Project title:	Asparagus: Management of *Phytophthora* rot
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Project leader:	Dr K R Green ADAS Arthur Rickwood
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Location of project:	ADAS Arthur Rickwood ADAS Terrington Field site (on a grower's holding) in Cambridgeshire
Project co-ordinator:	Mr Philip Langley
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Key words:	Asparagus, *Phytophthora*, spear rot, fungicides, Metalaxyl-M, potassium phosphite, AL567A, fungicide, pesticide, disease

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

AUTHENTICATION

I declare that this work was done under my 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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1. GROWER SUMMARY

1.1 Headline

Spear rot on asparagus caused by *Phytophthora* sp. affected crops in at least five counties in 2004, confirming the widespread nature of the disease in the UK.

The pathogen causing spear rot of asparagus in the UK was confirmed (by molecular methods) as the same species of *Phytophthora* that is pathogenic on asparagus in other countries. This is now recognised as distinct from *Phytophthora megasperma* (previously regarded as the main *Phytophthora* species on asparagus) and has the proposed name *P. asparagi*.

Under environmental conditions suitable for disease development, a pre-harvest treatment with SL567A (metalaxyl-M) delayed development of spear rot by 3 weeks and symptoms only appeared in the fifth week of the harvest season.

In an inoculated field trial, *Phytophthora* sp. had a deleterious effect on crop establishment. The pathogen was controlled using a soil drench of SL567A applied to re-filled gulleys immediately after crown planting.

1.2 Background and expected deliverables

Symptoms of *Phytophthora* on asparagus were widespread in the UK for the first time in 2002. The disease is known to have become a major production constraint in New Zealand and the USA (California), with yield losses in excess of 50 %. Losses may occur at crop establishment and in mature crops. There is now an off-label approval for use of metalaxyl-M as SL567A on asparagus. Despite the reported effectiveness of this product for control of *Phytophthora* in the short-term, there are reports of a reduction in efficacy over time due to microbial degradation in soil. In addition, growers may be wary of using the product on a routine basis on established crops, because of the cost involved.

The overall aim of the project is to develop integrated strategies for the management of *Phytophthora* rot on asparagus.

The specific objectives of the project are:

- Confirm the species of *Phytophthora* causing asparagus rot and determine the extent of the disease in the UK.
- Collate information on disease spread and develop a quantitative method for determining levels of *Phytophthora* inoculum in soil.
- Provide recommendations and raise grower awareness of pre-planting measures necessary to reduce the risk of developing asparagus *Phytophthora* and other diseases.
- Determine the efficacy of metalaxyl for control of *Phytophthora* during crop establishment

- Produce a Factsheet update to summarise available information on the use of metalaxyl for control of asparagus rot.
- Evaluate the use of phosphite fertiliser for its incidental effect against asparagus *Phytophthora* and do a cost-benefit analysis on use of this product compared with metalaxyl and an untreated control
- Evaluate two fungicides for control of *Phytophthora* in asparagus, in an inoculated pot trial (year 2).

1.3 Summary of the project and main conclusions

HDC Factsheet no. 06/04 was written as part of this project to alert growers to the problem of *Phytophthora* rot on asparagus, and to summarise available knowledge of the disease and potential management strategies, including the use of SL567A (metalaxyl-M).

1.3.1 Identity and distribution of *Phytophthora* sp affecting asparagus in the UK

To confirm the identity and determine the distribution of *Phytophthora* on UK asparagus in 2004, spears with suspect symptoms were checked for *Phytophthora* by molecular techniques (PCR and DNA sequencing) at the Scottish Crop Research Institute (SCRI).

For all samples with typical symptoms of spear rot, *Phytophthora* sp. was confirmed as the causal organism. The pathogen causing spear rot of asparagus in the UK was confirmed by DNA sequencing as the same species of *Phytophthora* that is pathogenic on asparagus in New Zealand, France and Italy. This pathogen has only recently been recognised as being distinct from *Phytophthora megasperma*, the main pathogen on asparagus described in the scientific literature. The name *P. asparagi* has been proposed for this separate species.

A PCR-based molecular diagnostic test for the asparagus *Phytophthora* was developed by SCRI. This may be used within the project as a research tool for testing of spears, soil and planting material.

Asparagus spear rot was widespread in 2004 with typical symptoms reported by five growers each from a different county of the UK: Cambridgeshire, Cornwall, Northamptonshire, Warwickshire and West Sussex. *Phytophthora* was confirmed as the cause of spear rot at each of the five farms. *Phytophthora* was particularly severe in crops where it had been observed in previous seasons, with one grower observing symptoms of the disease in packed produce. This has prompted more growers to apply a pre-harvest application of metalaxyl-M in 2005, particularly on fields where the crop has a history of the disease. One grower who applied metalaxyl-M in 2005 had less symptoms of *Phytophthora* during the harvest season, however, it should be noted that environmental conditions were less conducive for disease development, compared with 2004 (lower rainfall).

