117281	9.50	16.80	0.180	12.0	21.3	0.647
7	Post-emergent UK634	5.25	10.80	0.231	25.8	63.0	0.153
8	Post-emergent UK831	3.50	4.50	0.398	14.5	26.3	0.509
9	Pre-drilling Amistar and Post-emergent SL567	2.00	2.20	0.217	11.3	23.0	0.688
10	Pre-drilling Calcium carbonate	2.50	4.20	1.074	19.3	62.0	0.526
11	Pre-drilling Calcium monocarbamide	6.75	13.00	0.713	15.8	28.8	0.396
12	Pre-drilling Calcium carbonate and post-emergent SL567	5.00	8.30	0.443	18.8	47.0	0.430
13	Pre-drilling Calcium monocarbamide and post-emergent SL567	2.00	2.20	0.360	12.8	23.3	0.733
	mean	3.94	6.60	0.33	16.4	39.1	0.605
	SED (39df)	3.232	6.660	0.4257	8.15	28.45	0.4576
	P Value	*	*	*	ns	*	*

* = not suitable for analysis
ns = not significant

Table 8: Percentage roots affected with cavity spot at first harvest in Norfolk, 4 November 1999.

Treatment Number	Treatment	Total % roots with cavity spot	% roots with disease severity category 1 (NIAB)	% roots with disease severity category 2 (NIAB)	Mean number of lesions per affected root	Mean % area affected by cavity spot
1	Untreated	23.0	6.50	15.3	0.615	0.54
2	Post-emergent SL567	18.3	5.25	10.0	0.395	1.24
3	Post-emergent Amistar	20.8	7.75	7.0	0.573	1.18
4	Post-emergent F279	14.5	7.00	7.0	0.415	0.34
5	Post-emergent RP10623A	13.8	3.75	5.0	0.378	1.16
6	Post-emergent RH-117281	20.3	10.75	7.7	0.380	0.83
7	Post-emergent UK634	29.8	11.75	16.5	0.738	0.38
8	Post-emergent UK831	14.8	8.25	7.2	0.308	0.91
9	Pre-drilling Amistar and Post-emergent SL567	12.5	5.25	6.2	0.252	0.90
10	Pre-drilling Calcium carbonate	21.8	11.00	11.3	0.663	1.60
11	Pre-drilling Calcium monocarbamide	22.0	9.50	10.8	0.418	1.11
12	Pre-drilling Calcium carbonate and post-emergent SL567	23.0	8.25	12.0	0.553	0.87
13	Pre-drilling Calcium monocarbamide and post-emergent SL567	14.5	7.25	7.5	0.255	1.90
	Mean	19.1	7.87	9.50	0.457	0.93
	SED (39df)	7.92	4.184	5.52	0.2992	0.713
	P Value	ns	ns	*	*	*

* = Data not suitable for analysis.
ns = not significant

Table 9: Yield, root number and defects at first harvest in Norfolk, 4 November 1999.

Treatment Number	Treatment	% fanged roots	% small roots	% misshapen roots	Yield (t/ha)	Number of roots ('000/ha)
1	Untreated	3.75	25.8	11.25	50.06	1104.0
2	Post-emergent SL567	3.25	19.0	6.75	53.49	1289.0
3	Post-emergent Amistar	2.75	19.8	6.25	57.10	1379.0
4	Post-emergent F279	2.50	17.0	13.75	59.13	1301.0
5	Post-emergent RP10623A	2.75	15.5	8.25	56.46	1368.0
6	Post-emergent RH-117281	2.75	14.5	7.75	54.70	1232.0
7	Post-emergent UK634	4.75	17.8	10.5	56.16	1229.0
8	Post-emergent UK831	2.75	28.8	8.25	54.44	1194.0
9	Pre-drilling Amistar and Post-emergent SL567	1.75	14.2	5.50	61.02	1319.0
10	Pre-drilling Calcium carbonate	3.75	13.0	8.25	45.96	1067.0
11	Pre-drilling Calcium monocarbamide	2.25	26.5	8.25	59.15	1425.0
12	Pre-drilling Calcium carbonate and post-emergent SL567	1.00	11.0	2.50	58.47	1282.0
13	Pre-drilling Calcium monocarbamide and post-emergent SL567	1.25	14.7	6.50	52.28	1190.0
	Mean	2.71	18.3	7.98	55.26	1260.0
	SED (39df)	2.175	7.07	3.338	4.415	144
	P value	*	ns	0.028	ns	ns

* = Data not suitable for analysis.
ns = not significant

Table 10: Summary of other pest and disease damage at first harvest in Norfolk, 4 November 1999.

Treatment Number	Treatment	% roots with carrot fly damage	% roots with scab	% roots with violet root rot
1	Untreated	1.25	5.00	4.25
2	Post-emergent SL567	0.75	2.00	3.50
3	Post-emergent Amistar	0.00	1.50	6.50
4	Post-emergent F279	2.25	8.25	4.50
5	Post-emergent RP10623A	0.75	2.75	6.75
6	Post-emergent RH-117281	0.50	6.00	5.25
7	Post-emergent UK634	2.25	6.00	2.00
8	Post-emergent UK831	2.50	8.50	10.50
9	Pre-drilling Amistar and Post-emergent SL567	3.00	6.00	8.50
10	Pre-drilling Calcium carbonate	2.75	7.00	4.25
11	Pre-drilling Calcium monocarbamide	0.75	4.00	12.00
12	Pre-drilling Calcium carbonate and post-emergent SL567	0.25	3.25	3.00
13	Pre-drilling Calcium monocarbamide and post-emergent SL567	1.50	0.25	2.50
	Mean	1.42	4.65	5.65
	SED (39df)	1.401.	2.572	3.753
	P Value	*	0.049	*

* = Data not suitable for analysis.

Table 11: Incidence and severity of old and new cavity spot lesions at second harvest in Norfolk, 11 January 2000.

