Managing bean root and stem diseases

Andrew Watson
NSW Department of Primary Industries (NSW DPI)

Project Number: VG03002

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This report is published by Horticulture Australia Ltd to pass on information concerning horticultural research and development undertaken for the vegetable industry.

The research contained in this report was funded by Horticulture Australia Ltd with the financial support of the vegetable industry.

ISBN 0 7341 1597 0

Published and distributed by:

Horticultural Australia Ltd

Level 1
50 Carrington Street
Sydney NSW 2000
Telephone: (02) 8295 2300
Fax: (02) 8295 2399

E-Mail: horticulture@horticulture.com.au

VG 03002 (June 2007)

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Andrew Watson
NSW Department of Primary Industries
Yanco Agricultural Institute
Yanco,
2703.
Phone 02 69 512611
Fax 02 69 512719
Email andrew.watson@dpi.nsw.gov.au

Co-authors: Dr Hoong Pung (Peracto-Tasmania) and Dr John Duff (Queensland Department of Primary Industries)

Researchers in New South Wales-Andrew Watson, Lee Brown, Meryl Snudden and Liz Mudford
Researchers in Tasmania-Hoong Pung and Susan Cross
Researchers in Queensland-John Duff, Caroline Church and Heidi Martin

This report covers the activities undertaken during the period of the project from January 2004 till June 2007.

Report Completed -August 2007.

This project has been facilitated by the NSW Department of Primary Industries and Horticulture Australia Limited in partnership with AUSVEG, and has been funded by the vegetable levy and the Australian Government.

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MEDIA SUMMARY

This project “The management of bean root and stem diseases” **(**VG03002) was to provide an update on the current diseases of green beans in Australia and to investigate management options for soil borne diseases. The collaborative project was carried out in New South Wales, Tasmania and Queensland.

Beans can be affected by a number of diseases. Soil borne organisms initiate establishment diseases and stem rots that can be serious in certain bean growing areas. Their damage results in large areas either not germinating or damage at a later growth stage. Many of these organisms can survive for long periods in soils, in plant material or on volunteer weeds or alternate crops.

This project commenced in January 2004. The aim was to investigate disease problems currently associated with beans especially those that contribute to stem and root rots. Earlier work identified a disease affecting beans on the north coast of NSW as *Aphanomyces* root rot (ARR). A fungicide was found that controlled the disease but soon after the product was removed from sale. Since then, large crop losses continue to occur. Management of this fungus is a priority and had not been examined thoroughly. Avoiding land that has grown beans for up to ten years is the only control option for ARR. Its occurrence in other growing regions had not been fully investigated.

Through this project ARR was discovered for the first time affecting beans in Tasmania. Black root rot was also a new disease discovered in Tasmania and Queensland, not being recorded before on beans from these states.

A pre-plant soil test was established so that growers could have some knowledge of ARR disease levels before planting.

Work on managing ARR identified some fungicides controlled the disease when used as either seed dressings or soil drenches but the products were either not available or registered for use in Australia. The project also examined disease management options such as biological control, potential break crops and soil fumigation to reduce disease impact. Fumigation showed some success at controlling the disease but may be too costly to adopt. All bean varieties tested were found to be susceptible.

Work was carried out to investigate fungicide control of white mould on beans in Tasmania and Queensland. This was undertaken due to the withdrawal of a commonly used fungicide. In Tasmania the first fungicide timed at flowering was considered critical. In Queensland all fungicide treatments applied reduced levels of white mould as compared to the untreated plots.

Seed dressings to replace thiram (a broad spectrum fungicide) were examined and found to be suitable replacements for controlling other seedling diseases.

TECHNICAL SUMMARY

This project, **"**Managing bean root and stem disease" **(**VG03002), commenced in January 2004. The aim was to investigate disease problems associated with green beans (*Phaseolus vulgaris* L.) especially those that contribute to stem and root rots. One of the main aims was to investigate disease issues in Tasmania and New South Wales that had not been addressed in a previous bean root project VG024-*Bean root rot aetiology and control*. Project VG024 targeted a bean disease in Queensland especially around Gympie which has been given the name red root. VG024 considered that a fungal complex contributed to the disease red root that included *Fusarium, Pythium, Rhizoctonia* and *Aphanomyces*. The disease was identified to be worse in Gympie especially in cold seasons.

In the 1980s a disease was identified in the Macksville area of New South Wales (north coast). Investigations identified the disease as *Aphanomyces* root rot caused by *Aphanomyces euteiches* Drechs f.sp *phaseoli* Pfend & Hag. A fungicide Le-san® (fenuminosulph) was found to control the disease. Not long after this work Le-san® was withdrawn from use and since that time when conditions are conducive to disease large losses have resulted. *Aphanomyces euteiches* management had not been investigated thoroughly and its occurrence in other growing regions is unknown.

Control of this fungus currently relies on avoidance of infected fields, however this becomes difficult where land is either under development or buying new land is not possible. There is a lack of resistant varieties though some resistance has been identified, the loss in other agronomic traits render them unacceptable for production.

This collaborative project consisted of disease surveys in Tasmania, Queensland and New South Wales. New diseases of beans were recorded for Tasmania including *Aphanomyces* root rot and black root rot caused by two fungi *Aphanomyces euteiches* f.sp *phaseoli* (ARR) and *Thielaviopsis basicola* (Berk. & Br.) Ferr. (BRR) respectively. ARR has been recorded on peas before in Tasmania but not on beans. BRR was also recorded on beans for the first time in Queensland.

Aphanomyces euteiches f.sp *phaseoli* was confirmed as the main disease of beans on the north coast of New South Wales. Its damage was most severe when extreme rainfall events occurred but also infected beans with normal irrigation, however symptoms were not as severe or widespread. Peas were not affected by the fungus.

Work carried out in the project identified hymexazol controlled ARR when used as a seed dressing or as a soil drench, however the product is not available in Australia. Previcur® (propamocarb) and Amistar® (azoxystrobin) showed some ability to reduce infection as soil drenches but they have no registration for this purpose in Australia. Fumigation is an option to control these diseases but may not be economical. Biofumigation had no success at reducing disease levels. Non-chemical management of *Aphanomyces* appears to be difficult. Characteristics of the fungus itself, its survival in plant tissue and its ability to survive on alternate hosts makes its control difficult. An antagonistic bacterium, *Burkholderia* (formerly *Pseudomonas*) *cenocepacia*, was found during the project and further development in this area of research may hold the key to controlling this fungus.

Bean root and hypocotyl diseases can now be considered a complex of different fungi depending on each growing region. In some growing regions of Queensland and Tasmania, *Thielaviopsis*, *Aphanomyces*, *Rhizoctonia*, *Fusarium* and *Pythium* all provide some component to root/hypocotyl disease. In NSW it is mainly *Aphanomyces* but there is also some contribution by *Fusarium* and *Pythium* species especially as secondary or complementary invaders.

Work was carried out to investigate fungicide control of white mould (*Sclerotinia sclerotiorum*) on beans in Tasmania and Queensland. This was undertaken due to the withdrawal of a commonly used fungicide. In Tasmania the first fungicide timed at flowering was considered critical. In Queensland all fungicide treatments applied reduced levels of white mould as compared to the untreated plots.

Alternative seed dressings to thiram were identified in the project to control damping off of beans. Combinations of azoxystrobin, fludioxonil and metalaxyl-M in new fungicide seed dressings, improved seedling establishment and reduced root rot severity.

The role of *Thielaviopsis* and *Aphanomyces* in root and hypocotyl rot needs to be further investigated in both beans and peas in Tasmania. Industry should consider having hymexazol or propamocarb available for ARR control in Australia as there are no other products for this purpose.

INTRODUCTION

Green beans (*Phaseolus vulgaris* L.) consisting of French or dwarf, runner or climbing beans are a valuable crop to Australia with production approximately 34,000 tonnes worth $63M (source Australian Bureau of Statistics, 2005). Beans are grown for fresh market and for processing (i.e. canned or frozen). Queensland and Tasmania are the biggest producers of beans in Australia. Beans are often grown on sloping sites, using diversion drains to catch water runoff. Reducing "wet feet" is a priority for healthy bean plants. Where needed irrigation is carried out using moveable aluminium pipes with overhead sprinklers, travelling irrigators or furrow irrigation.

Harvesting is carried out from 7 to 11 weeks after planting. French beans are harvested by machine or by hand. Machine harvesting only allows a single pick and harvested material is sorted in packing sheds to remove leaves etc. Like many crops, plant material not harvested remains in the paddock and either ploughed in or eaten by stock.

Beans can be affected by a number of diseases including those listed in Table 1. Soil borne organisms are responsible for causing establishment diseases and stem rots that can be serious in certain bean growing regions. The damage results in large areas of plantings either not germinating or causing damage at a later growth stage. Many of these organisms can survive for long periods in soils, plant material or survive on volunteer weeds or alternate crops.

Soil borne disease management is important for the bean industry to maintain a reliable supply of high quality product.

This project **(**VG03002) commenced in January 2004. The aim was to investigate disease problems associated with beans especially those that contribute to stem and root rots. One of the main aims was to investigate disease issues in Tasmania and New South Wales that had not been addressed in a previous bean disease project VG024-*Bean root rot etiology and control*. Project VG024 targeted a bean disease in Queensland especially around Gympie which has been given the name red root. VG024 considered that a fungal complex contributed to the disease red root that included *Fusarium, Pythium, Rhizoctonia* and *Aphanomyces*. The disease was identified to be worse in the Gympie area especially in cold seasons (Wright *et al*. 1997).

In the 1980s a disease was identified in the Macksville area, of New South Wales (north coast). Investigations identified the disease as *Aphanomyces* root rot cause by *Aphanomyces euteiches* Drechs f.sp *phaseoli* Pfend & Hag (Allen *et al.* 1987). A product called Le-san® (fenuminosulph) was found able to control the disease however not long after this work Le-san® was withdrawn from use and since that time, when conditions are conducive to disease, large losses have resulted. *Aphanomyces euteiches* management had not been investigated thoroughly and its occurrence in other growing regions had not been fully investigated.

Aphanomyces has been recorded on other crops in Australia including lucerne (Abbo and Irwin 1990), clover (Barbetti 1991), subterranean clover (Greenhalgh *et al.*1985), faba beans (Leur *et al.* 2003), peas and beetroot (Hutton and O'Brien 1986, Martin 2003). Members of this genus can also cause diseases of fish.

A thorough review of *Aphanomyces* species that affected peas and sugar beet was undertaken by Papavizas and Ayers (1974). But since then the fungus has been identified on beans and recognised as one that is specific to beans (Pfender and Hagedorn 1982). Since that time others have found it associated with bean root rot (Allen *et al.* 1987, Oyarzun and Loon 1989).

Control of this fungus currently relies on avoidance of infected fields, however this becomes difficult where land is either under development or buying new land is not possible. There is a lack of resistant varieties though some resistance has been identified, the loss in other agronomic traits render them unacceptable for production.

Table 1: Common diseases of beans in Australia

Common name	**Organism**	**Symptoms**
Damping off	*Pythium, Rhizoctonia, Fusarium* sp	Damage to seedling restricting emergence before or after germination.
Ashy stem blight	*Macrophomina phaseolina*	Damage to lower stem of younger plants often lesion on one side of stem.
Sclerotium rot	*Sclerotium rolfsii*	Young plants affected causing plant death.
Fusarium root rot	*Fusarium solani, F. oxysporum*	Rotting of lower stem causing reddening and reduced plant vigour.
Aphanomyces root rot	*Aphanomyces euteiches* f.sp *phaseoli*	Watery brown colouring of roots especially tap root and hypocotyl. Whole blocks affected.
Sclerotinia rot	*Sclerotinia sclerotiorum*	Infection of stems causing weak plants or death. Pods may be affected.
Rhizoctonia stem rot	*Rhizoctonia*	Lesions on roots/hypocotyl.
Black root rot	*Thielaviopsis basicola*	Blackening of roots.
Root rot complex	*Fusarium, Pythium and Aphanomyces*	Red root. Lower hypocotyl reddish coloured. Plants survive but weak.
Bacterial brown spot	*Pseudomonas syringae pv syringae*	Leaf/pod spot
Common bacterial blight	*Xanthomonas campestris pv phaseoli*	Leaf/pod spot
Halo blight	*Pseudomonas syringae pv phaseolicola*	Leaf/pod spot
Pod twist	*Pseudomonas flectens*	Pod twist
Angular leaf spot	*Phaesiosariopsis griseola*	Leaf/pod spot
Anthracnose	*Colletotrichum lindemuthianum*	Pod spot
Ascochyta blight	*Phoma exigua (Ascochyta phaseoulorum)*	Leaf spot
Cercospora leaf spot	*Cercospora canescens*	Leaf spot
Cottony leak	*Pythium aphanidermatum*	Water soaked area on leaves and pods that may become covered in cottony growth.
Pleiochaeta brown spot	*Pleiochaeta setosa*	Leaf spot
Rust	*Uromyces appendiculatus*	Leaf spot
Viruses	Bean yellow mosaic, common mosaic, peanut mottle, bean summer death	Various symptoms from mosaic patterns on leaves to cupping and twisting or plant death.

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NEW SOUTH WALES RESEARCH ACTIVITIES

1. DISEASE SURVEY-MAJOR BEAN DISEASES IN NEW SOUTH WALES-

Introduction

Beans are an important crop and one of the many vegetables grown in northern New South Wales. The crop produced is of high quality supplying the fresh market. Crops are sown from October till March with harvesting being carried out from November till May. The production time fits into a harvesting window between some hotter areas in Queensland and some of the cooler areas in the south of the country. Some crops are harvested by hand whereas others are harvested mechanically. The area has had a long history of growing beans dating back to the 1950's. Generally the region has ideal conditions for bean production with a reliable rainfall which is augmented by sprinkler irrigation from dams in dry periods. Cattle are an important supplementary enterprise for north coast NSW bean growers.

Fig.1. Beans on the north coast of New South Wales with movable irrigation (left) and mechanical harvesting (right).

1.1 DISEASE SURVEY

A component of the project was an update on current disease issues affecting beans across Australia (surveys were carried out in Queensland, Tasmania and New South Wales). Plant samples were collected and root diseases identified. The main diseases found in New South Wales included the following:

Aphanomyces root rot

This disease as mentioned previously was first found on beans in the 1980's. *Aphanomyces euteiches* infects various crops including species of the genera of *Vicia*, *Phaseolus* and *Trifolium*. The symptoms maybe minimal, exhibited as root discolouration or more serious infections can cause rot of the primary roots, tap root and the hypocotyl (Fig. 2). Plants may either die early or maintain growth with reduced vigour until harvest. However if the crop is to be mechanically harvested, any weakness in the stems causing them to snap off and not allow the beans to be picked by the harvester.

Symptoms are expressed more severely under wet conditions; however in more seriously infected soils normal irrigation will encourage the disease. The fungus is similar in habit to *Pythium*.

The reproductive structures include zoospores (swimming type spores that require free water for movement within the soil) and oospores which are longer lived structures (as compared to zoospores) and are commonly seen in roots of infected plants.

Fig. 2. Symptoms of *Aphanomyces* infection on bean roots/hypocotyl from a pathogenicity test (interaction of fungus and host without outside biological interactions) with *Aphanomyces*. Plants on the left are beans in sterile vermiculite with *Aphanomyces* added and those on the right without any added *Aphanomyces*. Note the grey to light brown lesions that go from the tap root to the hypocotyl, the brown roots and smaller root mass (explanation of terms see Fig. 5).

Aphanomyces is very difficult to isolate from plant material and when attempted, fungi such as *Pythium* and *Fusarium* often out grow it on fungal media. A selective media that selects for *Aphanomyces* species is available but it is not always successful at isolating the fungus alone. Some success at isolating *Aphanomyces* is achieved by first treating soil (suspected of containing the fungus) with a fungicide that controls *Pythium* and then planting beans followed by watering heavily after plant emergence. Identifying the fungus on the plant may be achieved by placing roots in small dishes such as petri dishes with water and watching under a microscope over the next 48 hours for the characteristic sporangia and method of zoospore production. Alternatively looking for oospores on the roots that are typical of *Aphanomyces* can also assist in its identification.

Other diseases.

Other disease causing organisms were encountered in the disease survey but considered minor compared to *Aphanomyces*. These included *Rhizoctonia* (Fig. 3), *Sclerotium*, *Pythium* and *Fusarium*. No *Sclerotinia* was found during the survey. Rust (*Uromyces appendiculatus*) was also found during the survey but was a minor issue for most growers due to the varieties grown being partially resistant. One grower of small beans did have some problems with rust due to the lack of suitable tolerant varieties.

Fig. 3. Typical lesions of *Rhizoctonia* root rot. The brown *Rhizoctonia* can be seen lower on the image on the right.

2. *APHANOMYCES*-ISOLATION OF *APHANOMYCES*, PATHOGENICITY TESTING, SOIL BIOASSAY AND POTENTIAL FUNGICIDE CONTROL OPTIONS.