1.3.2 Soil baiting

A seedling baiting technique was successfully used to test soil for the presence of *Phytophthora* pathogenic to asparagus. The presence of *Phytophthora* was confirmed in soil samples from two asparagus fields where spear rot had been observed in 2002/3, demonstrating survival of the pathogen between seasons in the soil.

1.3.3 Management of asparagus *Phytophthora* in an establishing crop

An inoculated field trial was planted in May 2004 (ADAS Terrington, Norfolk), to determine the effects of SL567A (metalaxyl-M) applied by two different techniques at crown planting, on crop establishment and *Phytophthora* development over two seasons. SL567A was applied either as a crown drench in gulleys, or to re-filled gulleys immediately after planting.

In 2004, the impact of *Phytophthora* sp. on asparagus crop establishment was demonstrated, with plant stand reduced by 27% in untreated inoculated plots. Applications of SL567A to soil immediately after planting (up to 1.3 L product/ha) resulted in good crop establishment, equivalent to the uninoculated control treatment, with no evidence of phytotoxicity. Crown drench treatments of 150 and 300 ppm a.i. reduced plant counts and vigour, indicating that it may be difficult to achieve effective disease control without phytotoxicity. To date, there have been no reports of asparagus crop establishment failures due to *Phytophthora* sp. in the UK, and so the economic benefit of fungicide treatment at planting will need to be assessed.

1.3.4 Management of asparagus *Phytophthora* in an established crop

The effects of metalaxyl-M and potassium phosphite on yield and spear rot incidence were assessed in an experiment located in an established asparagus crop where spear rot had previously been confirmed. In 2004, spear rot was widespread in the experimental plots and throughout the field. Due to poor plant stand in the experimental plots, the effect of treatments on yield could not be ascertained. However, in plots that were untreated or treated with potassium phosphite (4 L product/ha), spear rot developed in the 2^{nd} week of the harvest season, compared with the 5^{th} week for plots treated with SL567A (1.3 L product/ha).

1.4 Financial benefits

Assuming a UK area of 856 ha and yield of 2.2 t/ha, returning £2,600 per tonne, the annual value of the crop is approximately £4.95 million. With yield losses in excess of 50 % reported in New Zealand and California, this soil-borne disease is a serious threat to the UK asparagus industry. The benefit of the industry of a successful project would be continued profitable production of asparagus despite the threat of *Phytophthora* from soil and/or crowns.

1.5 Action points for growers

The widespread nature of the disease in the UK means that development of *Phytophthora* on asparagus is a real risk, particularly when there is heavy spring rainfall (as in 2004). For a particular farm, one asparagus field may be affected, while others may be disease-free. During the harvest season, it is important to monitor each field for symptoms of spear rot, and send suspect symptoms for laboratory confirmation of *Phytophthora* sp. This will enable an appropriate disease management strategy to be formulated for each crop the following season.

1.5.1 Establishing crops

- Factsheet 06/04 provides guidance on cultural practices for avoidance of *Phytophthora* in an establishing crop.

- To date, there have been no reports of *Phytophthora* affecting establishing asparagus crops in the UK. However, growers should be aware that in an establishing crop, symptoms of *Phytophthora* infection are more likely to be apparent as reduced plant stand and vigour, rather than visible lesions on emerging spears and ferns.

1.5.2 Established crops

- Factsheet 06/04 provides guidance on cultural practices to avoid or reduce the risk of disease development and best-practice guidelines for chemical control.

- If *Phytophthora* was not observed in a crop in the previous season, treatment of that field with metalaxyl-M is unlikely to be economic.

- If symptoms of spear rot due to *Phytophthora* were confirmed in a field in the previous harvesting season, an application of SL567A (metalaxyl-M) in that field prior to spear emergence may be warranted (follow the SOLA conditions of use).

- Spears with symptoms of spear rot should not be harvested, as symptoms can develop further in the packed product after harvest.

2. SCIENCE SECTION

2.1 Introduction

Phytophthora rot of asparagus is characterised by soft, watersoaked, slightly sunken lesions on spears at, or just above soil-level. Under wet conditions, the lesions become slimy because of secondary invasion by saprophytic bacteria. Spears usually have a crooked appearance with lesions on the inside of the crook. Under dry conditions, the whole lesion may become light brown and the spear may finally shrivel up. Because severe infection may affect buds and spears before they emerge from the soil, yield losses due to *Phytophthora* are often underestimated (P. Falloon, pers. comm). The disease can cause establishment failures (plant losses up to 80%), reduce yields in an established crop (40-70%), and can also cause post-harvest losses if infected spears are packed together with healthy spears.

The disease is common in New Zealand and also California, USA and most research on the biology and control of the disease has been carried out in these countries. The disease causes sporadic problems in France (e.g. in 2003) and Spain, and is endemic in the Netherlands and Germany. Up until 2002, reports of the disease on asparagus in the UK were rare. In 2002 and 2003, however, the disease was more widespread.