Treatment Number	Treatment	Mean % roots affected (new lesions)	Mean number of new lesions /100 roots **	Mean % root area affected (new lesions)	Mean % roots affected (old lesions)	Mean numbers of old lesion /100 roots **	Mean % root area affected (old lesions)
1	Untreated	12.00	3.7 (15.8)	0.44	31.0	8.5 (76.2)	1.60
2	Post-emergent SL567	8.25	2.9 (12.8)	0.36	26.5	7.0 (51.7)	1.63
3	Post-emergent Amistar	9.25	3.7 (17.3)	0.66	27.3	7.3 (55.0)	2.06
4	Post-emergent F279	10.00	4.1 (17.0)	0.88	25.5	7.0(50.0)	1.63
5	Post-emergent RP10623A	8.50	3.4 (12.0)	0.38	21.8	6.9 (53.2)	1.18
6	Post-emergent RH-117281	5.50	2.7 (7.5)	0.36	22.0	6.9 (48.2)	2.33
7	Post-emergent UK634	7.25	3.7 (14.5)	0.57	32.0	8.5 (78.7)	1.60
8	Post-emergent UK831	7.00	3.8 (15.5)	0.66	26.5	7.5 (57.0)	2.88
9	Pre-drilling Amistar and Post-emergent SL567	8.00	3.1 (9.5)	0.20	29.8	7.2 (51.7)	1.34
10	Pre-drilling Calcium carbonate	5.00	2.3 (6.5)	0.17	32.2	8.4 (75.7)	1.48
11	Pre-drilling Calcium monocarbamide	11.00	4.1 (19.8)	1.27	35.0	8.8 (78.7)	2.91
12	Pre-drilling Calcium carbonate and post-emergent SL567	15.25	4.5 (21.3)	0.69	33.2	8.2 (78.4)	0.97
13	Pre-drilling Calcium monocarbamide and post-emergent SL567	10.25	3.7 (15.3)	1.07	32.7	8.1 (68.0)	1.75
	mean	9.02	3.51	0.59	28.9	7.71	1.80
	SED (39df)	5.018	1.184	*	8.51	1.686	0.860

	P Value	ns	ns	*	ns	ns	ns

data not suitable for analysis. ns = not significant
** Transformed data. Data was unsuitable for analysis and has been transformed using a square-root transformation (raw data in parenthesis)

Table 12: Percentage roots affected with cavity spot at second harvest in Norfolk, 11 January 2000.

Treatment Number	Treatment	Total % roots with cavity spot	% roots with disease severity category 1 (NIAB)	% roots with disease severity category 2 (NIAB)	Mean number of lesions per 100 roots	Mean % area affected by cavity spot
1	Untreated	38.2	19.8	17.0	0.920	2.03
2	Post-emergent SL567	30.8	13.3	10.5	0.645	1.99
3	Post-emergent Amistar	34.0	12.5	11.3	0.723	2.72
4	Post-emergent F279	33.0	9.0	17.3	0.670	2.51
5	Post-emergent RP10623A	28.8	14.3	11.8	0.653	1.56
6	Post-emergent RH-117281	26.0	9.3	12.3	0.558	2.69
7	Post-emergent UK634	38.2	13.8	18.3	0.933	2.16
8	Post-emergent UK831	31.3	8.5	10.5	0.725	3.54
9	Pre-drilling Amistar and Post-emergent SL567	35.0	18.5	19.3	0.613	1.54
10	Pre-drilling Calcium carbonate	36.2	11.0	11.8	0.823	1.64
11	Pre-drilling Calcium monocarbamide	40.2	11.5	14.3	0.985	4.18
12	Pre-drilling Calcium carbonate and post-emergent SL567	43.5	16.8	20.8	0.998	1.65
13	Pre-drilling Calcium monocarbamide and post-emergent SL567	40.7	14.5	19.0	0.833	2.82

	Mean SED (39df) P Value	35.1 8.76 ns	13.3 6.14 ns	14.9 5.17 ns	0.775 0.2890 ns	2.39 1.102 ns

ns = not significant

Table 13: Yield, root number and defects at second harvest in Norfolk, 11 January 2000.

Treatment Number	Treatment	% fanged roots	% small roots	% misshapen roots	Yield (t/ha)	Number of roots ('000/ha)
1	Untreated	1.50	18.5	13.3	45.74	1101.0
2	Post-emergent SL567	1.75	14.8	13.0	53.28	1136.0
3	Post-emergent Amistar	0.50	13.3	7.7	59.14	1257.0
4	Post-emergent F279	4.50	22.5	14.3	60.33	1304.0
5	Post-emergent RP10623A	2.25	22.5	16.0	50.57	1232.0
6	Post-emergent RH-117281	3.75	24.5	18.0	55.12	1178.0
7	Post-emergent UK634	4.25	18.0	8.3	58.37	1249.0
8	Post-emergent UK831	2.25	24.8	9.0	53.07	1174.0
9	Pre-drilling Amistar and Post-emergent SL567	1.50	12.3	16.8	55.60	1307.0
10	Pre-drilling Calcium carbonate	2.50	23.3	17.0	54.43	1192.0
11	Pre-drilling Calcium monocarbamide	2.25	16.5	15.3	46.99	1125.0
12	Pre-drilling Calcium carbonate and post-emergent SL567	1.25	13.8	12.8	57.62	1225.0
13	Pre-drilling Calcium monocarbamide and post-emergent SL567	1.50	16.3	13.8	58.83	1244.0
	Mean	2.29	18.5	13.5	54.54	1203
	SED (39df)	1.447	9.00	6.85	4.843	133.9
	P value	ns	ns	ns	ns	ns

ns = not significant

Table 14: Summary of other pest and disease damage at second harvest in Norfolk, 11 January 2000.

Treatment Number	Treatment	% roots with carrot fly damage	% roots with scab	% roots with violet root rot
1	Untreated	1.00	5.25	11.8
2	Post-emergent SL567	0.75	8.00	11.3
3	Post-emergent Amistar	2.00	8.25	11.8
4	Post-emergent F279	1.25	10.50	13.3
5	Post-emergent RP10623A	3.25	2.75	21.0
6	Post-emergent RH-117281	2.00	6.50	21.0
7	Post-emergent UK634	1.75	7.00	6.7
8	Post-emergent UK831	1.00	13.75	14.3
9	Pre-drilling Amistar and Post-emergent SL567	0.25	11.00	17.0
10	Pre-drilling Calcium carbonate	1.25	4.75	18.3
11	Pre-drilling Calcium monocarbamide	0.50	8.25	18.5
12	Pre-drilling Calcium carbonate and post-emergent SL567	1.00	9.50	9.8
13	Pre-drilling Calcium monocarbamide and post-emergent SL567	0.25	9.50	17.0
	Mean	1.25	8.12	14.7
	SED (39df)	0.900	4.411	9.43
	P Value	ns	ns	ns