2.1 ISOLATION OF *APHANOMYCES*

The fungus *Aphanomyces* is very difficult to isolate from plant material. Unfortunately other fungi associated with bean plants that may have come from the seed or the soil often outgrows *Aphanomyces*. These fungi are usually *Pythium* and *Fusarium*. Eliminating these fungi is difficult with standard media.

We often used a selective media known as MBV (metalaxyl-benomyl-vancomycin media) that was developed for the isolation of *Aphanomyces* (Pfender *et al.* 1984). It contains the following ingredients.

- Difco Bacto Agar 10g
- Difco Cornmeal agar. 10g
- Distilled water 1L
- Metalaxyl 30mg (dissolved in 95% ethanol at 10mg a.i./ml).
- Benomyl 5mg
- Vancomycin 200mg
- Amphotericin B 0.5mg

The first three ingredients are autoclaved and the rest of the ingredients are added when the agar cools to approximately 45-50^{0}C.

Plant tissue is placed on the media and then pieces of any fungal colonies that grow are also placed on new plates of the same media. Contamination was still a problem especially with *Pythium,* most likely due to metalaxyl resistant species. It is very difficult to isolate *Aphanomyces* from mature plants. If infected soil is available planting bean seed into the soil that has been treated with an anti *Pythium* fungicide can reduce *Pythium* levels in plants and subsequently on media when using infected tissue for *Aphanomyces* isolation.

2.2 PATHOGENICITY TESTING

Introduction

This trial was undertaken to test the pathogenicity (i.e. to prove that symptoms were caused by the fungus) of *Aphanomyces* using an isolate of *Aphanomyces* that had been cultured from beans.

Materials and methods.

An *Aphanomyces* culture was isolated from bean root tissue on MBV media. The culture was isolated from beans that were grown in infected soil previously treated with Fongarid® (active ingredient fluralaxyl). Sterile vermiculite was placed into ten 90mm x 115mm pots. Five untreated seeds of the variety “Strike” were sown into each pot. After one week half the pots were treated with half an agar plate of *Aphanomyces* mashed into the vermiculite. The plants were wet up at the two leaf stage.

Results

After one month, plants that had been treated with the *Aphanomyces* showed symptoms of the disease, either as a root discolouration or lesion affecting the lower stem. The lesions were a light grey to tan colour with roots brown and not as developed (Fig. 2). Those that had not been treated with *Aphanomyces* showed no symptoms Pieces of root material from infected plants were then placed either into petri dishes with sterile water or onto MBV media.

Observation of the roots in water showed the development of the typical *Aphanomyces* sporangia and zoospores (Fig. 4). *Aphanomyces* was isolated on the MBV media.

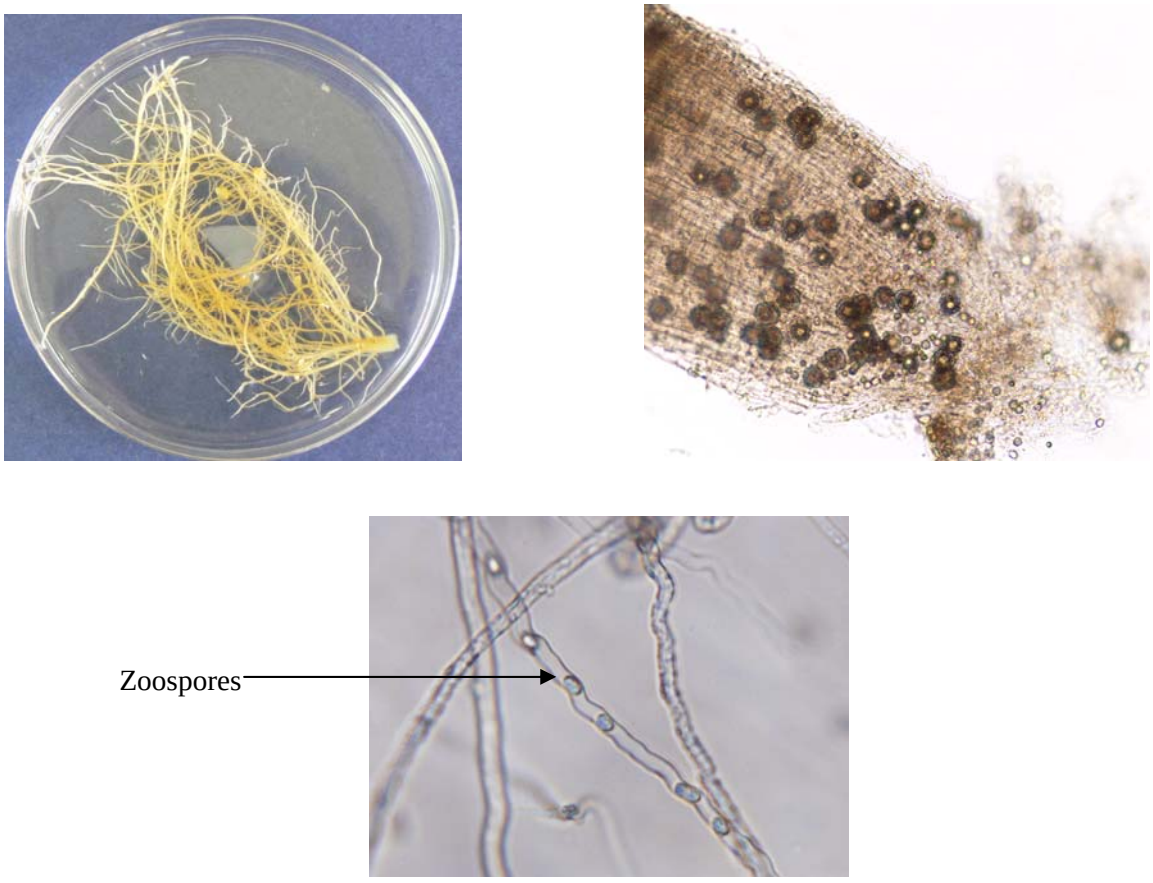

Fig. 4. (From upper left) Browning of roots associated with infection from *Aphanomyces* on the agar piece in the middle of the roots oospores in the roots, on the photograph on the right hand side. Lower photograph of zoospores ready to move out of the sporangia into water.

Discussion

The root rot that is found in the Macksville area of New South Wales was previously identified as being caused by *Aphanomyces euteiches* (Allen *et al.* 1987). This observation was confirmed during the course of this project but it was found to be very difficult to isolate the pathogen. Once isolated, *Aphanomyces* was found to lose its pathogenicity (infection capability) quite quickly. Therefore when the fungus is to be used for trials, fresh isolates need to be reisolated and tested for pathogenicity.

2.3 PRE-PLANTING SOIL BIOASSAY.

A soil bioassay (test using plants) was trialled that would give some indication prior to planting, the level of *Aphanomyces* root rot that would likely be encountered for particular blocks. Soil was collected from the site randomly so that it was a good representation of the block. It was well mixed and stones removed, then placed into five pots for each block. Bean seeds were planted and then watered up till they germinate in a glasshouse or warm spot (around 20-25^{0}C). At the two leaf stage they were watered three times a day and in two weeks disease symptoms were assessed and a

percentage calculated. Below 30% disease was considered an acceptable level to plant into whereas 30-50% was considered marginal. Above 50% was considered not suitable to plant beans. However these figures have not been adequately tested with enough samples to accurately determine the parameters. Further developments on this system have been applied to assessing *Aphanomyces* root rot risk to peas where ratings of disease are used to calculate an index referred to as the disease severity index (Sherwood and Hagedorn 1962, Singleton *et al.* 1992)

2.4 FUNGICIDAL CONTROL

Control of *Aphanomyces* is limited by the lack of fungicides. Those fungicides that have some efficacy against *Pythium* do not control *Aphanomyces*. Potential fungicides for control are included in Table 2 (Erwin *et al.* 1983).

Table 2: The table below is a list of fungicide active ingredients and the fungal organisms against which they have some efficacy.

Fungicide active ingredient and control				
Soil Borne Organism	metalaxyl, fluralaxyl, benalaxyl	propamocarb	fosetyl-aluminium	hymexazol
Aphanomyces	-	+/-	?	+*
Fusarium	-	-	-	+
Phytophthora	+	+	+	-
Pythium	+	+/-	+	+

(- = no control, + = good control, +/- =variable control, ? =unknown).
*Hymexazol has been shown to assist in the management of *Aphanomyces cochloides* on sugar beet, buts its efficacy on the bean *Aphanomyces* in Australia is not known.

2.5 METHOD OF DISEASE ASSESSMENT

Disease symptoms for trials were assessed using a 0-5 scale based on root and hypocotyl (Fig. 5) colour and health. The 0 rating was no disease and the 5 rating was high disease. For most trials roots and hypocotyls were assessed separately, whereas with others often only the hypocotyl was assessed. The disease ratings were based on the symptoms shown in (Fig. 6).

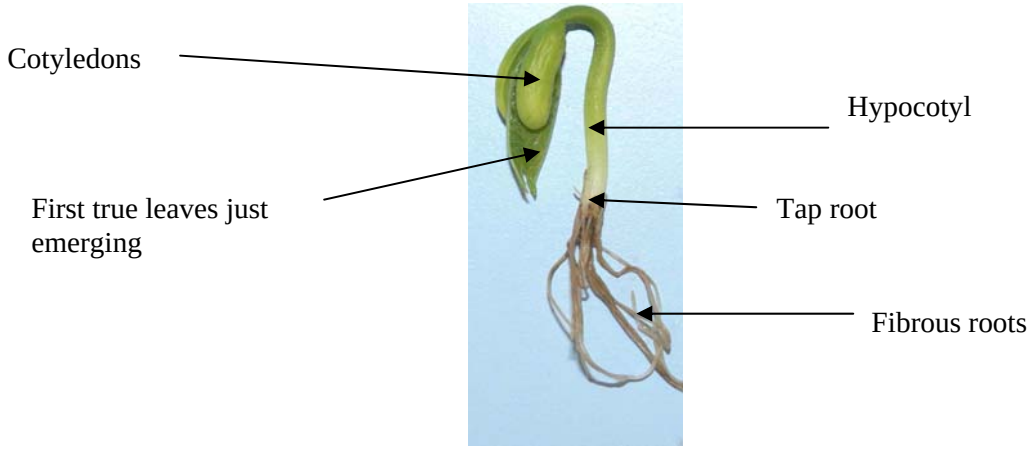

Fig. 5. Parts of the bean plant showing the hypocotyl region which was the main area examined for disease symptoms.

Fig. 6. Disease ratings were based around the symptoms shown in the above photograph. Often root colour was no different but showed various levels of decay.

2.5 WETTING UP PERIOD

When carrying out trials in the NSW component of this report, plants were given a wet period to instigate infection by *Aphanomyces*. The fungus needs free moisture to produce zoospores (swimming spores) that then use the water to swim from infected tissue to non infected. These zoospores do not move across long distances possibly only as far as 10mm (Papavizas and Ayers 1974). The wetting-up period occurred at about the two leaf stage and consisted of watering the containers three times per day for three days.

For many of the glasshouse trials infected soils were used that had been collected from growers' properties, these were either used on their own or mixed with vermiculite. Vermiculite is a product that is commonly used in potting mixes.

2.6 VARIETY TRIAL

Introduction

A trial was established to identify any differences that may exist in susceptibility across available bean varieties. Some pea varieties were also included.

Materials and method

Ten seeds from a number of commercially available bean varieties were planted into large pots containing infected soil collected from the Valla area of New South Wales. The soil was mixed with sterile vermiculite in a ratio of 50:50. Seeds were planted and pots placed in a glasshouse. At the two leaf stage plants were put through the wetting up process. Plants were examined four weeks after sowing for tap root/hypocotyl lesions.

Results

All bean varieties expressed similar symptoms of *Aphanomyces* root rot whereas peas were free of disease symptoms.

Table 3 The appearance of symptoms on varieties of peas and beans*.

Variety	Plant	Symptom development
Greenfeast Pea	Pea	-
Snow Pea Oregon Dwarf	Pea	-
Telephone Pea	Pea	-
Dwarf Blue Bantam Pea	Pea	-
Early Crop Massey Pea	Pea	-
Sugar Snap Pea	Pea	-
Dwarf French Bean	Bean	+
Blue Lake Climbing Bean	Bean	+
Epicure Climbing Bean	Bean	+
Purple Queen Dwarf Bean	Bean	+
Brown Beauty Dwarf Bean	Bean	+
Tendergreen Dwarf Bean	Bean	+
Pioneer Dwarf Bean	Bean	+
Hawkesbury Wonder Dwarf Bean	Bean	+
Dwarf French Bean	Bean	+
Purple King Climbing Bean	Bean	+
Borlotti bean	Bean	+

* Beans and peas were “off the shelf” varieties. Commercial varieties were also tested and these were also positive.

Discussion

All bean varieties were susceptible, producing the typical lesions on the hypocotyl. No symptoms appeared on the peas indicating that the fungus in this growing region is currently only specific to beans.

2.7 THE LEVEL OF *APHANOMYCES* IN NORTH COAST SOILS WITH DIFFERENT HISTORIES OF BEAN PRODUCTION

Introduction

The soil bioassay mentioned previously can indicate the level of disease or the potential expression of disease if conditions are favourable. This technique was used to rate soils from different histories of bean production across the Macksville area of northern NSW. It would also provide an indication as to whether *Aphanomyces* has always been in this region or whether it has appeared since the introduction of beans to the area.

Methods and materials

Twelve soils with varying histories of bean production were collected and used in the trial. Each soil was sieved to remove stones and then placed into six totes (square plastic containers with dimension 385mm long x 290mm wide x130mm deep soil depth 75 mm). Seed variety "Simba" was sown into each tote. Plants were maintained in a glasshouse at between 20^0 C and 30^0 C. At the two leaf stage plants were wet up and at twenty two days after sowing plants were assessed by counting the number with typical hypocotyl lesions as a percentage of the total that had germinated.

Results

The percentages of plants infected are represented in the Table 4 and Fig. 7.

Table 4: The table lists the soils collected and the history of bean production from each block and disease incidence. Disease incidence was related to cropping history, the more recent that the soils had beans then the higher the disease levels.

Soil number	Farm	History	Percentage of stems showing infection
1	1	Beans 30 years previous.	2
2	2	Never had beans before.	6
3	3	No beans for 6 years.	11
4	4	Last beans 8 years ago.	18
5	4	Last beans 10 years ago.	28
6	5	Beans three years ago.	68
7	3	Beans three years ago.	69
8	5	Beans previous year.	79
9	3	Beans within the last year.	80
10	3	Beans within the last year.	86
11	4	Beans within the last year.	91
12	3	Beans within the last year.	96

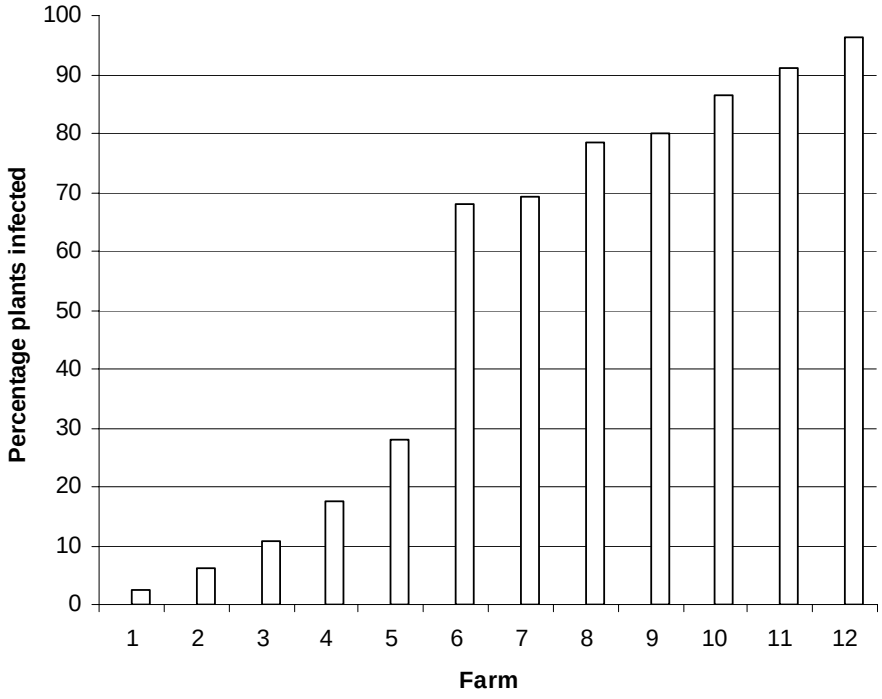

Fig. 7. The graph indicates the percentage of plants showing typical *Aphanomyces* lesions on the hypocotyl. Blocks with more recent bean production (e.g. Soil 12) were more affected than those such as Soil 1 and 2 that have had nil or low levels of bean production.