While *Phytophthora* in asparagus crops had been confirmed on two farms in the UK at the beginning of this project, there were several farms where although possible symptoms had been observed, the disease had not been confirmed. Further information is needed to determine the extent of the disease in the UK and to confirm the species of *Phytophthora* causing the disease. In New Zealand and California, the species most commonly associated with the disease is *P. megasperma* var *sojae*.

Until the start of this project, there were no fungicides approved specifically for the control of asparagus *Phytophthora* either in UK or the rest of Europe (HDC, 2002). SL567A (metalaxyl-M) now has a specific off-label approval for pre-harvest use on asparagus in the UK. However, routine use of metalaxyl will be a costly control option (£185-240/ha for a single treatment). Metalaxyl has been used successfully for control of asparagus *Phytophthora* in New Zealand and California for the past 15 years (Falloon *et al*., 1985). In some areas, however, the efficacy of the chemical against *Phytophthora* is now decreasing, due largely to the problem of microbial degradation in the soil. Asparagus growers in these regions are now looking for alternative management options, such as the use of phosphite fertiliser, which is reported to have incidental activity against oomycete fungi on other crops (eg onion downy mildew, *Phytophthora* on peppers and avocados). Published trial results for control of *Phytophthora* on asparagus are not available, although there are reports of moderate control (P. Falloon, pers. comm.). Recent research efforts in New Zealand have focused on developing hybrids with durable resistance to *Phytophthora* rot (Falloon *et al*., 2001).

This project aims to provide recommendations to growers on the integrated management of asparagus *Phytophthora*, from crown production through to the established crop, both by continued compilation and presentation of available knowledge of the disease, and by experimental work on the biology and control of the disease, to fill knowledge gaps.

2.2 *Identity and distribution of Phytophthora sp affecting asparagus in the UK*

2.2.1 Molecular characterisation

2.2.1.1 Methods

To confirm the distribution of *Phytophthora* on asparagus in the UK, growers who observed possible symptoms of the disease in 2004, sent spear samples for laboratory analysis. The presence of *Phytophthora* sp. was confirmed by isolation onto agar and subsequent microscopic examination. A seedling baiting technique (see Section 2.2.2) was used to test soil samples from two asparagus fields where spear rot had previously been confirmed (in Cambridgeshire and West Sussex) for the presence of *Phytophthora* sp. pathogenic on asparagus. *Phytophthora* isolates and spears with symptoms due to *Phytophthora* sp. were examined by Scottish Crop Research Institute (SCRI) using PCR amplification and DNA sequencing of the internal transcribed spacers (ITS) of rDNA (Cooke *et al*., 2000).

2.2.1.2 Results and discussion

During the 2004 harvest season, suspected symptoms of spear rot were sent in by one grower from each of the following counties of the UK: Cambridgeshire, Cornwall, Gloucestershire, Northamptonshire, Warwickshire and West Sussex. *Phytophthora* sp. was confirmed as the causal organism of spear rot symptoms on all of the samples received, except the sample from Gloucestershire (spear crooking due to wind damage). Varieties affected included Geynlim, Darian and Gito. *Phytophthora* was particularly severe in crops where it had been observed in previous seasons (West Sussex and Cambridgeshire). A grower in Lincolnshire also observed spear rot symptoms in 2004, but samples were not received for laboratory confirmation.

Prior to this project in 2001, a *Phytophthora* sp. isolated from infected asparagus spears from one farm in West Sussex, was considered to be morphologically close to *P. megasperma* var. *sojae* (CSL laboratory report, 2001). In 2004, isolations from infected plant material by SCRI and ADAS yielded homothallic (i.e. capable of generating oospores in single culture) isolates of *Phytophthora* in which hyphal swelling were abundant. Sporangia were non-papillate, variable in shape (mainly ovoid to ovate) with dimensions of 52.3 (40-60) µm length x 36 (30-40) µm breadth, and showed extended proliferation. Zoospore release from sporangia was observed. Sporangiophores were mainly non-branched, but occasionally branched. The morphological description matched that of *Phytophthora* isolates previously examined *ex* asparagus (from other countries) by SCRI. The ITS sequences of the UK isolates were identical to those from diseased asparagus in New Zealand, France and Italy confirming that the disease was caused by the same pathogen. The sequence data also confirmed that this is related to but clearly distinct from *P. megasperma,* which has previously been reported as the causal organism of spear rot. A re-description of this species as *Phytophthora asparagi* has been proposed (D. Cooke pers. comm., 2005). Isolates baited from soil in two fields in which spear rot had been observed in 2002/3, were also confirmed as the same species of *Phytophthora* by molecular methods, clearly demonstrating survival of the pathogen between seasons in field soil. A PCR-based molecular diagnostic test for the asparagus *Phytophthora* was developed by SCRI on the basis of ITS sequence variation and this was validated on several asparagus spears from infected UK crops (Fig. 1). It is intended that this diagnostic test may be used in 2005 as a research tool for testing asparagus spears, soil and crowns.