ns = not significant

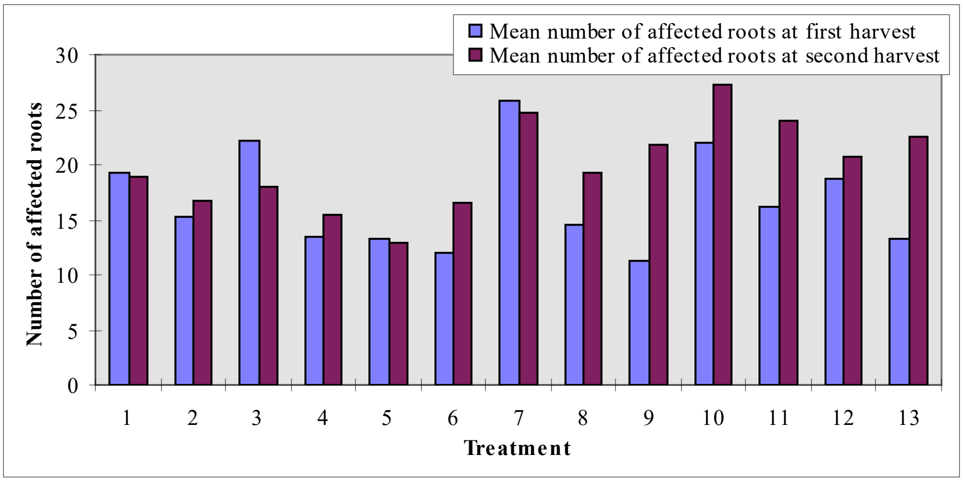

Figure 2: Percentage of roots with old lesions for both harvest dates.

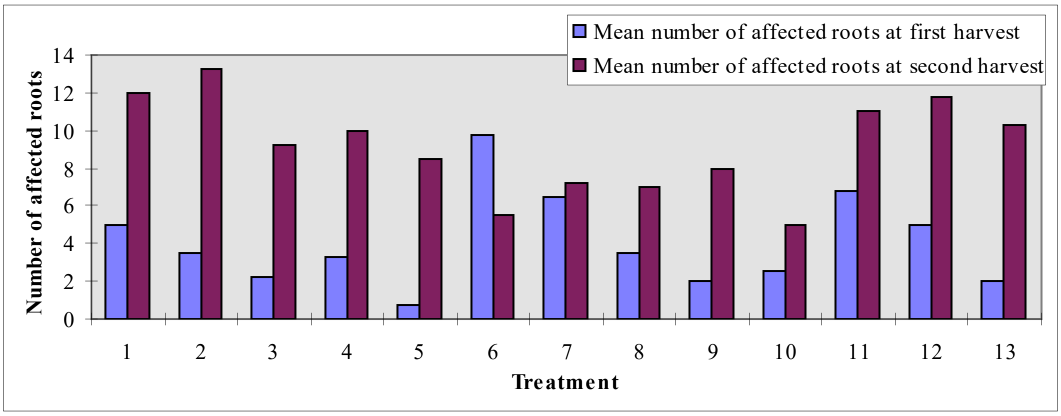

Figure 3: Percentage of roots with new lesions for both harvest dates

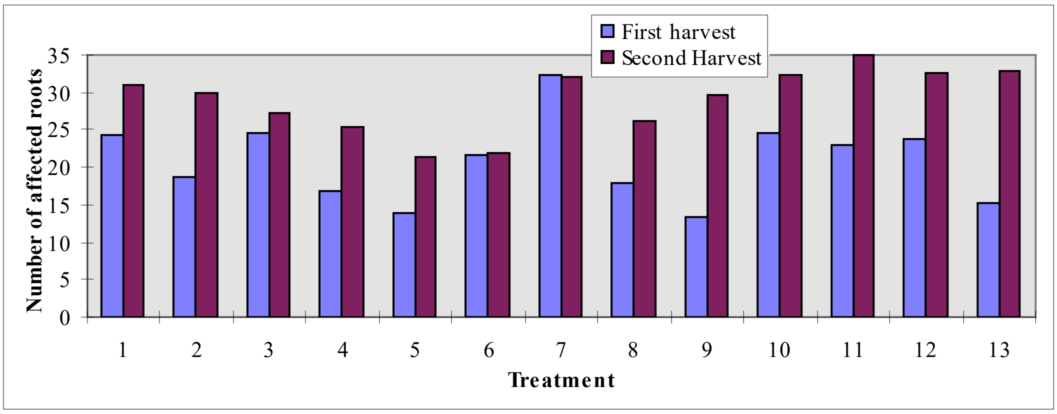

Figure 4: Total percentage of roots with cavity spot for both harvest dates.

B. Part III – Fungicide and calcium studies, enhanced microbial degradation of metalaxyl and resistance in *Pythium violae*

Fungicide and calcium studies

Introduction

One function of work at Wellesbourne is to screen on a small scale fungicides at an early stage of development for signs of activity against cavity spot. Below we report results with EC125 (Novartis), and three molecules from Bayer, UK634, UK831 and UK876.

The first year report of this project gave detail of pot tests in which a range of calcium compounds and a soil conditioner were tested for ability to suppress cavity spot. From those treatments calcium carbonate and calcium hydroxide were selected for further study. Because the effect of calcium has been shown to work through a process of conditioning the soil microflora, it was decided to examine the effect of applying the compounds at different times before drilling, with one month and two months pre-drilling being compared with application immediately before drilling.

Materials and Methods

The same experimental system used in Year 1 was again employed, with soil from a cavity spot site at Wellesbourne. For each of three experiments the soil was put through a 1 cm sieve to remove stones and bulk batches were sub-sampled for the soil for individual experiments.

The treatments in the first experiment were:-

Nil - untreated control

EC125 - 12 l/ha

UK634 - 360 g/ha

UK831 - 2 l/ha

UK876 - 160 g/ha

SL567 - 1.25 l/ha

The treatments in the second experiment were:-

Nil - untreated control

Calcium carbonate at 3 t/ha

Calcium carbonate at 6 t/ha

Calcium carbonate at 9 t/ha

Calcium carbonate at 12 t/ha

Calcium hydroxide at 3 t/ha

Calcium hydroxide at 6 t/ha

Calcium hydroxide at 9 t/ha

Calcium hydroxide at 12 t/ha

All treatments applied immediately before drilling.

The treatments for the third experiment were:-

Nil - untreated control

Calcium carbonate at 12 t/ha applied one month before drilling

Calcium carbonate at 12 t/ha applied immediately before drilling

Calcium carbonate at 12 t/ha applied one month before drilling with SL567 post -emergence

Calcium carbonate at 12 t/ha applied immediately before drilling with SL567 post-emergence

Calcium hydroxide at 12 t/ha applied one month before drilling

Calcium hydroxide at 12 t/ha applied immediately before drilling

Calcium hydroxide at 12 t/ha applied one month before drilling with SL567 post-emergence

Calcium hydroxide at 12 t/ha applied immediately before drilling with SL567 post-emergence

Calcium monocarbamide at 300 l/ha applied one month before drilling

Calcium monocarbamide at 300 l/ha applied immediately before drilling

Calcium monocarbamide at 300 l/ha applied one month before drilling with SL567 post-emergence

Calcium monocarbamide at 300 l/ha applied immediately before drilling with SL567 post-emergence.