Discussion

The information collected from this trial showed that soil from areas that had beans more recently had more serious disease symptoms; therefore planting beans in these blocks would have increased the risk of disease development. The time span between bean crops is important to reduce disease as any of the above soils that had beans planted in them in the previous four years had quite serious infections. This situation makes it very difficult to continue bean production as new ground must always be found. Growers do not have land available to achieve this; therefore for the survival of this industry in this region controlling this disease is critical.

This information also indicates that some disease was present even in soil that had not had beans planted in it for many years or even soil that had never had beans at all, indicating that this fungus is most likely a natural inhabitant of this area. These soils were reused in a later seed dressing trial where it was shown the disease levels were even high in Soils 1 and 2 indicating that build of disease is quite rapid.

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3. BEAN DISEASE MANAGEMENT TRIALS-GLASSHOUSE

3.1 ASSESSMENTS OF FUNGICEDS AS SEED DRESSINGS TO CONTROL ROOT ROT OF BEANS

Introduction

Seed dressings of various fungicides are commonly used across different crops to prevent pre-emergence and post-emergence damping off. Currently bean seed is treated with either of the fungicides captan, thiram or Apron XL/Maxim (which is metalaxyl-M and fludioxonil). Damping off is the term used to describe the interruption of plant development at the seedling stage usually by soil borne fungi. The infection results in weakened or often dead plants. The fungi involved are usually those that have been referred to before such as *Pythium*, *Fusarium* or *Rhizoctonia*. The effect of seed dressings on *Aphanomyces* root rot of beans has not been determined in Australia, therefore trials were undertaken to assess various seed dressings on the possibility of reducing disease incidence. If infection could be reduced early, the plants may survive better till flowering and pod production.

A number of trials were carried out in the glasshouse or in the field to assess the efficacy of seed dressings.

Materials and method.

Seed dressings for various trials and active ingredients are listed in Table 5. These were applied to seed and allowed to air dry. Some seed was washed to remove seed dressing because untreated seed was unavailable at the time, or when available untreated seed was used. At assessment time plants were carefully removed from soil, washed and rated for root and hypocotyl lesions.

Table 5. The details of fungicide seed dressings, active ingredients and rates. The activity of these fungicides against different organisms has been listed in Appendix I.

Seed treatment Code	Active ingredient(ai)	Concentration of ai	Product rate/100kg seed	Active ingredient concentration g/100 kg seed
Captan	captan	800 g/kg	1 kg	800
Thiram	thiram	800g/kg	1 kg	800
A	azoxystrobin	100 g/L	50 ml	5
F	fludioxonil	100 g/L	50 ml	5
FM	fludioxonil + metalaxyl-M	25 g/L + 10 g/L	150 ml	3.75 + 1.5
MF	metalaxyl-M + fludioxonil	37.5 g/L + 25 g/L	150 ml	5.625 + 3.75
DM	difenconazole + metalaxyl-M	92 g/L + 23 g/L	130 ml	11.96 + 2.99
AFM	azoxystrobin + fludioxonil + metalaxyl-M	75 g/L + 12.5 g/L + 37.5 g/L	100 ml	7.5 + 1.25 + 3.75
Hymexazol	hymexazol	700g/kg	0.5 kg	500
Alliette	fosetyl Al	800g/kg	0.6 kg	480

Trial 1

Three soils from different farms known to cause root rot in beans were collected from the growing region. Soils were sieved to remove stones and were placed into totes (square plastic containers with dimension 385mm long x 290mm wide x130mm deep soil depth 75 mm). There were three replicates of each. Ten seeds of the variety "Strike" (no seed dressing) with seed dressings that included: thiram, captan, DM, FM, F and untreated were sown into totes therefore six rows per tote. The totes were placed in a glasshouse at 28^0C day and 22^0C night temperatures. At the two leaf stage, seven days after sowing, they were watered heavily. At fourteen days after sowing plants were carefully removed from

the soil and roots washed and assessed for disease incidence. The germination and dry weight of plants was also measured.

Trial 2

The same twelve soils used in a previous trial (section 2.7) were replanted with seed variety "Simba" (washed to remove commercial seed dressing) that had been treated with various seed dressings that included captan, thiram, A, F, MF, FM, DM, AFM, hymexazol, fosetyl Al, simba (with the commercial seed dressing-Apron XL/ Maxim) and washed simba (with seed dressing removed). Six rows of ten seeds of each seed dressing were sown into each tote. After nine days plants were put through a wetting up period. After 15 days the plants were assessed for disease symptoms.

One soil from a Gympie grower was included in the trial but due to the small quantity was not replicated.

Results

Trial 1

Captan and thiram gave significantly less disease symptoms compared to the other treatments for both hypocotyl rating and the root rating (Table 6). For dry weights the FM treatment was significantly higher than the other treatments. Germination was not affected by any of the seed treatments.

Table 6: Results showing that thiram and captan showed a significant improvement in disease levels on hypocotyls and roots.

Seed treatment	Hypocotyl/tap root rating	Root rating	Mean dry weight (g)
Thiram	0.1 a	1.3 a	1.6 b
Captan	0.4 a	1.2 a	1.7 b
DM	1.4 b	1.8 b	1.5 bc
FM	1.4 b	1.9 b	1.8 a
F	1.7 bc	1.9 b	1.6 b
Untreated	1.9 c	2.1 b	1.4 bc

Values with the same letter are not significantly different (at the 1% level and 5% for dry weight).

Trial 2

Hymexazol showed reduced disease symptoms in all soils (Table 7). All the other treatments showed some variability across all soils with captan and thiram showing some disease control in some of the soils. The reactions of the seed dressings in the Gympie soil were totally different to the other soils.

There was no significance with the interaction between dressings and soils (Table 8). Graphs of the disease ratings of all the soils are in Appendix II.

Table 7: Mean disease rating for each seed dressings across all soils. Only hymexazol was significantly different from all dressings across all soils. Captan was significantly better in some soils. Hymexazol also had the highest significant dry weight.

Fungicide	Hypocotyl rating	Root rating	Mean dry weight (g)
Hymexazol	1.3 a	1.7 a	3.31 e
Captan	2.9 b	2.3 b	2.50 bc
Fosetyl Al	3.0 bc	2.4 bc	2.82 d
Thiram	3.1 bcd	2.4 bc	2.62 bcd
AFM	3.1 bcd	2.3 b	1.99 a
F	3.2 cde	2.4 bc	2.63 cd
DM	3.2 cde	2.6 d	2.49 bc
FM	3.2 cde	2.6 d	2.59 bcd
A	3.2 cde	2.5 cd	1.92 a
Simba(treated with ApronXL/Maxim)	3.3 de	2.6 d	2.46 bc
MF	3.3 de	2.4 bcd	2.31 b
Untreated (washed simba)	3.4 e	2.6 d	2.54 bcd

Observations with the same letter are not significantly different at the 5% level LSD

Table 8. Each soil and the disease ratings related to each seed dressing. Graphs of these ratings are in Appendix II.

Soil number	AFM	A	Captan	DM	F	FM	Fosetyl Al	Hym	MF	Thiram	Simba (treated)	Simba (washed)
1	2.7	3.3	1.7	3.6	2.3	2.8	2.8	0.2	3.1	2.2	1.9	2.8
2	2.8	3.4	2.7	3.5	3.1	2.8	3.3	0.8	3.4	2.9	2.5	3.2
3	2.8	3.3	0.8	1.9	3.0	2.1	1.5	0.0	2.7	2.4	2.0	2.4
4	3.2	3.1	2.4	2.7	3.3	3.0	3.3	0.6	3.7	3.4	2.9	3.6
5	3.6	3.1	3.1	3.5	3.2	3.4	3.0	0.6	3.7	3.1	3.4	3.5
6	3.9	3.2	3.3	3.4	2.9	3.4	2.8	2.1	3.8	2.9	3.9	3.3
7	3.4	3.8	3.0	3.6	3.3	3.7	3.2	1.0	3.3	3.7	3.2	3.7
8	3.4	3.3	4.1	2.7	3.0	3.6	2.4	1.4	3.3	2.8	4.0	3.7
9	3.5	3.4	2.9	3.0	3.4	3.5	3.3	1.1	3.1	3.8	3.3	3.6
10	3.1	3.3	2.8	3.4	3.0	2.8	3.8	2.0	3.3	3.4	3.8	3.4
11	3.7	3.9	3.5	4.0	4.0	3.9	2.9	2.0	3.5	3.5	4.0	3.8
12	3.8	3.4	3.9	3.9	3.6	3.8	3.8	1.4	3.1	3.7	3.4	3.9

Discussion

The seed dressing trials showed some improvement with disease control using thiram and captan but the best control was achieved with hymexazol. Hymexazol has some registration in other countries to control *Aphanomyces* in sugar beet. The product however is not available in Australia. The correct seed dressing appears vital in assisting management of this disease and the use of hymexazol on beans in Australia should be considered.

The success of hymexazol, which is known to target *Aphanomyces*, also provides some confirmation that the disease issue on the north coast is definitely caused by *Aphanomyces*. The rate selected for this trial showed good control of disease symptoms but whether lower rates would also be successful were tested in a later trial.

3.2 EVALUATION OF VARIOUS RATES OF HYMEXAZOL AS A SEED DRESSING TO CONTROL BEAN ROOT ROT.

Introduction

As hymexazol had shown some efficacy against *Aphanomyces* in the previous trial, an experiment was developed to investigate various rates of the seed dressing to observe if reduced rates would give adequate control.

Materials and method.

Seeds of the variety Simba (washed to remove the seed dressing) were treated with hymexazol (in an appropriate amount of water) and allowed to air dry. Seeds of each dressing rate (Table 9) were sown into *Aphanomyces* infected soil that had been put into five totes and after a wetting up period, plants were assessed for disease symptoms at three weeks after sowing.

Results

Disease control was best with the highest rate of hymexazol for both hypocotyl and root lesions. However statistically the highest three rates were not significantly different for hypocotyl lesions. For root lesion ratings the highest rate was the best but statistically only significantly different to the untreated control.

Table 9: Hymexazol rates used in the trial and disease ratings.

Hymexazol Rate/100kg (g)	Hypocotyl lesion rating	Root lesion rating
500	2.6 a	2.0 a
400	3.1 a	2.3 ab
300	3.2 a	2.1 ab
200	3.8 b	2.5 bc
Untreated	4.1 b	2.9 c

Observations with the same letter are not significantly different at the 5% level LSD.

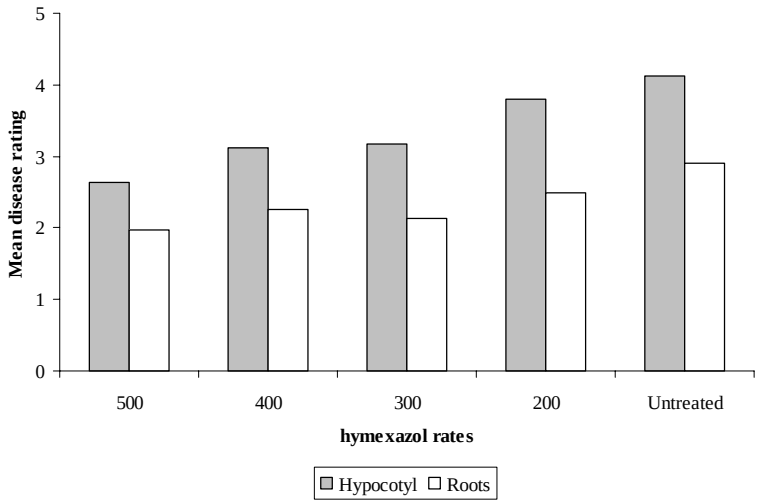

Fig. 8. Levels of disease symptoms as in Table 9.

Discussion.

The highest rate of hymexazol was the best overall at controlling this disease however it was not statistically different to the next two lower rates. Further work could be considered with this fungicide however its lack of registration etc, makes the importance of this work debateable. Seed dressings are easy to apply and have low environmental impact. Hymexazol in these conditions showed no effect on germination or plant health.

Hymexazol was registered for minor use on sugar beet in the United States to control *Aphanomyces cochloides*. This was an industry response that involved many agencies. Like *Aphanomyces euteiches* on beans, *A. cochloides* once established in a field, avoidance from growing in that field is the only option to reduce disease. Sugar beet producers are also having difficulty finding new land (Harveson *et al.* 2007).

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3.3 ASSESSMENT OF FUNGICIDES AS SOIL DRENCHES TO CONTROL ROOT DISEASES OF BEANS

Introduction

Soil borne disease management can be assisted by the targeted use of soil drenches. Products used to control other soil borne organisms such as *Pythium* and *Phytophthora* do not normally control *Aphanomyces* (Table 1). Therefore potential fungicides for management of *Aphanomyces* root rot were investigated using soil known to carry the disease. Thiram and captan are broad spectrum fungicides that were trialled as they showed some efficacy against root rot as seed dressings. Thiram has registration in Queensland as a soil drench to control *Pythium*. Hymexazol has the best known activity against *Aphanomyces* where overseas it is used as a seed dressing and as a soil drench. Propamocarb may also have some potential to control *Aphanomyces*. Azoxystrobin has broad spectrum activity; the activity of these fungicides has been listed in Appendix I.

Method and Materials

Soils collected previously from a known infected site were mixed with vermiculite. The soil was then placed into plastic totes. The drenching treatments included two rates each of Thiram®, Captan®, Amistar®, Previcur®, hymexazol and water only. Active ingredients for the fungicides are listed in Table 10. The rates of each fungicide are listed in Table 11. One litre of each treatment was applied per tote and each treatment was replicated three times. Twenty seeds of the variety Simba were planted into each tote.

At the two leaf stage the totes were wet up and after 25 days plants symptoms were assessed. Heights and dry weights were measured.

Table 10: The fungicides, active ingredients and concentrations used in the trials.

Fungicide	Active ingredient(ai)	Concentration of ai
Amistar	azoxystrobin	500g/kg
Captan	captan	800g/kg
Hymexazol	hymexazol	700g/kg
Previcur	propamocarb	600g/L
Thiram	thiram	800g/kg

Table 11: Fungicides and their rates used in the soil drench trial.

Fungicide	Low rate ai/m^2	High rate ai/m^2	Fungicide rate/m^2 (Low)	Fungicide rate/m^2 (High)
Amistar	1.1 g	4.5 g	2.2 g	9.0 g
Captan	2.9 g	9.0 g	2.3 g	11.3 g
Hymexazol	1.3 g	3.8 g	1.8 g	5.4 g
Previcur	3.4 g	13.4 g	5.6 ml	22 ml
Thiram	3.6 g	10.7 g	4.5 g	13.4 g

Results

Hymexazol, Previcur and Amistar as soil drenches were successful at controlling *Aphanomyces* stem rot (Table 12, Fig. 9). Hymexazol also had the highest plant height and dry weight (Fig. 10).

Table 12: The effect of fungicide drenches on controlling disease in *Aphanomyces* infected soil. Disease was significantly reduced by the application of Hymexazol, Previcur and Amistar.

Fungicide	**Mean disease rating (hypocotyl/tap root)**	**Percentage of disease free plants**	**Average Plant Height (cm)**	**Plant dry weight (g/plant)**
Hymexazol H	0.0 a	100.0	14.2 a	9.4 a
Previcur H	0.1 a	96.2	12.3 bc	7.6 de
Amistar H	0.2 ab	82.9	10.5 cd	7.2 de
Previcur L	0.4 ab	73.4	13.6 ab	9.0 a
Amistar L	0.5 ab	56.2	12.9 ab	9.0 a
Thiram H	0.9 bc	46.8	12.8 ab	7.8 cde
Hymexazol L	1.3 cd	16.4	14.2 ab	8.8 ab
Captan H	1.5 cde	20.8	13.5 ab	7.8 cde
Captan L	1.9 de	21.3	13.8 ab	8.3 abc
Thiram L	2.2 ef	10.4	13.9 ab	9.1 a
Untreated	2.7 f	7.3	13.2 ab	6.0 f

Observations with the same letter are not significantly different at the 5% level LSD.