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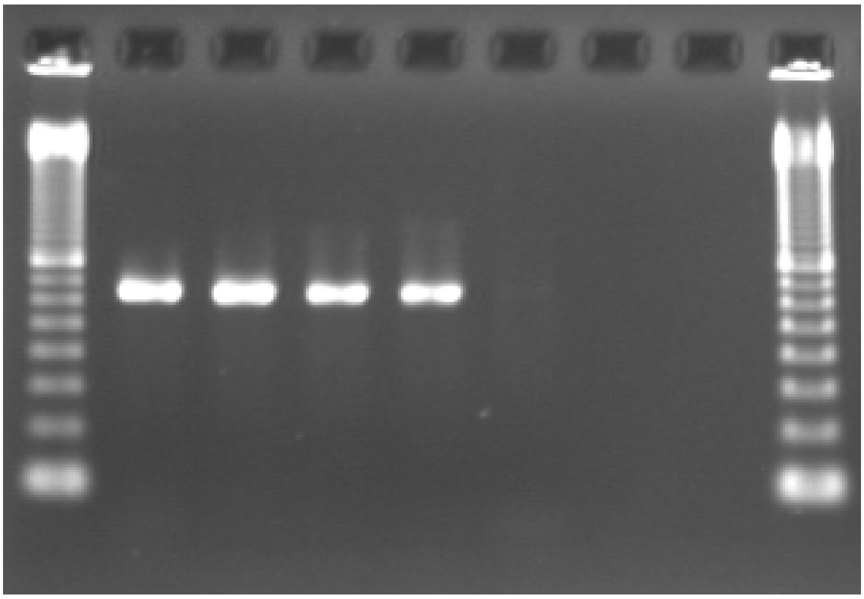

(courtesy of SCRI)

Figure 1. An example of the outcome of PCR testing of DNA from spears infected with asparagus *Phytophthora*. Amplification generated a *c*. 650bp PCR product from each of four infected spears. L = 100 base pair size marker

2.2.2 Soil baiting

2.2.2.1 Method

The following technique (based on the method of Falloon, 1982) was used to test soil samples for the presence of *Phytophthora* sp. pathogenic on asparagus.

Soil samples (3-5 litres) were collected from the top 150 mm of soil from areas of fields to be tested for *Phytophthora* sp. pathogenic on asparagus. The soil was thoroughly mixed and stored in sealed and labelled plastic bags at 4ºC until tested.

Approximately 100 asparagus seeds (cv. UC 157) were surface sterilised in 3% sodium hypochlorite for 3 seconds, and rinsed three times in sterile distilled water. The seeds were sown at a depth of 10 to 20 mm in moist autoclaved sand in seed trays (four rows of five seeds per tray). The trays were incubated in the dark at 30ºC for approximately 10 days until seedlings had emerged 10-15 mm above the sand, with roots 20-40 mm long.

Seedlings were gently removed from the sand and washed in distilled water. They were prepared for baiting by removing any seed remains, and by lightly crushing the plumule and radicle with forceps, approximately 10 mm above and below the point of attachment of the seed, to encourage infection.

Soil (30-40 ml) of each sample was placed in each of four deep plastic boxes. Each box was flooded with 30-40 ml of distilled water. Five of the prepared seedlings were floated in the water over the soil in each dish. The boxes were covered to prevent them drying out and incubated at 20ºC. Five seedlings were also floated in a Petri dish of sterile distilled water, as a check.

The roots were observed after 4 to 6 days for symptoms of *Phytophthora* infection (seedlings water-soaked and flaccid). Seedlings with possible symptoms were observed under a binocular microscope for sporangia.

Infected seedlings were surface sterilised for 30 sec in 1% sodium hypochlorite. Sections of the seedlings were plated onto P_{10}ARP (selective agar for *Phytophthora* spp.) and incubated at 15-18ºC. Plates were monitored for growth of *Phytophthora* sp. and sub-cultured onto V-8 Juice agar or PDA to get pure cultures.

2.2.2.2 Results and discussion

This technique was used successfully as part of other described experiments to confirm the presence of *Phytophthora* sp. pathogenic on asparagus in field soil (see Sections 2.2.1, 2.3 and 2.4).

2.3 Effects of metalaxyl-M (SL567A) on asparagus crop establishment in a field inoculated with Phytophthora sp.

The aim of this experiment was to determine the effects of metalaxyl-M , on crop establishment and *Phytophthora* development over two seasons when applied by two different techniques at crown planting. The work was done in part of a field inoculated with *Phytophthora* sp.

2.3.1 Methods

(See Appendix 1 for the Experiment Diary)

SL567A (metalaxyl-M, 480 g/L a.i.) was applied either as a drench to asparagus crowns planted in gulleys, or as a soil application immediately after crown planting to re-filled gulleys, at three different rates. The full list of treatments is given in Table 1.

The experiment was laid out in a randomised block design, with four replicates of eight treatments. Plots were 6 m long, containing a row of 20 plants, separated by 1.5 m (five guard plants). Plots were 1.8 m wide, containing one row of plants, separated by a single (shared) guard row (1.8 m). Plant spacing along the row was at 30 cm.. Treatments were applied to the central row only in each plot. Assessments were done on the 20 plants in the central rows of each plot.