SL567 was applied post-emergence

Soil was either used to fill pots containing 1.5 kg of pea gravel, or first treated with the appropriate chemical (calcium carbonate and calcium hydroxide) in a concrete mixer and then put in the pots. Calcium monocarbamide was sprayed onto the surface of bare soil, and SL567 was applied at first true leaf stage. There were eight replicates of every treatment.

Prepared pots were sown with 40 seeds of the cavity spot susceptible cultivar Nanco and placed on a glasshouse bench in a formalised randomised design and standing in saucers which always contained water. Watering was always into the saucers apart from a light application made to all pots after application of the SL567. Seeds were sown respectively on 21. 5. 99, 29. 6. 99 or 8. 7. 99. The seedling stand was thinned to 20 per pot and plants were harvested between 29. 9. 99 and 20. 11. 99.

Assessment of cavity spot was by counting on ten roots per pot the cavities less than 1 cm diam and those greater than 1 cm diam. The NIAB area assessment described above was also used, and each root was weighed. Results were subjected to analysis of variance, data for percentage disease first being converted to Angles for reasons of statistical correctness.

Soil pH was measured at the end of the experiment in a 1 : 5 mixture of soil and 0.01 calcium chloride mol l^{-1}.

Results

In all three experiments the untreated controls generally produced carrots with high percentage cavity spot, and in all three there were treatments which significantly reduced different parameters of disease (Tables 15, 16, 17).

In the first experiment, the largest reduction in percentage of carrots with cavities was from SL567, which also significantly reduced the number of cavities formed. SL567 was superior to the other fungicides for both numbers of cavities formed, and the impact of disease as measured by percentage area affected (Table 15). This was particularly obvious with the highly significant reduction in number of large cavities as compared with that in the untreated controls. None of the experimental fungicides reduced the percentage of carrots with cavities. However, all of the fungicides significantly reduced the number of cavities per carrot, with UK831 and UK634 producing a highly significant reduction. All the fungicides reduced the number of small cavities, but only UK831 and UK634 reduced the number of large cavities and also the area of root affected. No treatment had any effect on root weight.

Both calcium carbonate and calcium hydroxide applied immediately before drilling significantly reduced cavity spot (Table 16). The 12 t/ha treatment of calcium carbonate gave the greatest reduction in percentage carrots with cavities. All rates of calcium carbonate gave highly significant reductions in number of cavities per carrot, the number of large cavities and also in the percentage root area affected. For calcium hydroxide, the 6 - 12 t/ha rates reduced percentage disease by similar amounts. The treatments reduced both the number of cavities which were formed, and obviously limited cavity size, a feature seen most clearly in the assessment of percentage area affected. The lower values for calcium carbonate at 12 t/ha and calcium hydroxide at 6 t/ha indicate minuscule amounts of disease. There were positive effects of treatments on root weight which could be related to reduced damage by root infecting fungi, which was also evidenced by generally health, white roots in these treatments compared with those of the untreated controls.

Table 18 shows the effects of calcium treatment on soil pH. Increase in excess of one pH unit caused by the higher treatment rates is in line with findings from Year 1.

Results of the third experiment are dealt with compound by compound.

Calcium carbonate

The most effective treatments were from calcium carbonate applied one month before drilling, with or without SL567 (Table 17). Percentage cavity spot was reduced from 77.5 % in the untreated control to 15 - 16 %, with highly significant reductions in both number and size of cavities. Results from calcium carbonate applied immediately before drilling were not so good as in the first experiment, but this would predictably be affected by the 20 % higher level of disease in the untreated controls. In neither case did the additional use of SL567 give further benefit.

Unusually, the treatments applied one month before drilling had a negative effect on root weight, for which at the present time there is no obvious explanation.

Calcium hydroxide

Consistent with results from Year 1, disease reduction from the use of calcium hydroxide was less than that from calcium carbonate (Table 17). However, all parameters measured except for root weight showed significant disease reduction compared with the untreated control values. In this case the additional use of SL567 gave benefits both as lower numbers of cavities per carrot, and as reductions in the size, and therefore root area covered by those lesions.

Calcium monocarbamide

Three treatments significantly reduced percentage cavity spot compared with the untreated controls (Table 17). For the fourth treatment (calcium monocarbamide applied immediately before drilling with SL567 applied post-emergence) results were essentially the same as for the untreated controls. The treatment made a month before drilling, along with SL567 was clearly significantly better than the other treatments in this set.

SL567

Although SL567 applied alone gave highly significant reductions in percentage of carrots with cavities and the total number of cavities formed, values for the number of large cavities and the percentage root area affected were similar to those of the untreated controls.

Root quality

Because of obvious treatment differences in roots with respect to skin finish and the appearance of lenticels an additional visual assessment was made. While skin finish was poor and lenticels blackened on the untreated controls, they were respectively good and normal for all but one of the calcium carbonate and calcium hydroxide treatments. For calcium carbonate applied alone immediately before drilling, skin finish was only average and lenticels were discoloured. For most treatments involving calcium monocarbamide root appearance was poorer than for the other calcium compounds. Roots from the SL567 alone treatment were similar in appearance from those of the less beneficial calcium carbonate treatment.

Table 19 shows that pH data was generally consistent with that from the second experiment here, and also with that from Year 1 of the project.

Pots from the two calcium trials were re-sown in spring of 2000 to determine the extent of carryover of effects. At the time of writing the roots have been harvested but statistical analysis is not complete. However, it is clear from scanning the data that benefits of some calcium treatments have carried over to a second crop.

Table 15. Control of cavity spot on carrots in soil from Wellesbourne treated with various experimental fungicides.