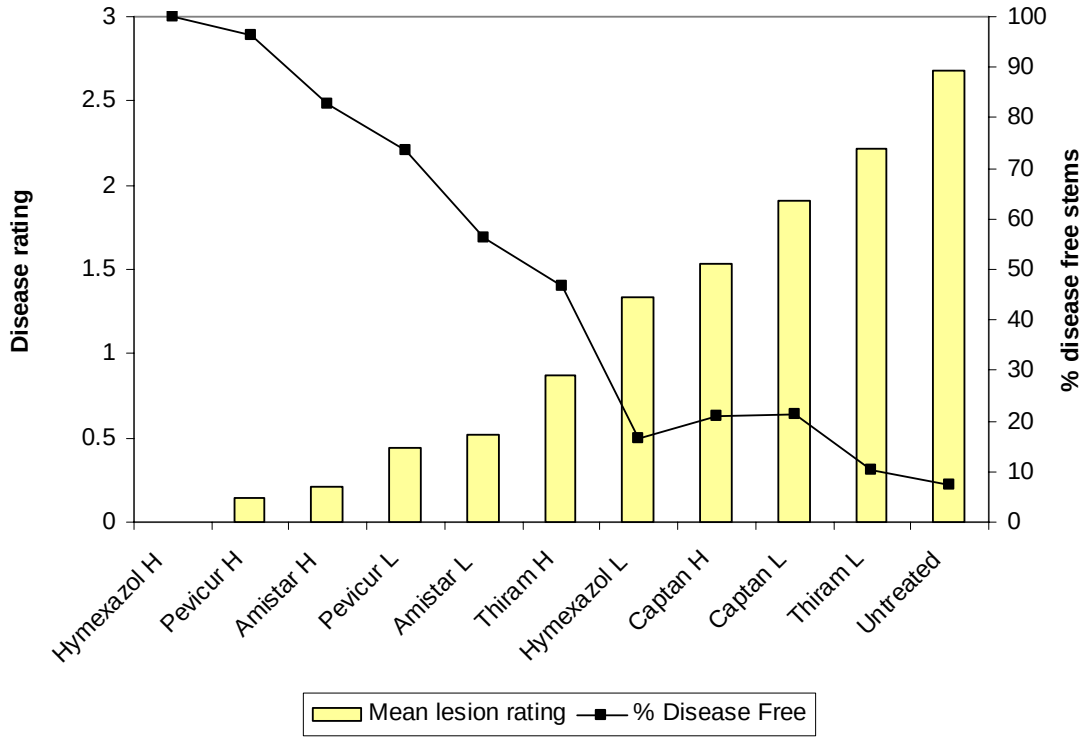

Fig. 9. Graph showing the effect of fungicides as a soil drench on disease levels.

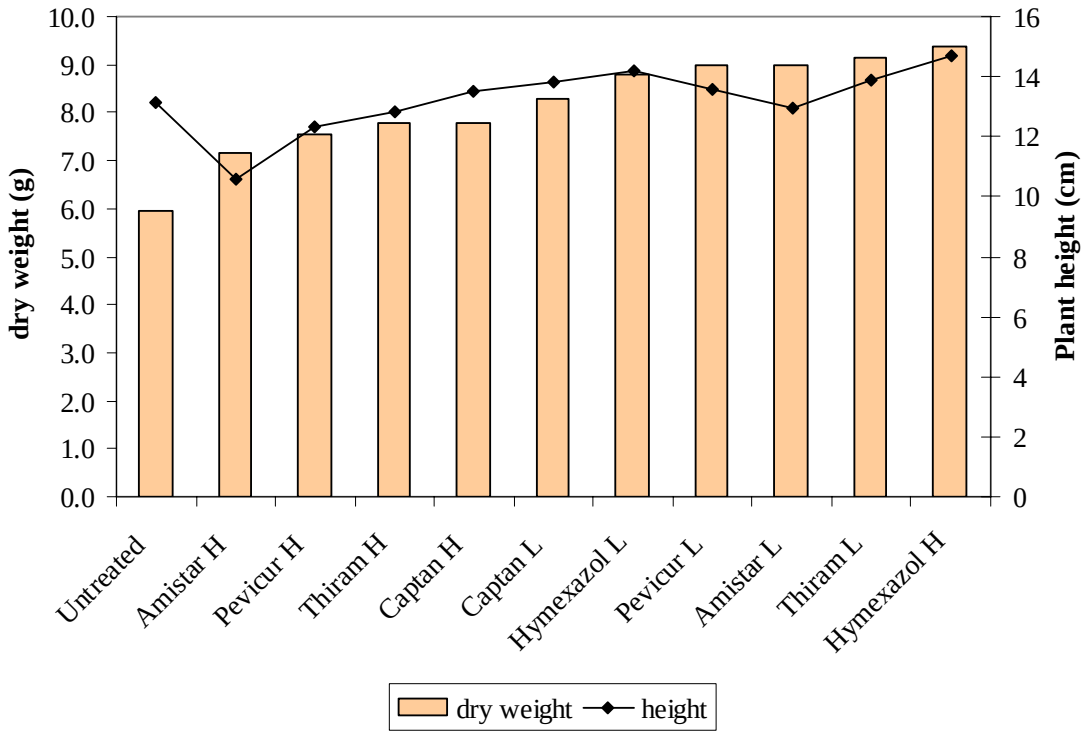

Fig. 10. Graph showing the effect of fungicides on dry weight and plant height. All fungicides improved dry weight significantly compared to the untreated control.

Discussion

Hymexazol also performed the best in this trial; however Amistar and Previcur also showed disease control potential. This is important as these fungicides may be able to be used for *Aphanomyces* control as they are available in Australia. Previcur is used for *Aphanomyces* control in European countries and a permit for its use may be obtainable, pending the availability of residue data. Thiram has a registration in Queensland for damping off on beans; it performed reasonably well indicating that it may also have some activity against *Aphanomyces* (also indicated in the seed dressing trials).

Apart from the potential of having some of these fungicides for *Aphanomyces* root rot, the economics of the application of these fungicides as soil drenches needs to be considered. Further development of the rates used also needs consideration.

3.4 THE POTENTIAL OF FUMIGATION TO CONTROL *APHANOMYCES* ROOT ROT

Introduction

Soil borne disease control in other crops can be achieved using the application of fumigants to soil. However this is only economic with some high value crops. The potential to control soil borne diseases of beans using a fumigant was examined. A preliminary trial had shown a reduction in disease levels when the basamid was applied at a single rate.

Materials and methods.

Basamid® (dazomet 940g/kg) was applied to soil at three rates 50, 25 and 12.5 g/m^2. This is equivalent to full, half and quarter normal rates of application to control soil borne diseases. The plots were 25 metres long by 1.8 metres wide. The plots were not replicated. The basamid was broadcast by hand and incorporated with a tractor mounted rotary hoe. The soil was then left undisturbed for two months after which soil was collected and placed into totes. Beans were sown into the totes and watered till germination and at the two leaf stage watered to produce symptoms. After 21 days, twenty beans from each treatment had their roots and hypocotyls assessed for disease symptoms using the 0-5 rating.

Results

The normal or full rate of basamid reduced disease levels compared to the other rates (Table 13). As this was not a replicated trial, statistical analysis was not undertaken.

Table 13: The disease ratings of the Basamid treated soil were lower than the other rates.

Basamid Rate	Hypocotyl Rating	Root Rating	Dry Weight (g/20 plants)
Full	0.4	0.2	16.1
Half	3.8	1.3	14.4
Quarter	3.6	1.95	13.1

Fig. 11. Bean stems with the normal rate of Basamid on the left showing whiter tap roots and fibrous roots as compared to the half rate on the right(quarter rate was the same).

Discussion

The use of fumigants has been successful in controlling other soil borne diseases of various crops; however rates and the economics of their use need to be considered.

This trial showed good disease control using Basamid. The site that the trial was situated was heavily infected with *Aphanomyces*, having beans earlier in the same year.

The use of fumigants needs to be decided by the economic constraints of doing so. The plant back period i.e. the period from application till crops can be sown without damage needs to be considered. Also the number of crops that can be replanted before disease returns needs to be taken in to account. Economics is going to be the deciding factor as returns on bean crops would not be considered high enough to treat large areas with fumigants.

One identified problem with fumigants is that after the population of beneficial fungi are also removed from a soil then if the target fungus is able to survive, its increase in the soil is not challenged by antagonistic organisms. The result of this is therefore that over time disease may be worse than before.

Another important consideration is the proximity of crops to residential areas and the potential of fumigant drift and its implications. Many of the north coast beans are close to residential areas.

3.5 THE EVALUATION OF ALTERNATE CROPS TO REDUCE *APHANOMYCES* DISEASE LEVELS IN SOIL

Introduction

Rotating crops or using alternate crops that may have some antagonistic reaction to soil borne diseases have been investigated by others (Fritz *et al.* 1995, Smolinska *et al.* 1997, Williams-Woodward *et al.* 1997). A trial was established to investigate if growing different crops before beans may assist in a reduction in disease levels. Soil known to contain *Aphanomyces* and various rotational crops were trialled in a glasshouse.

Materials and methods

Large plastic "ice cream" containers were filled with a mixture of vermiculite and known infected grower soil, and beans planted. Once the planted beans reached the two leaf stage the containers were wet up to produce symptoms. After one month at 20-27^{0}C these plants were then incorporated into the soil. The containers were then left for a further month to breakdown. At this stage seeds of Rangi rape (a common rotation crop used as a biofumigant), oats, barley, corn, snow peas and beans were sown into a container each. Each treatment was replicated three times.

The plants were allowed to grow for one month after which they were green mulched into the soil. The containers with beans were the only ones that developed any *Aphanomyces* type lesions. The containers were then left for one month when beans were planted and symptoms observed after a wetting up period. Another treatment of compost tea (sourced locally from a commercial producer of compost teas) was added where an application was made before the beans were planted. After six weeks plants were assessed for typical *Aphanomyces* lesions.

Results

Rotation crops had no effect on disease levels. There were no significant differences between treatments (Table 14).

Table 14: The effect of the rotation crop on disease levels on beans planted after the rotation crop.

Preceding plant type	Scientific name	Hypocotyl (Rating)	Root (Rating)
Barley	*Hordeum vulgare*	3.6	3.6
No rotation crop	N/A	3.8	3.0
Snow pea	*Pisum sativum*	3.9	3.0
Beans variety "Strike"	*Phaseolus vulgaris*	3.9	3.0
Oats	*Avena sativa*	4.0	3.0
Rangi rape	*Brassica napus oleifera biennis*	4.0	3.8
Corn	*Zea mays*	4.1	3.7
Compost tea	N/A	4.2	3.4

Discussion.

This was only a small trial but gave some indication that any alternate crops would not improve disease levels.

Aphanomyces may not be pathogenic to many plants but is able to exist on many plants. This list has not been developed for Australia but a list has been developed for the pea type *Aphanomyces* in America (Papavizas and Ayers 1974). This list is quite large and even though the plants did not always produce symptoms of disease the fungus often just survived on plant roots.

Rangi rape and many of the Brassica group have been identified as producers of isothiocyanates (ITC's) (Matthiessen and Kirkegaard 1994). An artificial form of ITC is metham sodium which is commonly used as a soil fumigant. Research has been undertaken on this method of

disease control but results are mixed and may be different for different fungal pathogens (Larkin and Griffin 2007).

Other considerations with green manures are the length of time that the crops have been incorporated into the soil and the age of the crop that is incorporated. These could be investigated more fully in the *Aphanomyces* root rot disease but other issues need to be considered such as how these crops can fit into the current farm management system, i.e. do they fit in with their other enterprises such as cattle. As disease control options are limited for controlling *Aphanomyces* root rot, the potential for more trials with *Brassicas* should be contemplated but unfortunately these trials take a long time.

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4. BEAN DISEASE MANAGEMENT TRIALS-FIELD

4.1 ASSESSMENT OF FUNGICIDE SEED DRESSING AND SOIL DRENCHES TO CONTROL ROOT ROT OF BEANS

Introduction

Field application of fungicides as a soil drench offer some control of soil borne diseases. Trials were established in spring 2006 in the Valla area of northern NSW to gauge the potential of this method in controlling bean root rot.

Materials and Method

Four initial field trials were established to examine the efficacy of fungicides to control bean root disease. The trials were based at two different sites. Site 1 had not had beans for six years whereas Site 2 had beans the previous year.

At each site there were two trials, a soil drench trial and a seed dressing trial. The fungicides used for the drench treatments were commonly available fungicides. The fungicides used for the seed dressing trials were a mix of commonly used fungicides for seed dressings plus some new seed dressings (those that were used in the glasshouse trials). Each treatment was replicated four times. The plots were 5m long and consisted of one row of beans. The dressings were applied to seed and allowed to air dry. Seed was sown by hand seeder. Untreated seed was also sown. In the soil drench trials the fungicides were applied by watering can at a rate of 0.5 litres per metre in a band width of 20 cm, untreated plots were also included. They were applied after planting Simba variety seed. The Simba seed had been already commercially treated with Apron XL/Maxim. Plots were assessed six weeks after sowing by removing plants covering two metres of each treatment when hypocotyls were rated for disease.

The fungicides used in both trials have been included in Tables 15 and 16.

Table 15: Fungicides used in the seed dressing trial.

Seed treatment Code	Active ingredient(ai)	Rate	Concentration of ai g/kg	Product rate/100kg seed
Captan	captan	High	800	0.5 kg
Captan	captan	Medium	800	1 kg
Captan	captan	Low	800	2 kg
Thiram	thiram	High	800	0.5 kg
Thiram	thiram	Medium	800	1 kg
Thiram	thiram	Low	800	2 kg
A	azoxystrobin	N/A	5	50 ml
F	fludioxonil	N/A	5	50 ml
MF	metalaxyl + fludioxonil	N/A	5.625 + 3.75	150 ml
FM	fludioxonil + metalaxyl-M	N/A	3.75 + 1.5	150 ml
DM	difenconazole + metalaxyl-M	N/A	11.96 + 2.99	130 ml
AFM	azoxystrobin + fludioxonil + metalaxyl-M	N/A	7.5 + 1.25 + 3.75	100 ml
Simba	N/A	N/A	N/A	N/A

Table 16. Fungicides used for the soil drench trial.

Fungicides	Active ingredient(ai)	Rate	Product Rate/100litres
Amistar	azoxystrobin	High	100 g
Amistar	azoxystrobin	Medium	50 g
Amistar	azoxystrobin	Low	25 g
Captan	captan	High	125 g
Captan	captan	Medium	62.5g
Captan	captan	Low	31.5 g
Previcur	propamocarb	High	250 ml
Previcur	propamocarb	Medium	125 ml
Previcur	propamocarb	Low	62.5 ml
Thiram	thiram	High	150 g
Thiram	thiram	Medium	100 g
Thiram	thiram	Low	50 g
Simba	N/A	N/A	N/A
Simba (washed to remove dressing)	N/A	N/A	N/A

Results

Seed dressing trials

Results (Table 17, Fig. 12) were variable for both sites with no single seed dressing showing any clear advantage over other dressings. A, FM and AFM and Captan (medium) had the lowest disease ratings for Site 1. There was some significance in values for Site 2 but the disease levels were far too high to be indicative of good disease control.

Table 17: The results of the seed dressing trials at the two sites showing the disease ratings. Results were variable. Site 2 had more disease pressure than Site 1 which can be seen by comparing the ratings from each site.

Site 1		Site 2	
Fungicide	**Disease rating**	**Fungicide**	**Disease rating**
A	1.3 a	AFM	2.9 a
FM	1.4 a	Untreated	3.1 a
AFM	1.7 ab	Thiram H	3.2 a
Captan M	1.7 ab	DM	3.5 b
Captan H	2.0 bc	Captan H	3.6 bc
F	2.0 bc	A	3.7 bcd
Thiram H	2.1 bc	Simba	3.7 bcd
Simba	2.2 bc	Thiram L	3.7 bcd
Captan L	2.3 c	Captan M	3.8 cd
DM	2.4 c	MF	3.8 cd
Thiram L	2.4 c	F	3.9 d
Untreated	2.5 c	Captan L	3.9 d
MF	3.3 d	FM	3.9 d
Thiram M	3.7 d	Thiram M	4.0 d

Observations with the same letter are not significantly different at the 5% level LSD

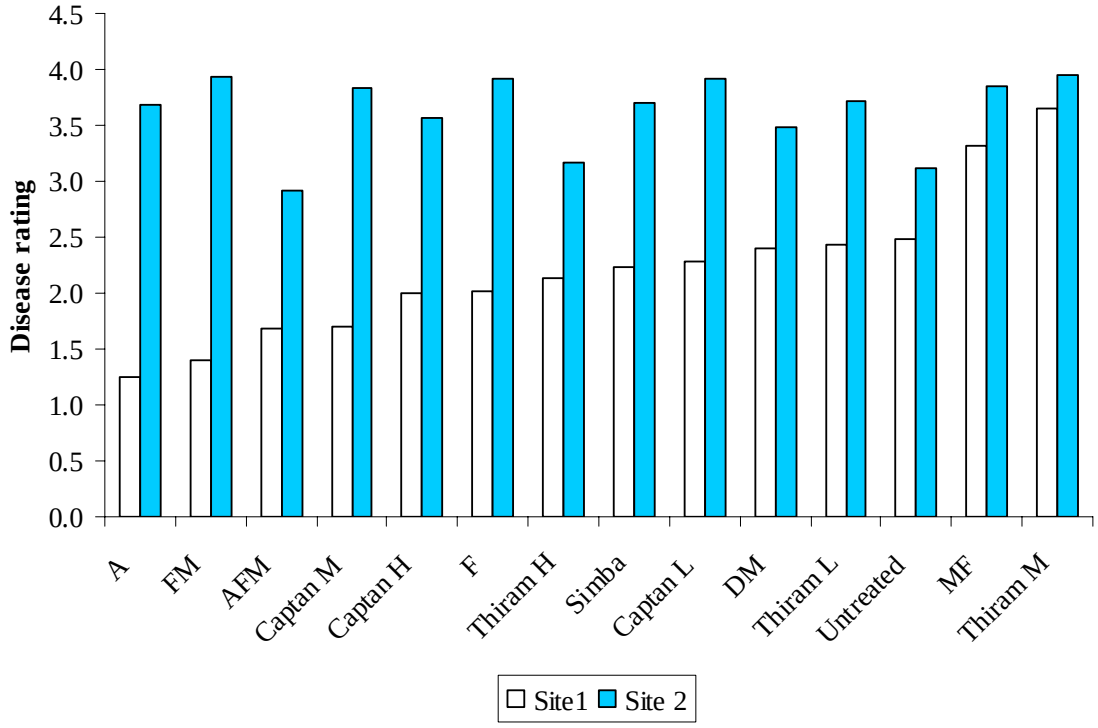


Fig. 12. Disease ratings for the seed dressing trials.