Table 1. SL567A treatments applied in the inoculated field experiment.

Treatment no.	Method of SL567A application	Inoculated soil	SL567A application rate (L product/ha)*	Crown drench concentration (ppm a.i.)*
1	-	No	-	
2	-	Yes	-	
3	Crown drench	Yes	0.25	300
4	Crown drench	Yes	0.125	150
5	Crown drench	Yes	0.0625	75
6	Soil application	Yes	1.3	
7	Soil application	Yes	0.65	
8	Soil application	Yes	0.325	

*Applied in 400 L water/ha

The trial was planted on 27 May 2004 at ADAS Terrington on a silt soil, previously cropped to rye grass. Results of soil pH and nutrient analyses were:

pH = 7.9,
P = 89 mg/L (index = 5)
K = 528 mg/L (index = 4)
Mg = 227 mg/L (index = 4)

After preparation of a clean seed bed, fertiliser was applied prior to cultivation (N at 50 kg/ha, P at 150 kg/ha and K at 150 kg/ha). Nitrogen was applied as a liquid fertiliser (37%); P and K were applied as 0:24:24 fertiliser. The land was cultivated with a power harrow to provide loose soil underneath the planted crowns. Nine gulleys 1.8 m apart, and 65 m long, were prepared with a potato ridger, aiming for a gulley width of 40 cm and a depth of 10 cm.

Dutch Grade B asparagus crowns (var. Geynlim) were obtained from Teboza's in The Netherlands via a UK supplier, and were stored in the cold store at ADAS Terrington until required. Crowns were planted at the base of the gulleys at a spacing of 30 cm, ensuring that the bud was placed upwards, and that the roots were spread evenly across the gulley base. Twin ridging bodies were used to fill in the gulleys.

Fungicide treatments were applied in a 50 cm band using an Oxford Precision sprayer with 03F110 nozzle at 2 bar pressure. Treatments 1 and 2 remained untreated. For treatments 3, 4 and 5, crowns planted in the gulleys were band-sprayed (0.5 m width) with SL567A at the rates shown in Table 1. For treatments 6, 7 and 8, once crowns had been planted in the gulleys and infested soil applied (see below), the gulleys were refilled with soil and SL567A applied as a soil drench (0.5 m width) at the rates shown above.

Soil to be used as artificial inoculum was collected from a commercial asparagus field (Cambridgeshire) where symptoms of *Phytophthora* had been confirmed in 2004. In addition, samples of spears collected from the field with typical symptoms of *Phytophthora* rot were chopped and macerated, then mixed evenly into the soil.

Treatment 1 plots and the guard rows remained uninoculated. For inoculated treatments (2 to 8), infested soil was spread evenly to the sides of the gulleys at a rate of approximately 3.8 kg soil per 6 m plot length. For treatments 3, 4 and 5, infested soil was applied after the crowns had been drenched and prior to re-filling gulleys. For treatments 6, 7 and 8, infested soil was applied prior to re-filling gulleys and the soil application of SL567A. The procedures for inoculating and applying SL567A are summarized in Table 2.

Table 2. Summary of inculation and treatment procedures

Treatment 1	**Treatment 2**	**Treatments 3-5**	**Treatment 6-8**
Plant crowns	Plant crowns	Plant crowns	Plant crowns
↓	↓	↓	↓
Re-fill gulleys	Add soil inoculum	Apply SL567A	Add soil inoculum
↓	↓	↓	↓
Level off	Re-fill gulleys	Add soil inoculum	Re-fill gulleys
	↓	↓	↓
	Level off	Re-fill gulleys	Level-off
		↓	↓
		Level off	Apply SL567A

To provide conditions conducive for *Phytophthora* development, the plot was irrigated regularly for two 1.5 h periods per day using Wright Rain misting equipment, for 7 weeks after planting.

The herbicide Simazine 90WG was applied at 3 L/ha in 225 L water/ha after crown planting, and before spear emergence. The experimental area was hand-weeded during July and August as necessary. Metaldehyde pellets were applied in mid-July and early August and mid-September for slug control.

The following assessments were done during 2004:

- Number of plants emerged (1, 2, 3 and 5 months after planting)
- Incidence of *Phytophthora* rot and other pests/diseases on emerging plants (1 and 2 months after planting)
- Incidence of fern diseases (5 months after planting)
- Plant vigour (0 to 10 index, 2 and 3 months after planting)
- Fern numbers per plant (5 months after planting)
- Fern height (tallest fern per plant in cm, 5 months after planting)

The soil temperature at 10 cm (depth of crown planting) was logged until the end of October 2004, using a Delta T logger.

Soil from each plot was tested for the presence of *Phytophthora* sp. pathogenic to asparagus in November 2004 (see Section 2.2.2)

Data were analysed by analysis of variance or by Friedman's test for non-parametric data.

2.3.2 Results and discussion

Results for the first year of the experiment are presented. Due to wet conditions (rain plus irrigation) in June and July, slug damage occurred on emerging plants. Further damage was checked by three applications of metaldehyde. The number of plants per plot affected by slug damage was assessed (1 and 2 months after planting) and was not found to vary significantly with treatment (data not presented). Fern diseases (rust and *Stemphylium*) were not observed in 2004.