Treatment	Percentage of carrots with cavities*	Total number of cavities per carrot	Number of small cavities per carrot	Number of large cavities per carrot	Percentage area of carrot infected *	Root weight as percentage of untreated control
Untreated control	47.5 (43.6)	1.75	1.10	0.65	0.7 (3.0)	100.0
EC125	37.5 (37.2)	1.14	0.63	0.51	0.9 (2.8)	96.3
UK634	36.2 (36.5)	0.83	0.60	0.23	0.3 (1.7)	103.4
UK831	38.7 (38.2)	0.76	0.52	0.24	0.3 (1.7)	104.6
UK876	45.0 (42.1)	1.10	0.65	0.44	0.6 (2.6)	98.3
SL567	26.3 (29.9)	0.51	0.34	0.18	0.2 (1.2)	100.8
LSD p 0.05	10.92	0.54	0.38	0.26	1.68	11.74
0.01	14.71	0.71	0.50	0.34	1.32	15.43
0.05	19.51	0.90	0.64	0.43	1.01	19.71

* arcsine transformation of percentages to which LSD applies in parentheses

Table 16. Control of cavity spot on carrots in soil from Wellesbourne treated with calcium compounds.

Treatment and rate		Percentage of carrots with cavities *	Total number of cavities per carrot	Number of large cavities per carrot	Percentage area of carrot infected *	Root weight as percentage of untreated control
Untreated control		57.5 (53.2)	1.85	0.91	1.4 (4.1)	100.0
$CaCO_3$ 3 t/ha		38.7 (35.8)	0.93	0.50	0.6 (2.4)	97.8
$CaCO_3$ 6 t/ha		32.5 (30.5)	0.71	0.43	0.5 (1.8)	114.2
$CaCO_3$ 9 t/ha		33.7 (35.2)	0.60	0.19	0.2 (1.2)	142.5
$CaCO_3$ 12 t/ha		13.7 (21.5)	0.26	0.09	0.1 (0.5)	113.1
$Ca(OH)_2$ 3 t/ha		47.5 (40.2)	1.49	0.64	0.8 (3.1)	113.3
$Ca(OH)_2$ 6 t/ha		12.5 (16.0)	0.23	0.06	0.1 (0.5)	132.3
$Ca(OH)_2$ 9 t/ha		21.3 (21.4)	0.50	0.25	0.2 (1.1)	124.8
$Ca(OH)_2$ 12 t/ha		20.0 (24.1)	0.60	0.30	0.3 (1.3)	151.6
LSD p	0.05	19.66	0.41	0.25	0.87	15.82
	0.01	26.15	0.54	0.32	1.14	20.79
	0.001	34.01	0.69	0.41	1.45	26.56

* arcsin transformation of percentages to which LSD applies in parentheses

Table 17. Control of cavity spot on carrots in soil from Wellesbourne treated with calcium compounds or SL567.

Treatment	Percentage of carrots with cavities *	Total number of cavities per carrot	Number of large cavities per carrot	Percentage area of carrot infected *	Root weight as percentage of untreated control
Untreated control	77.5 (62.5)	1.80	0.90	1.4 (5.2)	100.0
$CaCO_3$ 12 t/ha 1 month before drilling	16.3 (21.6)	0.19	0.11	0.2 (0.9)	58.3
$CaCO_3$ 12 t/ha Immediately before drilling	35.0 (36.0)	0.93	0.64	1.0 (3.0)	114.1
$CaCO_3$ 12 t/ha 1 month before drilling + SL567	15.0 (19.3)	0.29	0.09	0.1 (0.7)	75.1
$CaCO_3$ 12 t/ha Immediately before drilling + SL567	40.0 (37.0)	1.00	0.48	0.7 (2.6)	106.7
$Ca(OH)_2$ 12 t/ha 1 month before drilling	37.5 (37.1)	0.79	0.55	0.6 (2.6)	83.3
$Ca(OH)_2$ 12 t/ha Immediately before drilling	38.7 (37.6)	0.93	0.50	0.6 (2.5)	105.0
$Ca(OH)_2$ 12 t/ha 1 month before drilling + SL567	25.0 (29.4)	0.41	0.28	0.3 (1.4)	98.7

Table 17. continued

Treatment	Percentage of carrots with cavities *	Total number of cavities per carrot	Number of large cavities per carrot	Percentage area of carrot infected *	Root weight as percentage of untreated control
$Ca(OH)_2$ 12 t/ha Immediately before drilling +SL567	27.5 (29.4)	0.43	0.25	0.3 (1.5)	106.6
Ca monocarbamide 300 l/ha 1 month before drilling	46.2 (42.7)	1.00	0.79	1.2 (3.9)	97.5
Ca monocarbamide 300 l/ha Immediately before drilling	48.7 (42.5)	1.09	0.79	1.2 (3.8)	105.0
Ca monocarbamide 300 l/ha 1 month before drilling + SL567	30.0 (32.4)	0.43	0.31	0.3 (1.6)	84.0
Ca monocarbamide 300 l/ha Immediately before drilling + SL567	68.7 (60.4)	1.55	1.13	1.4 (5.3)	118.8
SL567	47.5 (41.6)	1.23	0.84	1.2 (3.8)	97.1
LSD p 0.05	15.33	0.37	0.29	1.17	11.49
0.01	20.26	0.49	0.39	1.54	15.10
0.001	26.11	0.63	0.49	1.96	19.29

* arcsin transformation of percentages to which LSD applies in parentheses

Table 18. pH ($CaCl_2$, 0.01M) of soil treated with calcium compounds.

Treatment and rate	pH
Untreated control	5.6
$CaCO_3$ 3 t/ha	6.3
$CaCO_3$ 6 t/ha	7.3
$CaCO_3$ 9 t/ha	7.2
$CaCO_3$ 12 t/ha	7.2
Ca $(OH)_2$ 3 t/ha	6.9
Ca $(OH)_2$ 6 t/ha	7.4
Ca $(OH)_2$ 9 t/ha	7.5
Ca $(OH)_2$ 12 t/ha	7.7

Table 19 . pH ($CaCl_2$, 0.01M) of soil treated with calcium compounds or SL567.

Treatment	pH
Untreated control	5.3
$CaCO_3$ 12 t/ha 1 month before drilling	6.6
$CaCO_3$ 12 t/ha immediately before drilling	7.0
$Ca(OH)_2$ 12 t/ha 1 month before drilling	7.5
$Ca(OH)_2$ 12 t/ha immediately before drilling	7.6
Ca-monocarbamide 1 month before drilling	6.3
Ca-monocarbamide immediately before drilling	5.7
SL567	5.5

Discussion

The pot trial in which SL567 was compared with four new or previously untested fungicides once again confirmed that metalaxyl continues to be the most effective fungicide for cavity spot. Highly significant reductions in all disease parameters were seen for SL567, with some minor benefits for some parameters from the experimental materials. This confirms the long held view that a synthesised fungicide replacement for metalaxyl will not be available in the short term.

With the above situation, it is essential that best use is made of findings on indirect control of cavity spot via the application of calcium products. In the present pot tests, results with calcium carbonate and calcium hydroxide applied immediately before drilling confirmed the findings from Year 1 of the project. One treatment of each compound significantly reduced all parameters of cavity spot measured, a feature normally expected from successful applications of SL567.