Soil drench trials.

Thiram (medium rate) and two Amistar rates had the lowest disease ratings in Site 1 whereas Amistar (low rate) was the best rate at Site 2 with Previcur (high rate) the next lowest disease rating (Table 18, Fig. 13).

Table 18: The results of the soil drench trials at the two sites showing the disease ratings.

Site 1		Site 2	
Fungicide	**Disease rating**	**Fungicide**	**Disease rating**
Thiram M	0.5 a	Amistar L	2.6 a
Amistar H	0.7 ab	Previcur H	3.2 b
Amistar L	0.8 ab	Previcur L	3.7 c
Thiram H	1.0 bc	Captan H	3.8 cd
Previcur M	1.1 bc	Amistar H	3.8 cde
Captan M	1.2 bc	Thiram M	3.8 cde
Amistar M	1.4 cd	Previcur M	3.9 cde
Previcur H	1.7 d	Thiram L	3.9 ef
Previcur M	2.4 d	Amistar M	3.9 ef
Untreated	2.5 d	Thiram H	4.0 ef
Captan L	2.5 d	Captan L	4.0 f
Thiram L	2.5 d	Captan M	4.0 f
Captan H	2.6 d	Untreated	4.0 f

Observations with the same letter are not significantly different at the 5% level LSD

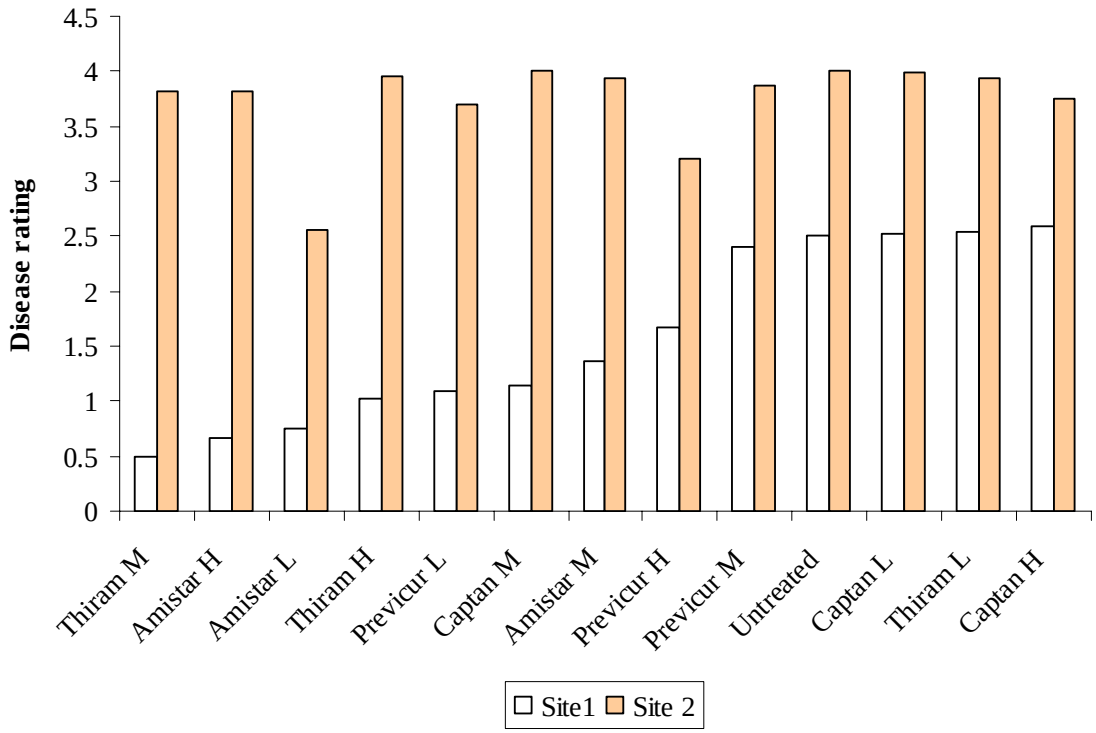


Fig. 13. Graph showing the disease ratings for the soil drench trials. Amistar was successful in Site 1 but not at Site 2.

Discussion

The results of these trials were not as clear as the glasshouse trials. Site 2 had more severe disease levels than Site 1. Site 1 was adjacent to the current season's crop whereas Site 2 had beans in the current year. Site 2 was also watered heavily to induce disease whereas Site 1 was watered only as the crop needed it. *Aphanomyces* thrives on heavily watered situations. Therefore disease pressure was higher in Site 2 as compared to Site 1; therefore the fungicide affect on disease control in Site 2 was not as successful as Site 1.

Hymexazol was not used in these trials as it was unavailable. It was included in two other trials referred to later in this report. Some soil drenches appeared to assist in reducing the development of symptoms, Previcur, Amistar and Thiram. Both Amistar and Thiram are broad spectrum fungicides however Previcur only targets *Aphanomyces* and *Pythium*. However disease levels were still high especially in Site 2. These field trials were also left for much longer than the glasshouse trials so disease would have progressed more.

As there was some reduction in disease levels the use of targeted soil drenches may be useful in managing *Aphanomyces* root rot. It may useful in reducing disease build up, so the application in reasonably "new" ground may give reduced disease levels for subsequent crops.

Thiram has registration on beans in Queensland to control damping off. The rate recommended is 150g/100L and the application rate is 2.5-5 litres/m^2. This is 25000 litres per ha (low rate). At this rate it is 12.5 kg per ha. This rate is the same as that applied in the above trials. This is a very high rate for large areas. If the spraying width is maintained at 20cm then the rate also works out to be 50 litres per 100m of row. If products were available such as Previcur or Amistar then application at these volume could be considered however Amistar is a very expensive fungicide.

A trial was developed that combined some promising soil drenches with seed dressings and planted into Site 2.

4.2 ASSESSMENT OF THE COMBINATION OF SEED DRESSINGS AND SOIL DRENCH FUNGICDES TO CONTROL BEAN ROOT ROT.

Introduction

Indications from previous trials had suggested that some seed dressings and drenches would reduce disease levels. Therefore a combination of treatments was used in a field trial. Hymexazol shown to have good activity against *Aphanomyces* in glasshouse trials was also included in the trial. The site used for the trial had beans in a previous trial (Site 2) and had a commercial crop of beans earlier in the same year, so disease levels would have been high. The trial was established at the end of 2006.

Materials and Methods

Seed treatments and soil drenches used are included in Table 19. Plots were 5 m long and consisted of one row. The seed (variety Simba) was sown before the application of the soil drench. The soil drench fungicides were applied by watering can at a rate of 0.5 litres per metre in a band width of 20 cm. The hymexazol treatment was included on its own as a seed dressing without a soil drench treatment. The treatments were replicated four times. Plants (20) were harvested four weeks after planting and assessed for disease levels.

Table 19. Fungicides used in the trial.

Seed Dressing/Soil Fungicide	Seed dressing rate g/100 kg	Soil fungicide rate g/100litres
Captan/Captan	500	62.5
Captan/Amistar	500	50
Thiram/Thiram	500	100
Thiram/Amistar	500	50
Hymexazol/Nil	500	N/A
Simba (treated with Maxim XL)	N/A	N/A

Results

All the fungicide treatments except one, significantly reduced disease levels (Table 20, Fig. 14). The Captan/Amistar treatment was significantly the best. Simba had the worst disease levels. Both the Amistar drench treatments were significantly better than the other treatments.

Table 20. The effect of treatments on disease with only the first treatment significantly less than others (at 5% LSD). Both treatments with amistar were significantly different to other treatments.

Fungicdes (Seed dressing/in furrow application)	Disease rating
Captan+ Amistar	1.8 a
Thiram+Amistar	2.3 b
Captan+Captan	3.0 c
Hymexazol	3.0 c
Thiram+Thiram	3.4 cd
Simba	3.6 d

Observations with the same letter are not significantly different at the 5% level LSD

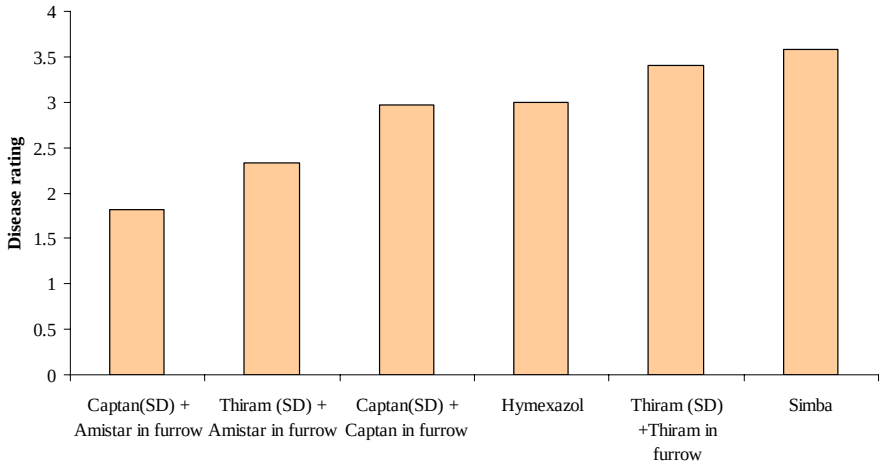


Fig. 14. The effect of treatments on the level of disease.

Discussion

This trial was based at Site 2 from a previous trial that had high disease levels. This trial again highlighted that Amistar does offer some disease reduction when used as a soil drench. All treatments gave some reduction in disease levels. Bothe the treatments with Amistar gave a significant improvement in disease levels. Hymexazol when used as seed dressing only was still significantly better than the plot without treatments.

Amistar does not have any recorded control of *Aphanomyces* however in trials carried out above some improvement in disease is apparent. Whether this is true activity against *Aphanomyces* or a reduction in the effects of other fungi in the soil environment was not determined in these trials. Amistar does have some control of *Rhizoctonia* and *Pythium*. These fungi are often involved in hypocotyl/root diseases and the reduction in disease levels observed maybe the removal of the contribution to disease expression by these fungi.

4.3 FURTHER EVALUATION OF THE ACTIVITY OF HYMEXAZOL TO CONTROL BEAN ROOT ROT IN THE FIELD SITUATION

Introduction

Towards the end of 2006 a small field trial was set up to examine the effectiveness of hymexazol as a seed dressing. The trial was based in the area as Site 1 in previous trials and therefore much less disease pressure. In a previous trial (4.2) hymexazol was included in Site 2. The trial was surrounded by the current season's crop.

Materials and Method

The treatments included hymexazol, captan and untreated seed. The seed with the captan was commercially treated whereas the hymexazol treated seed was the same as for previous trials. Plots were 5m long and consisted of one row. There were four replicates. 20 plants were assessed for stem lesions four weeks after planting at which time plants were flowering.

Results

The hymexazol treated plots rated lower for disease than the other treatments (Table 21 and Fig. 15)

Table 21. Disease ratings related to each seed dressing, hymexazol was significantly better than the other two treatments.

Treatment	**Disease rating.**
Hymexazol	1.7 a
Captan	3.6 b
Untreated	3.7 b

Observations with the same letter are not significantly different at the 5% level LSD

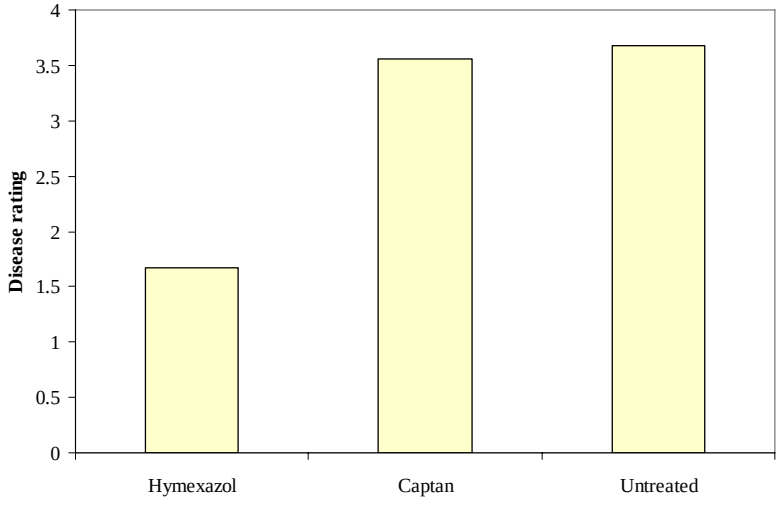


Fig. 15. Graph of the data represented in Table 21.

Discussion

Hymexazol was successful at reducing disease levels in this trial. The block was not extremely high in its level of background *Aphanomyces* but still bean plants showed a reduction in the level of hypocotyl lesions.

4.4 MANAGING *APHANOMYCES* USING BIOLOGICAL CONTROL.

Biological control of soil borne organisms has been investigated in many crops. There are a number of antagonistic fungi and bacteria commercially available such as species of *Trichoderma* and *Bacillus* that target various pathogens. A bacterium, *Pseudomonas cepacia* strain AMMD was recognised in the United States as giving some biological control against *Pythium* and *Aphanomyces* (King and Parke 1993).
During routine fungal isolations a bacteria showed potential as a biocontrol for *Aphanomyces*. It restricted growth of the fungus on media in petri dishes (Fig.16) When placed side by side the fungus would not grow anywhere near the bacteria colony compared to plates without the bacteria.

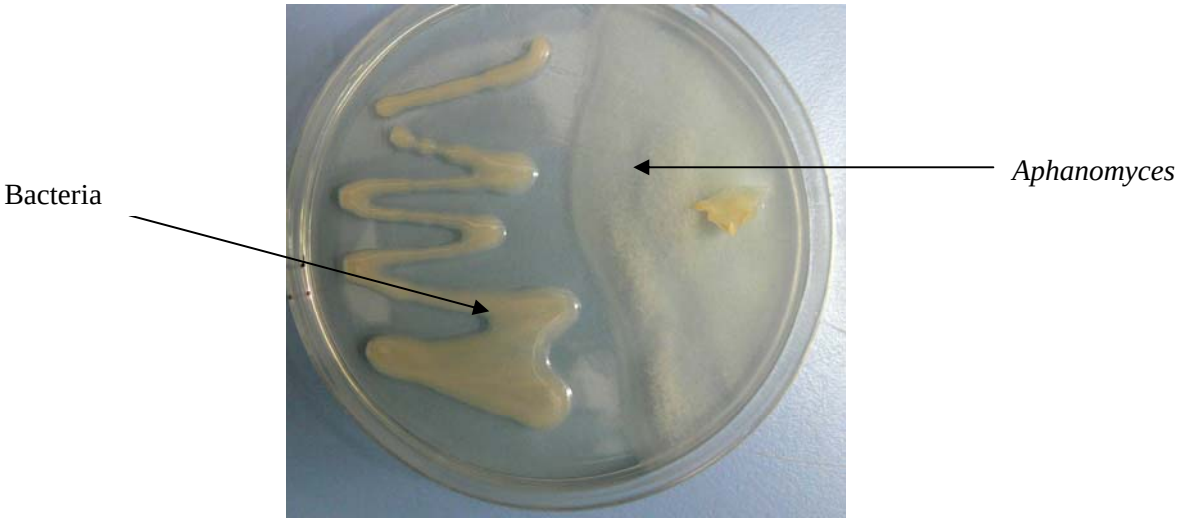


Fig. 16. Showing restricted growth of the *Aphanomyces* colony by the bacterium isolated.

The bacterium was identified as *Burkholderia* (formerly *Pseudomonas*) *cenocepacia.* It is a part of the *B. cepacia* complex known to contain strains that are effective against a wide variety of fungi in agriculture. Some are patented in the USA.

Small trials to assess the potential of assisting in the control of *Aphanomyces* were carried out where bean seed was either dipped in bacteria or bacteria/sterile water solution was added to pots of infected soil. After the wetting up period no reduction in symptoms was observed as compared to beans without bacteria.