Despite wet conditions during the summer, no symptoms of *Phytophthora* rot were observed on emerging plants during 2004. However, there were significant treatment effects on crop establishment. Treatment differences in plant emergence were apparent from 2 months after planting, with the highest plant counts recorded consistently for the uninoculated control treatment and the three soil application treatments (data not presented). At 5 months after planting, plant counts were significantly reduced ($P<0.001$) in the inoculated control treatment and the high and medium rate crown drench treatments, compared with the uninoculated untreated control (Table 3). Similar treatment effects were observed for plant vigour (Table 4) and mean fern height (Table 6). Differences in the number of ferns per plants (Table 5) were almost significant at the 5% level. For most of these assessments, results for the inoculated control treatment and the high and medium rate crown drenches were significantly lower than for the uninoculated control and soil application treatments.

The consistently poor results obtained for the inoculated control confirms the deleterious effect that *Phytophthora* sp. can have on asparagus crop establishment, with plant population (established plants) reduced by 27 % in this experiment. Due to the high risk of *Phytophthora* sp. on asparagus in New Zealand, a crown drench with metalaxyl-M is routinely applied prior to planting (P.G. Falloon, pers. comm.). In this experiment, poorest crop establishment occurred in plots receiving the medium and high rate crown drenches (150 and 300 ppm a.i., respectively), suggesting that this was a phytotoxic effect. Crop establishment results were better following the low rate crown drench (75 ppm a.i.), suggesting adequate pathogen control without phytotoxicity. Similar effects were reported by Falloon & Fraser (1990) indicating that optimising application rate to achieve pathogen kill without phytotoxicity can be problematic with crown drenches or dips. Application of SL567A to re-filled gulleys immediately after planting, appeared more promising, with crop establishment results similar to those obtained for the uninoculated control treatment. This method of application has the advantage that there is less chance of phytotoxicity, and less health and safety risk to operators.

*Table 3***.** Effect on plant counts (5 months after planting) of SL567A treatments applied immediately after asparagus crown planting in *Phytophthora*-infested soil.

Treatment	**Mean number of plants (of 20)**
1. Untreated – uninoculated	18.8
2. Untreated – inoculated	13.8
3. Crown drench high rate	13.8
4. Crown drench medium rate	15.8
5. Crown drench low rate	17.3
6. Soil application high rate	17.5
7. Soil application medium rate	18.8
8. Soil application low rate	18.8
d.f.	21
P	<0.001
SED	1.26

Table 4. Effect on plant vigour (3 months after planting) of SL567A treatments applied immediately after asparagus crown planting in *Phytophthora*-infested soil (data analysed by Friedman's non-parametric test).

Treatment	**Vigour (0-10 index) – estimated median**	**Sum of ranks**
1. Untreated - uninoculated	5.35	26.5
2. Untreated - inoculated	3.19	8.0
3. Crown drench high rate	3.24	8.0
4. Crown drench medium rate	3.72	12.0
5. Crown drench low rate	3.83	17.5
6. Soil application high rate	4.24	18.5
7. Soil application medium rate	5.03	30.0
8. Soil application low rate	4.62	23.5
d.f.	7	
P	0.005 (adjusted for ties)	
S	20.25	

Table 5. Effect on the number of ferns per plant (5 months after planting) of SL567A treatments applied immediately after asparagus crown planting in *Phytophthora*-infested soil.

Treatment	Mean number of ferns per plant
1. Untreated – uninoculated	2.9
2. Untreated – inoculated	2.5
3. Crown drench high rate	2.2
4. Crown drench medium rate	1.9
5. Crown drench low rate	3.0
6. Soil application high rate	3.0
7. Soil application medium rate	3.0
8. Soil application low rate	2.7
d.f.	21
P	0.06
SED	0.38

Table 6. Effect on fern height (5 months after planting) of SL567A treatments applied immediately after asparagus crown planting in *Phytophthora*-infested soil.

Treatment	Mean fern height (cm)
1. Untreated – uninoculated	76.9
2. Untreated – inoculated	61.5
3. Crown drench high rate	55.2
4. Crown drench medium rate	59.6
5. Crown drench low rate	63.7
6. Soil application high rate	70.5
7. Soil application medium rate	81.6
8. Soil application low rate	70.3
d.f.	21
P	0.015
SED	6.95

2.4 Effects of metalaxyl-M (SL567A) and potassium phosphite (DP98) on asparagus Phytophthora

The aim of this experiment was to determine the effects on the incidence of spear rot and spear yield of metalaxyl-M (SL567A) and potassium phosphite treatments over two seasons, in an established asparagus crop known to be affected with *Phytophthora* sp..

2.4.1 Methods

Treatments (Table 7) were applied using an Oxford precision sprayer with 3 m boom and medium flat fan nozzle (03F110).

Table 7. Product application rates of SL567A and DP98 (potassium phosphite) used in the established crop field experiment.