In the third pot trial, SL567 reduced percentage of carrots with cavities from 77.5 in the untreated control to 47.5, with coincident reductions in the number of small cavities formed. However, figures for disease severity were only just significantly different from those of the untreated controls. In contrast, calcium carbonate applied one month before drilling reduced percentage of carrots with cavities to 16.3, with massive reductions in number of cavities per carrot and in the disease severity parameters. Results were substantially the same when SL567 was applied with the calcium carbonate. The treatment positively affected skin finish, indicating some control of the organisms which contribute to poor root appearance. Benefits from the use of calcium hydroxide and calcium monocarbamide, although good, were generally less consistent than those from the use of calcium carbonate. As calcium carbonate has shown long-term effects in the field trial at Stockbridge House, it is obvious that this can be taken to the field. The challenge is now to optimise treatment effects.

Both calcium trials were re-sown in spring 2000, and although results are not fully analysed, it was obvious that some of the benefits from these treatments did carry over to the second crop.

Enhanced Microbial Degradation of Metalaxyl and resistance in *Pythium violae*

Introduction

This aspect of the project was set up in response to the deterioration in performance of metalaxyl (Fubol 58 WP) used in the treatment of carrot cavity spot, as observed by growers on their own field sites and by scientists during cavity spot field experiments (McPherson, 1995).

Possible causes for this reduced efficacy are development of resistance by the pathogen, or increased degradation by soil microorganisms.

Various studies have established that metalaxyl is subject to degradation by soil microorganisms (Bailey and Coffey, 1985; Droby and Coffey, 1991). Recent studies in Western Australia have shown that reduced persistence of metalaxyl in fields used for carrot production is associated with previous metalaxyl use (Davison and McKay, 1999).

In the first year of the project we specifically investigated sites where metalaxyl had been used and growers had reported serious problems with cavity spot on subsequent crops. All nine problem fields which were from the eastern counties showed rapid degradation of the fungicide. In the current study, we were required to sample fields from the major carrot production areas in the UK, giving growers the option on which fields were included. The intention was to have a mix of fields where metalaxyl had been used successfully, with some where disease had occurred after treatment. The survey comprised ten fields in Scotland, eight fields from Lancashire/Yorkshire and eight fields from Lincolnshire/Nottinghamshire.

Materials and Methods

Analytical (99.6%, Novartis) and technical (97.4%, Novartis) grade metalaxyl were used throughout the study.

For each field, approximately 1 kg of top soil was collected from each of 5 sites, along a 250 – 300 m transect across the field. A further sample was taken from a presumed untreated area (e.g. headland), as a control. This had previously been a problem, with some Year 1 control sites being too acidic to be true controls. Here it was intended to obtain control soil of a similar pH to that in the test field. The trowels used were washed and disinfected between sites. For each field an equal quantity of soil was taken from each of the samples 1-5 (excluding control) and mixed to provide a composite sample. All samples were stored at 5°C.

The water holding capacity (WHC) of the soil from both the composite and control samples was assessed in each case, as was the current water content of all 7 samples from each field. Where necessary, soil samples were air-dried to reduce the water content.

When handling soil, new or autoclaved equipment was used for each sample, and the bench was sprayed with IMS between samples. Stones were removed from the soil before weighing the required amount into a polythene bag. A solution of technical metalaxyl (0.5 g/l) was pipetted evenly onto the soil sample at 10 mg/kg dry soil and the sample was thoroughly mixed and contained in 500 ml pots. Sterilised distilled water (SDW) was pipetted around the edge of the pots, to increase the moisture levels to 40% of the soil's WHC. The lids were replaced loosely and pots were stored at 15°C, in the dark. Sub-samples of soil (15 g) were taken on day 0 and at regular intervals thereafter, on each occasion replacing any water lost from pots with SDW.

Metalaxyl was extracted from each 15 g sub-sample by shaking with 20 ml methanol for 50 minutes. The soil samples were allowed to settle for at least 10 minutes. Samples of clear supernatant were removed and analysed by HPLC using a LiChrospher-RP18 (5 µm) column and acetonitrile: water: orthophosphoric acid (70: 30: 0.25 by volume) eluant at a flow rate of 1 $mlmin^{-1}$; detection was by UV absorbance at 210 nm. The retention time of metalaxyl was 3.4 min. The HPLC was calibrated against a 5 mgl^{-1} analytical grade metalaxyl standard.

In addition to surveying the 26 fields, an additional experiment was made to benefit from the situation in Lancashire where a metalaxyl degrading field was identified as being adjacent to a non-degrading field. Soil from the former was added to soil from the latter in the proportions 1, 10, 100 g of fast degrading soil/kg of slow degrading soil. The compound soil samples were thoroughly mixed and then processed as above. One of the original samples from the degrading field (site 3) was repeated as a degrading positive control and one sample from the non-degrading field was re-run. The soil type and pH of the two fields were very similar. The hedgerow soil was also spiked with soil from the degrading site in the above proportions and again a non-spiked sample was re-run. The pH of the hedgerow soil was more acidic, being 5.6 as compared with 7.0 in the body of the fields.

Some growers have not provided the cropping details for fields they entered into the survey, so rather than present incomplete field data, we discuss EMD results as degradation patterns and only refer to previous cropping where it appears relevant.

Results

Data for Scotland comprised two groups, Moray Coast area and Fife. The results are shown in Figs 5 and 6. For the former, the graphs indicate a stable situation where metalaxyl was largely detectable throughout the 84 day test period. For fields 2 and 4 there were individual samples where the fungicide was lost by the 63 day assay. Cavity spot was not a problem on fields 1 and 3. Field 3 was known to have had recent severe cavity spot, fields 4 and 5 moderate/severe and moderate disease respectively. Data from Fife was considerably different, with only one of the fields retaining the fungicide throughout the 84 days. Field 3 showed the most rapid loss, with metalaxyl not detectable after 10 days. For the other fields the fungicide was gone between day 20 and day 63. Only field 4 was regarded as a severe cavity spot risk, the other fields being known to have minimal disease. A feature of the data for fields 1 - 4 is that metalaxyl was also degraded in the putative control samples, indicating the difficulty we have obtaining a true 'non-metalaxyl treated control'.