Beans that had been grown in sterile vermiculite and removed after germination were transplanted to infected soil. Before transplanting the roots of the plants were dipped in a solution of bacteria and sterile water and then transplanted. These also developed symptoms.

Unfortunately there was no success with this bacterium in soil; however this method of disease management should be further investigated.

References

King EB, Parke JL (1993) Biocontrol of *Aphanomyces* root rot and *Pythium* damping-off by *Pseudomonas cepacia* AMMD on four pea cultivars. *Plant Disease* **77,** 1185-1188.

King EB, Parke JL (1996) Population density of the biocontrol agent *Burkholderia cepacia* AMMDR1 on four pea cultivars. *Soil Biology & Biochemistry* **28**,307-312.

4.5 TASMANIAN SOILS-*APHANOMYCES* DETECTION

Introduction

As *Aphanomyces* was found to be an issue in New South Wales and had also been reported to be present in Gympie soils (in VG024), it was decided to investigate if the disease was present in the bean growing areas of Tasmania. A preliminary sampling was undertaken where four soil samples were collected by project collaborators in Tasmania. The soils had different histories of bean/pea production.

Materials and methods

Trial 1

Each soil (quantity quite small) was mixed with vermiculite (50:50) and placed into a large ice cream container. The soils were labelled as soil A, B, C and D. The containers were placed into a glasshouse at temp (20^0C night and 27^0C day). 16 bean seeds were placed into each container. After germination plants were wet up and after four weeks plants were inspected for typical *Aphanomyces* symptoms.

Trial 2

To further establish the role of *Aphanomyces* in these soils a small trial was set up to examine any disease control using seed treated with hymexazol. Two pots of each soil were either sown with hymexazol treated seed or untreated seed. After germination plants were wet up and after 4 weeks plants were inspected for typical *Aphanomyces* symptoms.

Results

Trial 1

Soils C (Fig. 17) and D had typical *Aphanomyces* lesion; soils A did not show serious symptoms. On examination of roots of soils C and D *Aphanomyces* was found to be present. *Aphanomyces* was also isolated from the roots.

After the beans had been removed, peas were planted into the same soils. After 4 weeks they were also assessed for disease. Soils A and D were free of any symptoms whereas Soils B and C had very severe symptoms.

Fig. 17. Plants in this figure are from the soils in the order (l-r) soils A, B, C and D. Soil A was clearly better of the four soils, soils C and D had more serious symptoms.

Trial 2

Seed treated with hymexazol showed reduced disease symptoms in soils B, C and D for both hypocotyl and root disease assessments as can be seen in Fig. 18 and 19.

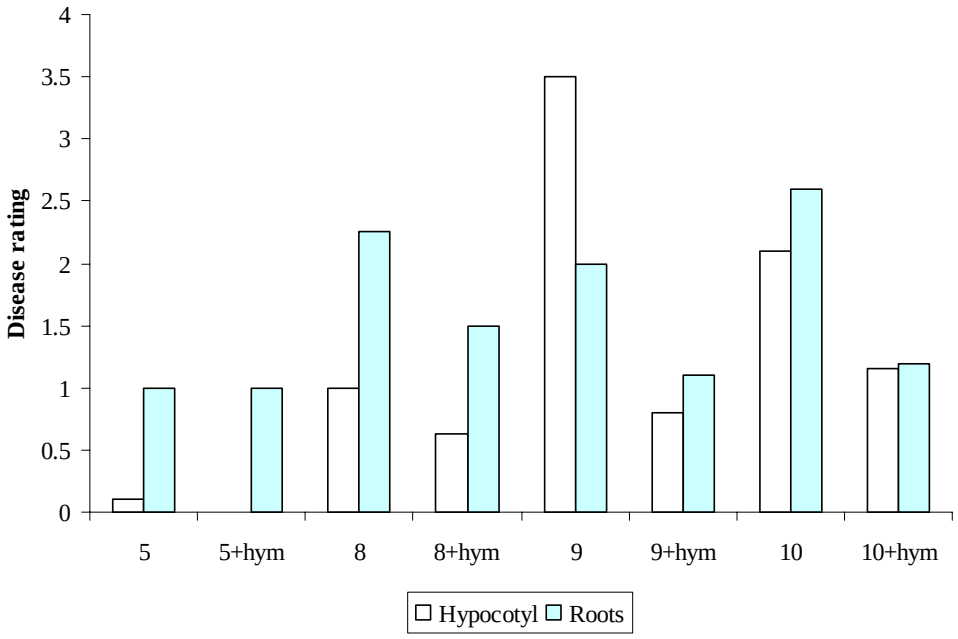


Fig. 18. Symptoms of disease were reduced by the treatment of seeds with hymexazol.

Fig. 19. Photograph of reduced disease symptoms on Soil C, untreated seed (left) and seed treated with hymexazol (right).

Discussion

This work and some work undertaken by Dr. Hoong Pung (Peracto) found that *Aphanomyces* had been found on beans in Tasmania. In Tasmania *Aphanomyces* was previously found on peas. As the fungus

is difficult to isolate and identify it may have gone undetected over many years. It does have implications for the Tasmanian bean industry as they too must consider management of a disease they had not considered they had before.

Dr Pung had also identified black root rot (*Thielaviopsis basicola*) as being involved often in conjunction with *Aphanomyces* (see Tasmanian report).

ACKNOWLEDGEMENTS

Thanks go to Scott Gough, Greg Silvia, Kevin Silvia and Ron Henderson growers of beans on the north coast of New South Wales where a lot of the trial work was undertaken. Thanks to growers in Gympie including Percy Bichel, Bob Euston, Ted Euston, Shane Mills, Ken Mills, and Mark Langton. Also thanks to Ken Melbourne in Bundaberg.
Also thanks to Sunland seeds for supplying seed, to Michael Priest (NSW DPI) for fungal identifications and Dorothy Noble (NSW DPI) for bacterial identifications.

Thanks also to Horticulture Australia in partnership with Ausveg. This project was funded by the vegetable levy and the Australian Government.

Statistics used in the report were either analysed by fitting a linear mixed model to the data using the statistical software ASReml (Gilmour *et al*. 2006) or with Statgraphics Plus.

Reference

Gilmour AR, Gogel BJ, Cullis BR, Thompson R (2006) ASReml User Guide Release 2.0 VSN International Ltd, Hemel Hempstead, HP1 1ES, UK

APPENDIX I

MATERIALS USED IN THIS PROJECT (NSW)

Totes =385mm long x 290mm wide x130mm deep soil depth 75 mm –volume-8.3 litres.
Pots-Small =95 mm x 95mm-volume 0.7 litres.
Pots-Medium =90 mm x115mm-volume 0.73 litres.
Pots-Large =135mm x135mm-volume 2 litres.
Large plastic "ice cream" containers =245 mm wide x 245mm x 160cm height soil depth 120 mm-volume 7.2 litres.

BEAN VARIETIES USED

"Strike" no seed dressing-Sunland seeds
"Simba" seed dressed with Apron XL/Maxim-Sunland seeds

FUNGICIDES USED IN TRIALS AND THEIR EFFICACY ON CERTAIN FUNGI

Fungicide	**Group**	**Company**	**Active ingredient**	**Soil borne organisms affected**
Captan	Y	Crop Care	captan	*Pythium* and *Rhizoctonia*
Thiram	Y	Crop Care	thiram	*Pythium* and *Fusarium*
MF	L+D	N/A	metalaxyl-M+ fludioxonil	*Pythium* and *Rhizoctonia*
F	D	N/A	fludioxonil	*Fusarium*, *Penicillium*
FM	D+L	N/A	fludioxonil + metalaxyl-M	*Rhizoctonia*, *Fusarium* and *Pythium*
DM	C+D	N/A	difenconazole + metalaxyl-M	*Rhizoctonia* and *Pythium*
AFM	D+K+L	N/A	azoxystrobin + fludioxonil + metalaxyl-M	*Pythium* and *Rhizoctonia*
Hymexazol	Heteroaromatic	Daiichi Sankyo Co. Ltd.	hymexazol	*Fusarium*, *Aphanomyces* and *Pythium*
Alliette	Y	Bayer	fosetyl Al	*Phytophthora*
Amistar	K	Syngenta	azoxystrobin	*Pythium* and *Rhizoctonia*
Previcur	Y	Bayer	propamocarb	*Pythium*, *Phytophthora* and *Aphanomyces*

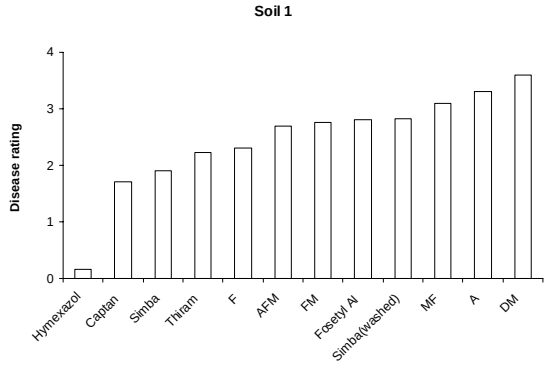
Source: Tomlin, CDS (2003). The Pesticide Manual Thirteenth Edition

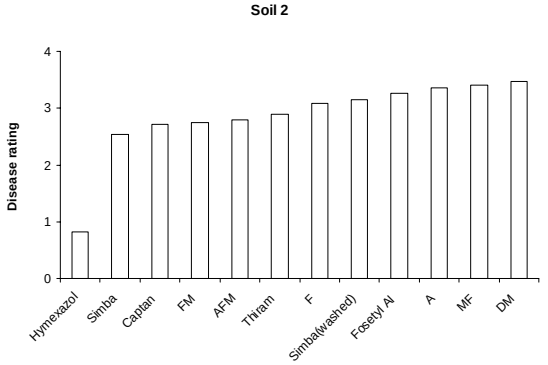
TERMS USED IN THE REPORT.

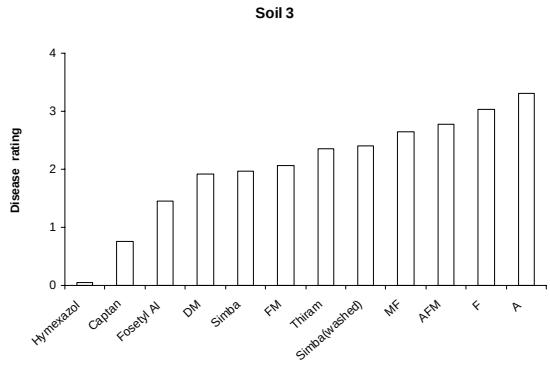
"wetting up" application of water three times a day.
"two leaf stage" after the cotyledon stage when two true leaves have emerged.
"cotyledons" first two leaves that emerge from the seed.
"hypocotyl" region of the stem between the seed and the cotyledons.

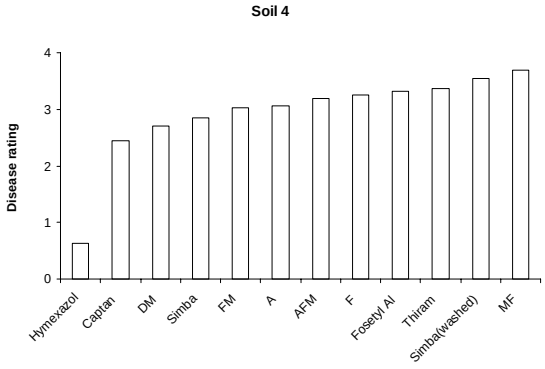
APPENDIX II

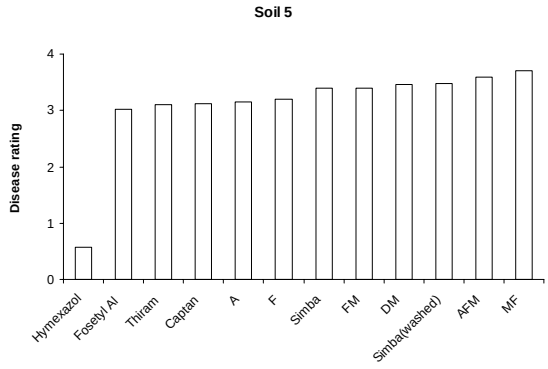
GRAPHS OF DISEASE RATINGS FROM THE VARIOUS SOILS AND SEED DRESSINGS FROM SECTION 3.1

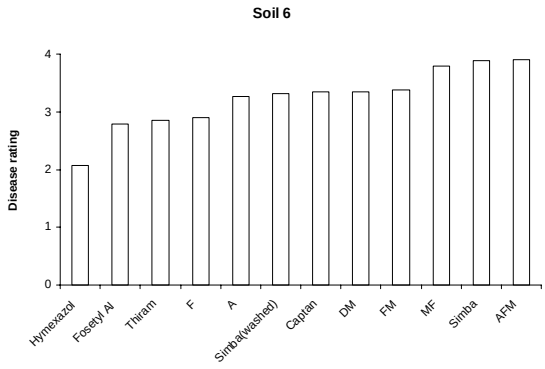


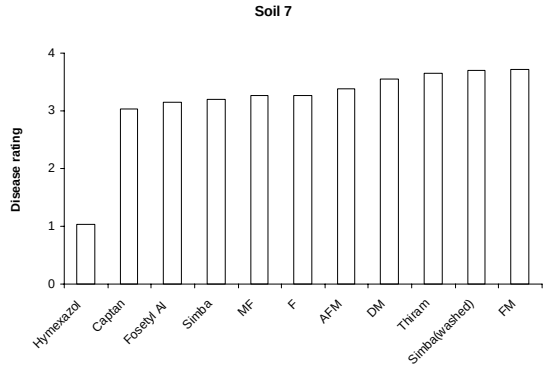


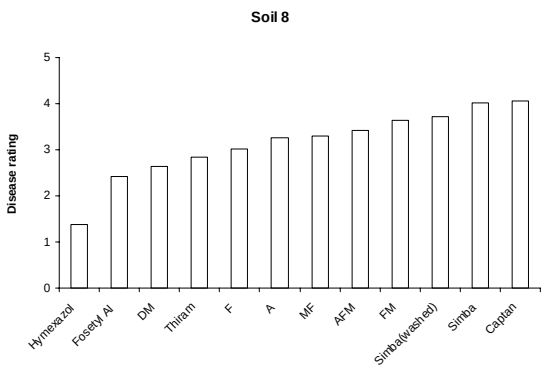


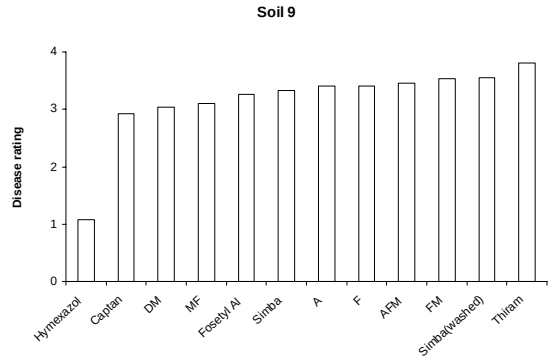


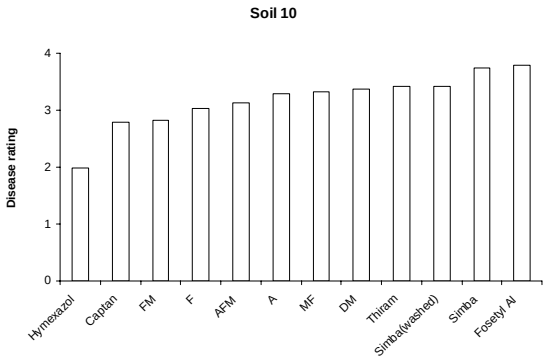


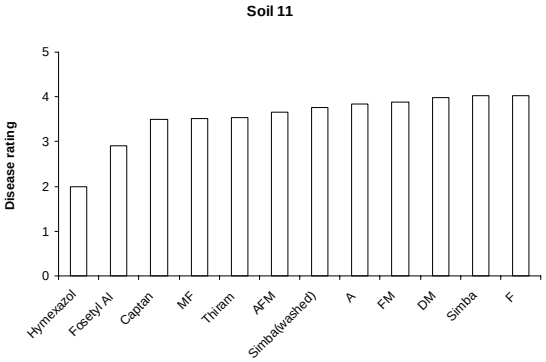


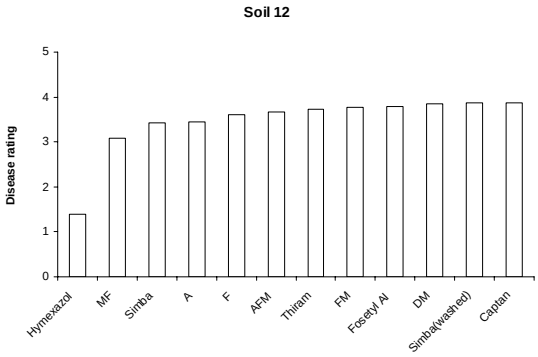


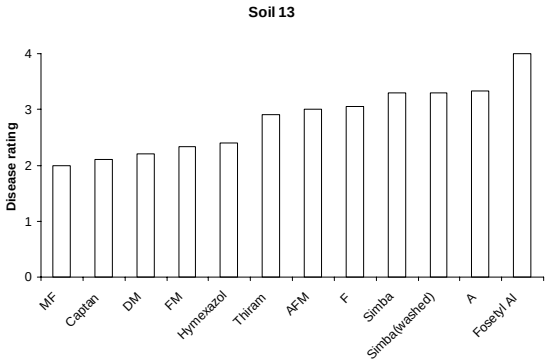



Soil 9
Disease rating
0
1
2
3
4
Hymexazol
Captan
DM
MF
Fosetyl Al
Simba
A
F
AFM
FM
Simba(washed)
Thiram