	Product	Active ingredient	Product rate (l/ha)	Water volume (l/ha)	Spray timing
1	-	-	-		-
2	SL567A*	Metalaxyl-M	1.3	400	Pre-harvest only
3	DP98**	-	4.0	400	Pre-harvest only
4	DP98**	-	4.0	400	Pre-harvest and pre-fern senescence

*SOLA 0611/04
**Potassium phosphite supplied by Omex

The experiment was sited in an established asparagus crop (Cambridgeshire, UK) where symptoms of *Phytophthora* were confirmed in 2002. The experiment was located in an area of the field that was low-lying with poor drainage, known to have shown disease symptoms. The presence of *Phytophthora* sp. pathogenic to asparagus in each of the experiment plots was confirmed by seedling baiting from soil samples (Falloon, 1982). Quantification of the soil population of asparagus *Phytophthora* for each plot would not have been meaningful for this experiment, since:

- There is no published information on inoculum thresholds for symptom development
- Inoculum potential could vary between plots depending on soil conditions (e.g. water-logging)
- Estimation of *Phytophthora* populations by soil dilution plating would not specifically quantify *Phytophthora* sp. pathogenic on asparagus.

The experiment was laid out in a randomised block design, with six replicates of each treatment. Each plot was 12 m in length and four rows wide (6 m). Plants were originally established at a spacing of 30 cm between plants, and 1.5 m between rows. Treatments were applied to whole plots but assessments were done on plants in the central 6 m of the central two rows of each plot only. The pre-harvest treatments were applied prior to spear emergence and 11 days before the first harvest.

The grower was responsible for the following field operations:

- Land preparation prior to harvesting (ridge formation, fertiliser and herbicide application)
- Subsequent herbicide applications
- Spear harvest except on assessment days
- Sub-soiling in gulleys (if appropriate), after harvest season
- Fungicide applications to fern
- Fern removal

From the start of spear harvest, yield assessments were made once per week until the end of the harvest period (as decided by the grower). Harvesting frequency was increased to twice weekly when symptoms of spear rot were observed in the crop. In each plot, only spears from the centrally marked out area were harvested and assessed. Apart from these assessments, the experiment area was harvested by the grower.

At each assessment time, the following were recorded for each plot:

- The total number of spears and weight
- Number and weight of marketable spears with symptoms of *Phytophthora* rot
- Number and weight of marketable spears in the following categories:
  - spears <10 mm diameter
  - spears >10 mm diameter
  - blown and twisted spears
- Number of spears with symptoms of phytophthora rot remaining in the plot after marketable spears were removed.

Statistical analyses was by analysis of variance.

2.4.2 Results and discussion

In 2004, weather conditions were conducive for the development of spear rot, with 38 mm rain in the first two weeks of the harvest season. Spear rot was widespread in the experimental plots and throughout the whole crop. Disease distribution was random rather than aggregated. Harvest commenced on 23 April 2004 and by the second week of the harvest season, spear rot was observed.

Due to poor plant stand in the experimental area, yields were generally low across all plots. There were no consistent treatment effects on the numbers or yield of spears (data not presented). However, there were apparent treatment effects on the length of time taken until development of first symptoms. For plots that remained untreated or that were treated with potassium phosphite, spear rot was recorded on harvested spears from the second week of the harvest season. In contrast, plots treated with metalaxyl-M remained free of *Phytophthora* symptoms until the fifth harvest week. Early in the harvest season, there was a significant effect of treatment on the number of spears with *Phytophthora* rot that remained in the field after marketable spears had been cut (Table 8). Treatment with metalaxyl-M significantly reduced the number of unmarketable spears with *Phytophthora* symptoms, up until late May (approximately 6 weeks after the fungicide was applied). Use of potassium phosphite prior to harvest did not reduce the numbers of unmarketable spears with *Phytophthora* symptoms.

In July 2004, stem base lesions were observed on emerging ferns, irrespective of treatment. *Phytophthora* sp. was consistently isolated from the stem base lesions and oospores were observed microscopically in the plant tissue, indicating that infected crop debris could provide a source of inoculum for the disease.

There was no effect of treatment on plant counts recorded in July. Generally low counts confirmed that the plant stand across the experiment area was very poor. For this reason, Treatment 4 (fern application of potassium phosphite) was not applied, and the experiment was re-located to another area of the field in early 2005.