Data for Lancashire and Yorkshire are shown in Figs 7 and 8. For the former, metalaxyl was stable in fields 3 and 4 but was lost between 30 and 56 days in fields 1 and 2. Both field 1 and 2 had cavity spot in 1999, whereas it is though the disease was not a problem on fields 3 and

4. For field 2 we were able to use an adjacent field which had never been treated with metalaxyl as an additional control. Results indicated that here we had the phenomenon of one field which degrade the fungicide immediately adjacent to one which did not. This feature was used to examine whether enhanced degradation of metalaxyl could be transferred for one soil to another (see below). For the Yorkshire fields metalaxyl was lost from one or more sites in all four fields before 84 days, with each field showing a different pattern of loss. Grower information was limited to field 1, severe disease in 1999, field 2, minimal risk, fields 3 and 4 moderate and variable disease respectively.

Data for Lincolnshire are shown in Fig 9, and indicate that two of the fields degraded metalaxyl rapidly, while the fungicide was generally stable in the other two fields. Fields 3 and 4 are known to have had severe cavity spot in the 1998-99 crop. At the time of writing processing of the Nottinghamshire samples was not complete, although the graphs in Fig 10 appear to indicate that all four fields will have lost the fungicide by 84 days.

A general feature of the above data is that the composite samples were seen to behave as did the individual samples. For future work this means that fields may be represented by a small number of composite samples, allowing an increase in the number of fields investigated.

Fig 11 shows that the soil from the field control which was originally a slow degrader (field 0 g/kg) showed an increasing degradation rate as the amount of soil added was increased. The unspiked hedge control (hedge 0 g/kg) was slower to degrade than the unspiked field control. The addition of 1 g/kg of fast degrading soil had no effect on the degradation rate, but with the addition of 100 g/kg there was clearly an increase in the rate of degradation.

Resistance in *Pythium violae* to metalaxyl

Introduction

To address the possibility that the causal agent of cavity spot, *Pythium violae,* may have developed resistance to metalaxyl reducing the chemical's efficacy in the U.K. carrot growing areas, the fungus was assessed for its sensitivity / resistance to metalaxyl using agar plate tests, to generate ED 50 values. ED 50 is a measure of the response of the fungus to the fungicide, and indicates the concentration of fungicide required to reduce the growth of the fungus to half that of the untreated control. To date resistance to metalaxyl has never been found in *P. violae* (White, Stanghellini & Ayoubi, 1988), including in the 10 isolates of *P. violae* collected in 1997-98 during year 1 of this study.

Materials and Methods

Isolates of *P. violae* were obtain from cavity spot lesions, found on UK carrots. Many of the carrots were sent to HRI by growers or ADAS, some were lifted directly from fields used in the enhanced microbial degradation (EMD) study, others were grown in the glasshouse in soil from fields used in the EMD study (Table 20).

As in year 1, the isolates of *P. violae* were prepared for assay by cleansing through 2 % water agar with rifamycin to remove contaminating bacteria. The isolates were then grown on V8 juice agar (3 g agar, 0.4 g calcium carbonate, 20 ml V8 vegetable juice [Campbell Grocery Products Ltd.], 180 ml distilled water). A dilution series of metalaxyl in corn meal agar was prepared to give concentrations of 0, 0.01, 0.1, 1, 5, 10, 50 or 100 µg/ml. Prepared plates were inoculated at the side with one of the test isolates, incubated at 19ºC, and the colony diameter was measured daily until the untreated controls had crossed the plates. There were four replicates of each concentration for each of the isolates. Genstat was used to fit a logistic curve to the data and to calculate ED 50 values with standard errors.

Results

Table 20 shows the origin of the *P. violae* isolates and their ED 50 values. All isolates were sensitive to metalaxyl. The values ranged from 0.061 – 0.076 µg/ml, which is consistent with results from Year 1.

Table 20. Origin of *Pythium violae* isolates and their ED 50 values for metalaxyl

P. violae isolate	Location	Method obtained	ED 50 value
11	Merseyside	Direct from field in study	0.073
12	Yorkshire	From field next to study field	0.073
13	Merseyside	Direct from field in study	0.067
14	Suffolk	Glasshouse grown in EMD soil	0.066
15	Yorkshire	Direct from field in study	0.076
16	Lancashire	Carrots given by grower	0.062
17	Norfolk	Glasshouse grown in EMD soil	0.061
18	ADAS, origin unknown	Sent by ADAS	0.072
19	Lancashire	Carrots sent by grower	0.063
20	Norfolk	Obtained from NIAB	0.064

Discussion on EMD and resistance to metalaxyl

The results of EMD work in Year 1 were clearly directed by the choice of known problem fields, but they showed that fields exist in which applied metalaxyl survives only for a few days. It was essential to find out the generality of the phenomenon in the major carrot growing areas, and on the basis of this survey where significant problems with metalaxyl usage have not been recorded, fast EMD of metalaxyl is less frequent. Because growers in general do not return to individual fields with carrots for a number of years it is possible that deterioration in this situation could be over the long-term.

Three features from the results raise new questions which must be addressed, firstly the fields where there is generally metalaxyl left at 84 days, but for individual samples the fungicide is lost before that time. This could imply that the fields are in the process of conversion to the ability to degrade the fungicide. The second aspect concerns neighbouring fields in clusters of fields used for carrots. In Lancashire we found immediately adjacent fields with completely different degradation characteristics. It is essential that we determine whether this is a common situation, or whether in an area used regularly for carrot, most fields have a greater or lesser ability to degrade the fungicide. Whatever the outcome, the results indicate the simple need for growers to have advance information on the status of the fields they plan to use.

Where we have previously demonstrated rapid degradation of metalaxyl, we have no knowledge of whether that becomes a permanent feature of fields or whether degrading ability reduces with time. By analogy with EMD of other pesticides, risk could decline with a number of years without metalaxyl, so then we need to know the dynamics of the process, and whether foliar applications to other crops contribute to maintenance of EMD. These aspects will be addressed in collaboration with growers in subsequent years of the project.

From the limited information we have on previous cropping/cavity spot problems it is clear that severe disease has occurred on fields where metalaxyl was rapidly degraded. However this was not exclusively the case, so it is essential to accept that a major component in cavity spot disease is the inoculum present in the field. If inoculum levels are very high, a crop may be lost even if the field does not degrade metalaxyl because it is not possible for the metalaxyl to give sufficient control of *P. violae.*

Data for ED50's of *P. violae* with metalaxyl were consistent with previous findings, and although one might expect the development of resistance in the pathogen, there continues to be no evidence of this.

C. OVERALL DISCUSSION

Results on fungicidal control of cavity spot have been consistent with those in Year 1 of the project and with earlier work. Metalaxyl remains by several measures the most effective synthetic fungicide. However, as work develops with calcium compounds we move towards a possible two-pronged approach with a calcium compound applied pre-drilling, and metalaxyl applied post-emergence. Experiments addressing this approach are currently in progress both as pot work at Wellesbourne, and in the field at Stockbridge House and as an ADAS trial with a commercial grower.