Soil 10
Disease rating
0
1
2
3
4
Hymexazol
Captan
FM
F
AFM
A
MF
DM
Thiram
Simba(washed)
Simba
Fosetyl Al


Soil 11
Disease rating
0
1
2
3
4
5
Hymexazol
Fosetyl Al
Captan
MF
Thiram
AFM
Simba(washed)
A
FM
DM
Simba
F


Soil 12
Disease rating
0
1
2
3
4
5
Hymexazol
MF
Simba
A
F
AFM
Thiram
FM
Fosetyl Al
DM
Simba(washed)
Captan


Soil 13
Disease rating
0
1
2
3
4
MF
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TASMANIAN RESEARCH ACTIVITIES


Bean root and stem diseases in Tasmania

HAL Project VG03002
(NSW03280)

Final Report

5 June 2007

by

Dr Hoong Pung

Peracto Pty Ltd
ABN: 97 109 472 559
Head Office: 16 Hillcrest Road
Devonport, Tas 7310 Australia
Telephone: +61 3 6423 2044
Facsimile: +61 3 6423 4876
Email: admin@peracto.com.au
Web: www.peracto.com.au

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Project Number: *VG03002*
Peracto reference: *NSW03280*

Report written by: Hoong Pung

Researchers in Tasmania: *Hoong Pung and Susan Cross*
Peracto Pty Ltd
16 Hillcrest Road
Devonport Tasmania 7310

Phone (03) 6423 2044
Fax (03) 6423 4876
Email: hpung@peracto.com.au

Report Date: *5 June 2007*

Acknowledgements

This project has been facilitated by the NSW Department of Primary Industries and Horticulture Australia Limited in partnership with AUSVEG, and has been funded by the vegetable levy and the Australian Government. The assistance of bean growers in Tasmania, Gary McNab from Simplot Australia Pty Ltd and Darren Briggs from McCain Foods, is gratefully acknowledged. We would also like to thank Michael Priest and Andrew Watson of the NSW Department of Primary Industries for confirmations of fungal identification, and Russell Burns of Plant Research Centre, South Australia Research and Development Institute, for *Rhizoctonia* tests.

TASMANIAN REPORT SUMMARY

Green bean is a major vegetable crop in Tasmania, with approximately 2,000 ha sown and 16,000 tonnes of green beans produced each year. Poor emergence, uneven plant stands, poor crop vigour and early crop senescence are becoming common in paddocks in the traditional bean production regions. There has been little or no research on the causes of these poor crop establishment and growth problems. Therefore, research studies were conducted in northern Tasmania under this project, to examine affected bean crops, and to conduct laboratory examinations and identification of major pathogens associated with bean root and stem rots. This study was conducted as part of the Horticulture Australia Ltd project VG03002. The use of seed dressings and soil treatments with fungicides, biological control agents and biofumigants for root rot management were also investigated. Following the withdrawal of procymidone (Sumisclex or Fortress) from commercial use on beans for *Sclerotinia* control in Australia in late 2004, field trials were also conducted to establish the efficacies of the alternative fungicides Filan and Amistar for *Sclerotinia* control on bean crops.

Thielaviopsis basicola and *Aphanomyces euteiches* are the two most devastating root diseases on green bean crops in Tasmania. *Pythium, Fusarium* and *Rhizoctonia* are common soilborne pathogens that are often found in association with damping off and root rot or discolouration. In paddocks where the bean crop's growth was poor, with sparse, uneven plant sizes or poor growth due to severe root rot, more than one pathogen was often found in association with bean hypocotyl and root rots. Soilborne pathogens can interact with one another to cause a root disease complex resulting in root rot that is usually more severe than that caused by a single pathogen. As *Thielaviopsis* is common in most paddocks where beans are regularly sown in crop rotations, the pathogen was often found in association with other soilborne pathogens in severe hypocotyl and root disease complexes.

Seed treatments were found to be useful in preventing damping off diseases by root pathogens, reducing root rot severity and in establishing bean crops. New fungicide seed dressing combinations with azoxystrobin, fludioxonil and metalaxyl-M were suitable alternatives to thiram in improving seedling establishment and reducing root rot incidence or severity. Since root rot was often caused by more than one soilborne pathogen, new fungicide seed dressings that have combinations of two or three active ingredients were more effective than a fungicide seed dressing containing only one active ingredient. The low levels of active ingredients required in the new fungicides were at least 25 times lower than the level required with thiram. The amount of fungicides used in seed treatments, however, is insufficient to completely prevent root infections or provide long-term protection for the duration of the crop. In preliminary investigations, the effects of the soil treatments within commercial bean crops with fungicides, biofumigants or biocontrol agents for prolonged root rot management in bean crops were inconclusive. Further studies are required to develop effective soil treatments for long-term root rot management in bean crops.

Poor crop establishment and growth may also be related to poor seed quality and additional tests may be required to ensure that good quality seeds are used.

White mould caused by *Sclerotinia sclerotiorum* is the most common and important above-ground disease on green bean crops in Tasmania, followed by *Botrytis cinerea*. Under warm, humid and wet field conditions, *Sclerotinia* disease can very be destructive, and crop losses can range from 20% to 100%. The early timing of the first fungicide application at the flowering stage was critical for effective white mould control. Filan applied at 0.8 and 1.0 kg/ha gave effective white mould disease control on bean crops, and it is a suitable alternative to Sumisclex for *Sclerotinia* control. Amistar gave little or no white mould control. Gypsum alone did not reduce *Sclerotinia* infections on treated bean plants, but when applied with Filan 1.0 kg/ha, appeared to slightly improve *Sclerotinia* control compared to Filan 1.0 kg/ha alone. Biological products based on *Bacillus subtilis* could potentially be used in alternation with fungicides to reduce fungicide applications, but further studies are required to confirm and support their use.

INTRODUCTION

Green bean is a major vegetable crop in Tasmania, with approximately 2,000 ha sown and 16,000 tonnes of green beans produced each year. Most of the green beans in Tasmania are produced for processing into frozen vegetables. Bean crops in Tasmania are mainly sown in December - January and harvested in February - April. Poor emergence, uneven plant stands, poor crop vigour and early crop senescence are becoming common in paddocks where beans are regularly sown in 2-4 year rotations. There has been little or no research on the causes of these poor crop establishment and growth problems. Damping off, hypocotyl and root rot diseases are expected to worsen, particularly in crops sown in wet and cold conditions, due to a build up of soilborne pathogens in traditional bean production regions and the lack of new ground or long-term rotation with other crops. The control of root pathogens in soils is extremely difficult due to a lack of knowledge on the type of pathogen present, a lack of predictive soil testing for pathogens prior to planting, and a lack of effective chemical or non-chemical control strategies. This study was conducted as part of the Horticulture Australia Ltd project VG03002, led by Andrew Watson of the NSW Department of Primary Industries.

Research studies were conducted in northern Tasmania to examine affected bean crops, and to conduct laboratory examinations and identification of major pathogens associated with bean root and stem rots. Isolates of fungal pathogens were also sent to NSW Department of Primary Industries for pathogenicity tests. Trial studies were also conducted within commercial crops in the field, on the potential use of fungicide seed dressings, and soil treatments with fungicides, biological control agents and biofumigants, for root rot management. Following the withdrawal of procymidone (Sumisclex or Fortress) from commercial use on beans for *Sclerotinia* control in Australia in late 2004, field trials were also conducted to establish the efficacies of the alternative fungicides Filan and Amistar for *Sclerotinia* control on bean crops.

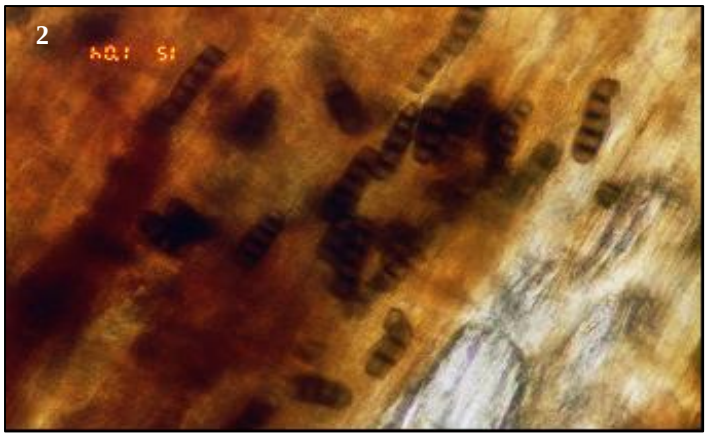
1. MAJOR GREEN BEAN DISEASES IN TASMANIA

INTRODUCTION

Green beans are a major vegetable crop in Tasmania, which are mostly produced for processing into frozen vegetables. They are usually sown in December and January, and harvested from February to April. Apart from white mould on maturing or matured crops caused by *Sclerotinia*, poor emergence, uneven plant stands, poor crop vigour and early crop senescence are also common in bean crops in Tasmania. Although hypocotyl and root rot are often observed, there have been little or no studies on the causes of these poor crop establishment and growth problems. Apart from crop rotations and the use of fungicide seed treatments to improve initial seedling establishment, there is no other effective management strategy for reducing root rot and improving root growth in affected paddocks. Accurate disease diagnosis is essential before effective disease management strategies can be developed or recommended. Therefore, in 2004-2007, plant and root specimens, as well as soil samples, were collected from affected bean crops to determine causal factors using microscopic examinations of thin sections, fungal isolations and baiting of soil. Photographic records of various disease symptoms were taken. The major pathogens associated with stem, hypocotyl and root rots in Tasmania were identified and are described below.

*THIELAVIOPSIS (*BLACK ROOT ROT)

Black root rot caused by *Thielaviopsis basicola* (Photograph 1), is the most common and important hypocotyl and root disease in Tasmania, occurring in approximately 53% and 33% of the bean crops surveyed in 2004 and 2007, respectively. The disease appears to have been more widespread and severe in the wet and cool growing season experienced in 2004, when compared to the relatively dry growing seasons in 2005-2007. The pathogen forms thick walled, dark brown and multicellular chlamydospores in infected tissues (Photograph 2). The multiple cells in each chlamydospore can break apart into separate single cell infection units. Black root rot lesions on hypocotyls are initially reddish-purple in colour, which eventually became black. As the disease progresses, the lesions will merge to form a large black rot on the hypocotyl or root (Photograph 3).



The effects of the disease on bean crops depend on field conditions. In 2004, when weather conditions were cold and wet, damage due to black rot was severe and widespread in north-west Tasmania. In waterlogged soils, the disease caused deep infections, stunted plants, early defoliation and plant death (Photograph 4). In warm weather and dry or well-drained soils, the disease appeared to initially cause superficial lesions on cortical cells, which could become deep infections and cause constriction of main roots of maturing or mature plants, resulting in wilting and early crop senescence as the diseased root systems struggled to meet the water and nutrient uptake of large foliage (Photograph 5).

APHANOMYCES (RED ROOT ROT)

Red root rot caused by *Aphanomyces euteiches* was found to be the second most devastating hypocotyl and root disease of beans in Tasmania. Secondary fungal invaders usually followed hypocotyl and root infections by *Aphanomyces*, hence making it difficult to detect the primary pathogen through fungal isolations. The presence of *Aphanomyces*, however, can be established by examining suspected roots for the characteristic thick walled oospores in infected root tissues (Photograph 6) or by baiting soil that had been pre-treated with fungicides in order to suppress other soilborne fungi (per. comm. Andrew Watson). Based on the extensive damages it caused on bean crops and the large aplerotic zone in the oospores, the pathogen may be *A. euteiches* f. sp. *phaseoli*. The affected roots are reddish-brown and soft in appearance (Photograph 7). The pathogen may also interact with other pathogens such as *Thielaviopsis, Pythium, Rhizoctonia or Fusarium* to cause more severe rot (Photographs 8-9). The true extent of the disease is difficult to establish due to its interactions with other pathogens, as well as invasion of infected tissues by secondary invaders. *Aphanomyces* red root rot was confirmed in approximately 15% of the bean crops examined. Although the pathogen produces oospores and sporangia as *Pythium* species, fungicides that are effective against *Pythium*, such as metalaxyl-M or thiram, have little or no effects on the pathogen.

Aphanomyces root rot

Aphanomyces + *Thielaviopsis* root

Aphanomyces + *Thielaviopsis* root

PYTHIUM, FUSARIUM & RHIZOCTONIA

Pythium, *Fusarium* and *Rhizoctonia* are common soilborne pathogens that are often found in association with damping off and root rot or discolourations. *Pythium*, *Fusarium* and *Rhizoctonia* are ubiquitous in soil, because of their broad host range as well as their ability to survive saprophytically in fresh organic matter. *Pythium irregulare, P. acanthicum, P. vexan, Fusarium compactum, F. culmorum, F. oxysporum, F. solani* and *Rhizoctonia solani* were isolated from bean roots. *R. solani* consists of collections of sub-species based on anastomosis groups (AG) and their genetic variations, and DNA tests have shown the presence of AG 2.1, AG 2.2, AG 3 and AG 4 in bean paddocks. The most common sub-species in Tasmanian soil appears to be AG 2.1. Further studies are currently being conducted to determine the pathogenicity of these sub-species on beans and other vegetable crops in Horticulture Australia Ltd project VG05090.

P. irregulare, F. culmorum and *R. solani* AG 2.1 were frequently isolated, and these pathogens have been shown to cause severe damping off on untreated bean seeds, drastically reducing seedling emergence and survival under relatively cool conditions (Table 1.1). Fungicide seed treatments such as thiram can prevent or reduce damping off, but seedling growth from the treated seeds was less vigorous, with lower average shoot weights compared to those grown in disease free soil. *P. irregulare also* reduced seedling emergence, survival and growth under warm conditions (Table 1.2). This indicates that *Pythium* may be the third most important root disease on beans.

Table 1.1: The effects of *Pythium, Fusarium* and *Rhizoctonia* on bean seedling survival and growth at 5-15°C in a pot trial at Devonport, Tasmania

	Untreated seed at 30 days after sowing		Thiram treated seed at 30 days after sowing	
Fungal pathogen	**Seedling emergence & survival**	**Average fresh shoot weight (g/surviving plant)**	**Seedling emergence & survival**	**Average fresh shoot weight (g/surviving plant)**
None	96	1.443	93	1.411
Pythium irregulare	0	0	78	1.032
Fusarium culmorum	0	0	96	1.249
Rhizoctonia solani AG2.1	19	1.160	93	1.119

Table 1.2: The effects of *Pythium, Fusarium* and *Rhizoctonia* on bean seedling survival and growth at 15-25°C in a pot trial at Devonport, Tasmania

	Untreated seeds at 21 days after sowing	
Fungal pathogen	**Seedling emergence & survival**	**Average fresh shoot weight (g/surviving plant)**
None	93	2.07
Pythium irregulare	77	1.30
Fusarium culmorum	85	2.05
Rhizoctonia solani AG2.1	90	2.34

Fusarium and *Rhizoctonia* appear to have caused severe damping off only under adverse conditions, which will slow the bean seed germination and emergence. In cold conditions, *Rhizoctonia* AG2.1 infection caused severe stunting of seedlings and damping-off (Table 1.1, Photograph 10), but under warm conditions and rapid seedling growth, the pathogen has little effect on seedling establishment and was mainly restricted to cortical cells (Table 1.2, Photograph 11). Damage to root systems by *Rhizoctonia* AG2.1 was limited unless it interacted with other pathogens (Photograph 13-15).

Similarly with *Fusarium* species, their impact on beans was also dependent on soil condition and presence of other soilborne pathogens.

ROOT DISEASE COMPLEX

In paddocks where the bean crop's growth was poor and variable, more than one pathogen was often found in association with bean hypocotyl and root rots. Soilborne pathogens can interact with one another to cause a root disease complex resulting in root rot that is usually more severe than that caused by a single pathogen (Photograph 12-15). As *Thielaviopsis* is common in most paddocks where beans are regularly sown in crop rotations, the pathogen was often found in association with other soilborne pathogens in severe hypocotyl and root disease complexes.