Table 8. Effect of treatments applied pre-harvest on the number of unmarketable spears with *Phytophthora* symptoms, during the 2004 harvest season

Treatment	**No. unmarketable spears with *Phytophthora* symptoms on harvest dates in 2004**						
	13/05	**17/05**	**19/05**	**24/05**	**28/05**	**02/06**	**10/06**
Untreated	5.5	4.5	2.3	1.3	1.7	0.5	0.5
SL567A	0.0	0.0	0.0	0.0	0.8	0.2	0.7
DP98	4.5	3.5	1.8	2.2	1.7	0.7	1.3
DP98	2.0		1.3	1.7	2.3	0.2	1.2
		4.8					
d.f.	15	15	15	15	15	15	15
P	<0.001	0.006	0.009	0.055	0.139	0.594	0.512
SED	1.13	1.25	0.60	0.74	0.60	0.44	0.63

2.5 Overall conclusions

- The pathogen causing spear rot of asparagus in the UK was confirmed by analysis of the rDNA ITS sequence, as the same species of *Phytophthora* that is pathogenic on asparagus in other countries (proposed name *P. asparagi*).
- A PCR-based molecular diagnostic test for the asparagus *Phytophthora*, developed on the basis of ITS sequence variation, was developed by SCRI. It is intended that this may be used within the project as a research tool for testing of spears, soil and planting material.
- A seedling baiting technique was successfully used to test soil for the presence of *Phytophthora* pathogenic on asparagus. The presence of *Phytophthora* was confirmed in soil samples from two fields where spear rot had been observed in 2002/3, demonstrating survival of the pathogen between seasons in soil.
- The impact of *Phytophthora* sp. on asparagus crop establishment was demonstrated in an inoculated field trial, with plant stand reduced by 27% in untreated inoculated plots. Applications of SL567A to soil immediately after planting (up to 1.3 L of product/ha) resulted in good crop establishment, equivalent to the uninoculated control treatment, with no evidence of phytotoxicity. To date, there have been no reports of asparagus crop establishment failures due to *Phytophthora* sp. in the UK, and so the economic benefit of fungicide treatment at planting will need to be assessed. However, since there is a direct relationship between yield and plant population, any minor loss of plants during the establishment years will have an effect on yield for the rest of the life of the crop. This cumulative effect on yield can be large (P. Falloon, pers. comm.).
- In an experiment sited in a mature crop, a pre-harvest treatment with SL567A (1.3 L of product/ha) delayed appearance of spear rot due to *Phytophthora* sp. by 3 weeks compared with the untreated control. The fungicide was effective for approximately 6 weeks after pre-harvest application to the soil.
- The disease was widespread in the UK in 2004 (confirmed in five counties), with at least one grower observing symptoms of the disease in packed produce. This has prompted more growers to apply a pre-harvest application of metalaxyl-M in 2005, particularly on fields where the crop has a history of the disease.

2.6 References

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HDC. 2002. Asparagus: control of *Phytophthora* rot. FV 246 Final Report. Horticultural Development Council.

3. Technology transfer

Phone advice to growers on management of *Phytophthora* on asparagus in 2004.

3.1 Publications

Green K & Dyer W. 2004. Management of *Phytophthora* rot on UK asparagus crops. HDC Factsheet 06/04. East Malling, Kent: Horticultural Development Council. 4 pp.

Green KR, Dyer W, Falloon PG, Cooke DEL & Chimento A. 2005. Management of *Phytophthora* rot on UK asparagus crops (abstract). Accepted for poster presentation at International Asparagus Symposium, Horst The Netherlands, June 2005.

3.2 Presentations

- 'Asparagus: management of phytophthora rot' Presentation by K. Green to an Open meeting of the Asparagus Growers Association, PGRO, November 2004.

- 'Biology and management of phytophthora diseases on vegetables' Presentation by K. Green (incorporating results from FV 246a) at HDC Roadshow on Field vegetable research, Kirton, Lincs, March 2005

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5. Appendix 1: experiment diaries

Effects of metalaxyl-M (SL567A) on asparagus crop establishment in a field inoculated with phytophthora

Date	Activity
26.05.04	Land culivated with a power harrow
27.05.04	Ridges formed, trial planted, sprays applied
28.05.04	Logger set up. Mist irrigation commenced
08.06.04	Pre-emergence herbicide applied (Simazine)
09.06.04	Spear emergence commenced
21.06.04	Approx 75 % spear emergence. Slug damage observed
23.06.04	Plant counts recorded
13.07.04	Metaldehyde applied
15.07.04	Irrigation stopped
29.07.04	Establishment and vigour assessment
04.08.04	Metaldehyde applied
31.08.04	Establishment assessment
20.09.04	Metaldehyde applied
22.10.04	Fern assessment

Effects of metalaxyl-M (SL567A) and potassium phosphite (DP98) on asparagus phytophthora

Date	Activity
12.04.04	Trial marked out, soil samples taken and spray treatments applied
23.04.04	Grower commenced harvest
30.04.04	1st harvest assessment.
07.05.04	2nd harvest assessment. Phytophthora symptoms seen in guard rows and another area of field
13.05.04	3rd harvest plus spear rot assessment
17.05.04	Spear rot assessment. Phytophthora symptoms widespread in field
19.05.04	4th harvest
24.05.04	Spear rot assessment
28.05.04	5th harvest and spear rot assessment
03.06.04	6th harvest and spear rot assessment
10.06.04	7th harvest and spear rot assessment
15.07.04	Assessment of plant numbers per plot. Poor plant stand evident
22.10.04	Trial visit. Plant density and vigour poor; decision made to move trial to another area of the field. Phytophthora confirmed on stem lesions.