Calcium carbonate emerges as the strongest candidate of the calcium compounds tested, and there was some evidence that application some time before drilling was advantageous. In discussions in the 2000 review meeting it was felt that even at 12 t/ha a treatment of calcium carbonate could be cost effective, particularly if the aspect of potentially improved skin finish is taken into account. Consideration will however have to be given to the extent to which the treatment can be incorporated at bed forming without diluting the effect through too great a depth of soil.

Results for enhanced microbial degradation of metalaxyl have also progressed significantly. We now know that the phenomenon can be accelerated in soil by the addition of further soil with fast-degrading ability. This has considerable implications for the movement of soil from field to field, these being implications that growers will be well aware of. However, from the survey conducted this year it is clear that not all regularly used fields have anything like fast degrading ability, indeed in some areas metalaxyl is clearly quite stable in the field soil. For future work we will address the points of how long fast-degrading fields retain that ability, and also the extent to which such fields might be the focus of clusters of fields with that ability. It is clear from present results that while a field may be a fast-degrader, cavity spot may not be severe because the inoculum level is low. Conversely, stability of metalaxyl in a field does not guarantee a clean crop if inoculum levels are very high.

There was again no evidence that *P. violae* has developed resistance to metalaxyl.

D. OVERALL CONCLUSIONS

- No fungicide in either pot tests or the field was as effective in controlling cavity spot as metalaxyl.
- Both calcium carbonate and calcium hydroxide did perform better than metalaxyl in pot tests, and the former did give long-term reduction in cavity spot in one field trial. As a general feature, the use of metalaxyl post-emergence did not improve on the disease control from the effective calcium treatments.
- As the effect of calcium is based on conditioning the soil microflora to be antagonistic to *Pythium* ways must be found to generate the effect before crops are drilled. there was preliminary evidence that once established, the antagonistic effect carried over to a second crop.

- While it is now obvious that enhanced microbial degradation of metalaxyl may be expected to occur in fields where there has been some regular use of metalaxyl, the consolation is that there is no evidence of resistance in the cavity spot pathogen.

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APPENDIX

Appendix Table 1

Mean Plant Measurements at Key Growth Stages (mean of 10 plants)

Date	Root Length (cm)	Root Diameter (cm)	No. Leaves
15 June 99	4.54	0.37	2.0
29 June 99	8.7	0.25	4.0
13 July 99	11.62	0.68	6.0
16 August 99	26.86	3.22	8.1
13 September 99	17.76	3.79	6.85

Appendix Table 2

Summary of Cavity Spot Assessment Data Recorded on 50 roots Sampled from Untreated Control Plots during Growing Season

Plot No.	Percentage Infection			Mean No. of Lesions			Mean Severity Score		
	19/7/99	16/8/99	13/9/99	19/7/99	16/8/99	13/9/99	19/7/99	16/8/99	13/9/99
13	0	2.0	30.0	0	1.0	4.0	0	1.0	1.8
23	0	2.0	18.0	0	1.0	2.0	0	1.0	1.2
43	4.0	18.0	26.0	1.0	1.2	3.0	1.0	1.1	1.7
53	0	18.0	22.0	0	1.4	4.1	0	1.2	1.3
68	2.0	8.0	12.0	1	1.2	3.8	1	1.0	2.5
83	0	4.0	16.0	0	1.0	2.0	0	1.0	1.2

Growth assessments for ADAS trial

Appendix Table 3. Number of leaves

Plant	Date 22.06.99	06.07.99	20.07.99	06.08.99	01.09.99	05.10.99
1	2	4	6	7	5	3
2	1	6	7	7	5	3
3	2	3	6	7	6	5
4	1	4	5	5	6	3
5	2	4	5	6	6	3
6	2	4	5	7	7	6
7	2	3	5	7	7	5
8	2	3	7	6	7	3
9	1	3	5	6	6	3
10	1	3	6	7	5	3
Mean	**1.6**	**3.7**	**5.7**	**6.5**	**6.0**	**3.7**

Appendix Table 4. Root diameter (mm)

Plant	Date 22.06.99	06.07.99	20.07.99	06.08.99	01.09.99	05.10.99
1	1	2	8	15	12	21
2	1	5	13	14	18	22
3	1	1	7	13	15	30
4	1	3	8	9	20	20
5	1	2	7	14	19	29
6	1	2	7	10	15	35
7	1	1	11	13	18	29
8	1	2	9	14	16	28
9	1	1	10	10	20	21
10	1	1	7	12	19	25
Mean	**1**	**2**	**8.7**	**12.4**	**17.2**	**26.0**

Appendix Table 5 - Site details: ADAS site 1999/2000

Location: South Pickenham, Norfolk (rented land courtesy of Watton Produce Co. Ltd)

Grid Ref: TL (OS Sheet 144)

Soil texture: organic sandy loam

Soil analysis :
pH 7.9
P 44mg/l
K 113mg/l
Mg 40mg/l
OM 3.52%

Cultivations pre-drilling:

12.5.99 - disced
17.5.99 - marking out and de stoning
18.5.99 - bedforming
19.5.99 - drilling (field, not trial)

Cropping diary:

Date	Chemical applied	Rate (/ha)
21.5.99	Drill c.v Lagor	1.63 million
18.5.99	Temik	18.18 kg
26.5.99	Sovereign	5.304 litre
26.5.99	Linuron	1.591 litre
04.06.99	Vinamul	205 litre
04.07.99	Dosaflo	2.578 litre
04.07.99	Afalon	0.9 litre
25.07.99	Manganese sulphate	4.0 kg
25.07.99	Hallmark	0.3 litre
25.07.99	Solubor	6.0 kg
25.07.99	Copper	0.3 litre
25.07.99	Zinc	0.3 litre
27.07.99	Fert Top Dressing	1.000 Ha
31.07.99	Dosaflo	3.759 litre
31.07.99	Afalon	1.250 litre
11.08.99	Manganese sulphate	4.0 kg
11.08.99	Solubor	6.0 kg
11.08.99	Copper 500	0.3 litre
11.08.99	Zinc	0.3 litre
17.08.99	Manganese sulphate	4.0 kg
17.08.99	Hallmark	0.3 litre
17.08.99	Solubor	5.998 kg
17.08.99	Copper	0.3 litre
17.08.99	Zinc	0.3 litre

Irrigation was applied once on 26.07.99