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Aphanomyces + *Thielaviopsis* disease

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Thielaviopsis + *Rhizoctonia* disease

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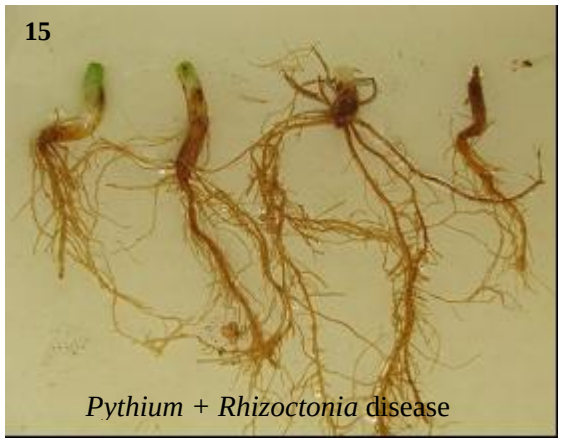
Thielaviopsis + *Rhizoctonia* + *Fusarium dise*ase complex



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Pythium + *Rhizoctonia* disease

POOR SEED QUALITY

Poor crop establishment and growth may also be related to poor seed quality. Although seeds are tested for germination rates, weak plants due to poor seed quality may not be detected until they are grown in soil or potting medium. In 2007, sparse plant densities and stunted seedlings with swollen and tapered roots were consistently observed in many bean crops sown in areas west of Wynyard (Photographs 16-17). Subsequently, seedlings grown in pots with pasteurised soil showed the same swollen root symptoms on 5% and 18% of the seeds from two of the three commercial seed batches used (Photographs 18-19). Germination of the affected seed batches was acceptable at 80% to 85%. No pathogen or herbicide applications could be associated with the abnormal root growth symptoms. This finding highlights the importance of seed quality.


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WHITE MOULD (*SCLEROTINIA* ROT)

White mould caused by *Sclerotinia sclerotiorum* is the most common and important above-ground disease on green bean crops in Tasmania. Stems, leaves and bean pods infected by the pathogen develop a white, cottony hyphal growth (Photograph 20). Affected tissues have a bleach white appearance when they dry out (Photograph 21). Under warm, humid and wet field conditions, the disease can very be destructive and crop losses can range from 20 to 100% (Photograph 22).

Infections usually start as primary infections at the flowering crop stage by ascospores germinating and colonising flowers. The pathogen will later spread through mycelial growth from the infected flowers, when they fall and attach onto stems, leaves and pods as secondary infections. Senescing or damaged plant tissues are also susceptible to ascospore infections. Under moist conditions underneath plant canopies, the secondary infections by *Sclerotinia* can spread very rapidly within a few days. Disease control is only effective when fungicides are applied during the flowering stage in order to prevent primary infections. Late disease control measures taken to prevent the spread of secondary infections usually have little or no effect. Under disease favourable conditions, effective disease control by fungicides may be difficult to achieve in crops that have dense planting, a long or uneven flowering period, or flowers hidden underneath plant canopies, due to poor spray coverage and penetration.


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GREY MOULD (*BOTRYTIS* ROT)

Grey mould cause by *Botrytis cinerea* is also common on green bean crops in Tasmania. Stems, leaves and pods infected by the pathogen develop a grey brown powdery mass on lesions (Photograph 23). Infections usually start when the fungus colonises senescent flowers and later spreads to the attached pods, or any parts of the plant that the infected flowers fall onto. Although *Botrytis* spreads in the same manner and conditions as *Sclerotinia*, grey mould lesions tend to be localised and restricted to small areas of the plant (Photograph 22). Therefore, crop damage by grey mould is often limited to individual infected leaves or pods. In contrast, white mould disease by *Sclerotinia* tends to spread more rapidly to affect the whole plant, as well as adjacent plants.


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PLEIOCHAETA SETOSA

Brown spot disease caused by *Pleiochaeta setosa* on green bean stems and pods was first recorded in Tasmania in 2004. *P. setosa* is a serious pathogen of lupins in Australia, causing leaf, stem and pod lesions. It had previously been recorded in Tasmania on lupin crops but not on bean crops. This disease appears to be rare, only occurring in paddocks where blue lupin crops had been regularly grown for green manure and soil improvement.

2. EVALUATION OF NEW SEED DRESSINGS IN FIELD TRIALS

SUMMARY

The effectiveness of new seed dressings containing a single or combinations of the fungicide active ingredients: azoxystrobin (A), difenconazole (D), fludioxonil (F) and metalaxyl-M (M), as well as an insecticide active ingredient thiamethoxam (Thx) were evaluated in three field trials for damping off and root rot control on beans. These were compared against thiram, an old broad-spectrum fungicide that is the current standard seed dressings for bean seeds. All trials were conducted within commercial bean crops.

The field trials demonstrated that the new fungicide seed dressing combinations with azoxystrobin, fludioxonil and metalaxyl-M were suitable alternatives to thiram in improving seedling establishment and reducing root rot incidence or severity. Generally, reduced seedling emergence and root rot were often caused by more than one soilborne pathogen. As the new fungicides were more selective in their target organisms, new fungicide seed dressings that have combinations of two or three active ingredients were more effective than a fungicide seed dressing containing only one active ingredient. The levels of active ingredients required in the new fungicides were at least 25 times lower than the level required with thiram, which could help contribute to an overall reduction in levels of chemical use in seed treatments and crop production.

INTRODUCTION

Fungicide seed treatment is the most cost effective early disease control on seed and seedlings, applied at a stage when they are most vulnerable to attack by plant pathogens. Currently, most vegetable seed treatments rely on old broad-spectrum chemicals, such as thiram, which are indiscriminate in their target organism and could be removed from use eventually. In recent years, new chemicals that are safer, more selective and can better target pathogen are being developed for use in broad-acre crops like wheat and canola. Seed dressings use only a small amount of chemicals, so even though the new chemicals are more expensive, their use in new seed dressings is still affordable to growers. Three field trials were conducted to examine the potential of new fungicide seed dressings based on azoxystrobin, difenconazole, fludioxonil and metalaxyl-M for damping off and root rot control. The use of a new insecticide seed dressing based on thiamethoxam, alone or in combination with fungicide seed dressings was also examined.

MATERIALS & METHODS

Seed dressing active ingredient and concentrations

Seed Treatment Code	Active Ingredient (ai)	Concentration of ai	Activity
Thiram DG	thiram	800 g/kg	Fungicide
Thiram Liquid	thiram	600 g/L	Fungicide
A	azoxystrobin	100 g/L	Fungicide
MF	metalaxyl + fludioxonil	37.5 g/L + 25 g/L	Fungicide
F	fludioxonil	100 g/L	Fungicide
FM	fludioxonil + metalaxyl	25 g/L + 10 g/L	Fungicide
DM	difenconazole + metalaxyl	92 g/L + 23 g/L	Fungicide

AFM	azoxystrobin + fludioxonil + metalaxyl-M	75 g/L + 12.5 g/L + 37.5 g/L	Fungicide
Thx	thiamethoxam	350 g/L	Insecticide
Apron XL	metalaxyl-M	350 g/L	Fungicide
Maxim FS	fludioxonil	100 g/L	Fungicide

Trial 2.1 and Trial 2.2

Trial 2.1 and Trial 2.2 were both conducted in grey sandy soil within a commercial bean crop at Wesley Vale, Tasmania. Green bean seeds (cv Celtic in Trial 1 and cv. Strike in Trial 2) were treated by coating seeds with a suspension of seed dressing product at the appropriate rates, and then air-dried. The trial design was randomised complete block. In Trial 2.1, there were three replicates in 2 m x 4 m plots and 60 seeds were sown per plot, and seedling emergence and survival were recorded at 14 and 48 days after sowing.

Treatment list for Trial 2.1

No.	Seed Treatment code	Active ingredient (ai)	Active ingredient concentration (g/100 kg seed)	Product Rate /100 kg seed
1	Untreated control	-	N/a	N/a
2	A	azoxystrobin	5	50 mL
3	F	fludioxonil	5	50 mL
4	MF	metalaxyl + fludioxonil	5.625 + 3.75	150 mL
5	FM	fludioxonil + metalaxyl-M	3.75 + 1.5	150 mL
6	DM	difenconazole + metalaxyl-M	11.96 + 2.99	130 mL
7	AFM	azoxystrobin + fludioxonil + metalaxyl-M	7.5 + 1.25 + 3.75	100 mL
8	Thiram DG	thiram	400	500 g
9	Thx	thiamethoxam	140	400 mL

Treatment List for Trial 2.2

No.	Seed Treatment Code	Active ingredient	Active ingredient concentration (g per 100 kg seed)	Product Rate (per 100 kg seed)
1	Untreated control	-	-	-
2	FM150	fludioxonil + metalaxyl-M	3.75 + 1.5	150 mL
3	FM250	fludioxonil + metalaxyl-M	6.25 + 2.5	250 mL
4	AFM75	azoxystrobin + fludioxonil + metalaxyl-M	5.63 + 0.94 + 2.81	75 mL
5	AFM100	azoxystrobin + fludioxonil + metalaxyl-M	7.5 + 1.25 + 3.75	100 mL

6	AFM200	azoxystrobin + fludioxonil + metalaxyl-M	15 + 2.5 + 7.5	200 mL
7	Thiram DG	thiram	400	500 g

In Trial 2.2, there were five replicates in 2 m x 1 plant rows, with 40 seeds sown per plot, and seedling emergence and survival were recorded at 24 and 53 days. Twenty consecutive plants from the middle of each plot were also collected and assessed for root rot incidence, root rot severity and average fresh shoot weight at 51 and 55 days after sowing in Trial 2.1 and Trial 2.2, respectively.

The root rot severity was rated according to the following disease rating:

0 Healthy plant
1 No hypocotyl rot and slight root discolouration.
2 Moderate hypocotyl discolouration or rot
3 Severe hypocotyl rot or tap root rot

Trial 2.3

This trial was conducted in grey sandy loam soil within a commercial processing bean crop at Sassafras, Tasmania. Green bean seeds (cv Flavor Sweet) were treated by coating seeds with the appropriate treatment and sealed with a polymer film coating. The trial design was repeated blocks, with eight replicates, in 1 bed x 200 m for each block. Seeds were sown with a precision commercial seed drill.

Treatment List for Trial 2.3

No.	**Seed Treatment**	**Active ingredient concentration (g per 100 kg seed)**	**Product Rate (per 100 kg seed)**
1	Thiram Liquid	120	200 g
2	Apron XL + Maxim FS + Thx (+ Zinc)	70 + 20 + 80.5	200 mL + 200 mL + 230 mL
3	Apron XL + Maxim FS + Thx	70 + 20 + 80.5	200 mL + 200 mL + 230 mL
4	Apron XL + Maxim FS	70 + 20	200 mL + 200 mL

At 47 days after sowing, approximately 40 plants within a 3 m plant row were assessed for plant wilting incidence and root rot severity as described below. At 49 DAS, 15 consecutive plants were also collected from each treatment plot, washed and then assessed for root rot severity as described below. The plants'' fresh root and shoot weights were also recorded.

Plant wilting severity rating

0 No wilt
1 Wilting of a few top leaves on one or two branches
2 Wilting of leaves on more than two branches or up to 30% of plant
3 Wilting on 30% to 70% of the plant.
4 Wilting on more than 70% of the plant or desiccation of whole plant

Root rot severity rating

0 Healthy plant
1 No hypocotyl rot and slight root discolouration
2 Moderate hypocotyl root discolouration or root rot

3 Severe hypocotyl rot or rotten tap root
4 Dead or dying plant

Analysis of variance was conducted on all data sets using Statgraphics Plus 2.0, and pairwise comparisons were made of the mean values using Least Significant Difference Test (LSD).

RESULTS

Table 2.1: Seed treatment effects in Trial 2.1

No.	Seed Treatment Code	Active ingredient concentration (g/100 kg seed)	% Seedling Emergence (14DAS)	% Seedling Survival (48DAS)	Fresh shoot weight (g/plant) (51DAS)	Root Rot Incidence (%) (51DAS)
1	Untreated control	N/a	71	84	38	34
2	A	5	55	76	41	12
3	F	5	60	79	51	18
4	MF	5.625 + 3.75	75	85	46	12
5	FM	3.75 + 1.5	48	67	40	14
6	DM	11.96 + 2.99	62	80	42	15
7	AFM	7.5 + 1.25 + 3.75	70	84	48	15
8	Thiram DG	400	67	86	46	17
9	Thx	140	51	72	43	28
p-value			0.411	0.183	0.353	0.469

DAS = Days after sowing

Figure 2.1: Seed treatment effects on root rot incidence in Trial 2.1

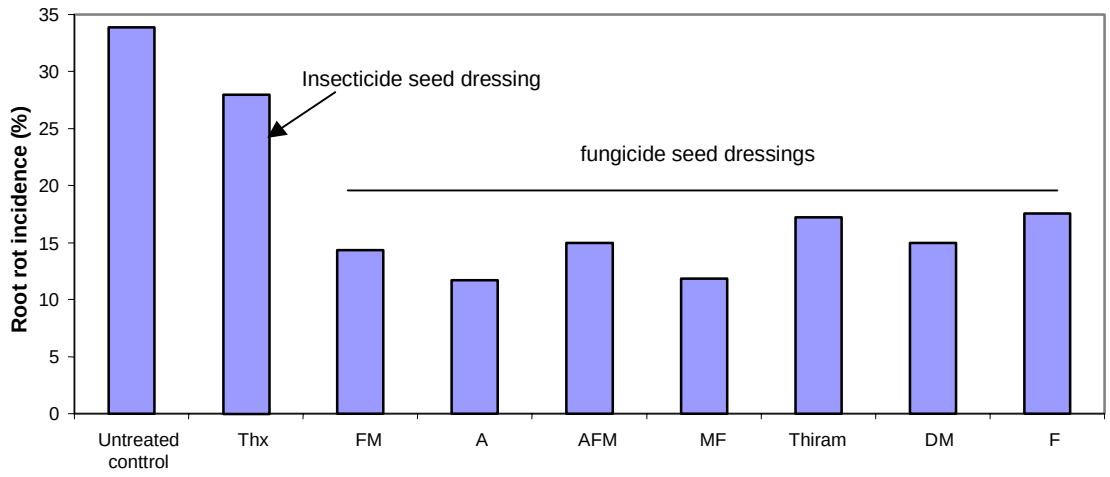


Table 2.2: Seed treatment effects in Trial 2.2

No.	Seed Treatment	Active ingredient concentration (g per 100 kg seed)	% Seedling emergence (24DAS)	% Seedling survival (53DAS)	Average fresh shoot weight g/plants (55DAS)	% Roots free of root rot (55DAS)	Root rot index of surviving plants (55DAS)
1	Untreated control	-	77	75	44	0 a	2.4 d
2	FM150	3.75 + 1.5	87	88	41	2 a	2.1 bc
3	FM250	6.25 + 2.5	81	80	41	2 a	2.2 cd
4	AFM75	5.63 + 0.94 + 2.81	83	81	36	6 ab	1.9ab
5	AFM100	7.5 + 1.25 + 3.75	86	85	38	11 bc	1.7a
6	AFM200	15 + 2.5 + 7.5	86	85	38	14 c	1.6a
7	Thiram DG	400	87	85	41	2 a	2.3 cd
p-value			0.434	0.282	0.243	0.0011	0.0001

DAS = Days after sowing
Means within columns followed by the same letter are not significantly different at the 5% level according to LSD test.

Figure 2.2: Seed treatment effects on healthy root development in Trial 2.2

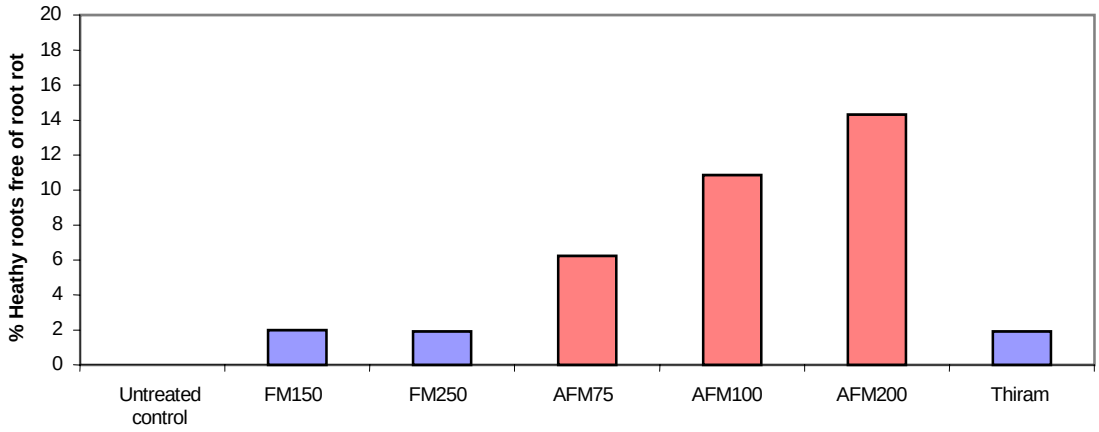


Figure 2.3: Seed treatment effects on root rot index in Trial 2.2

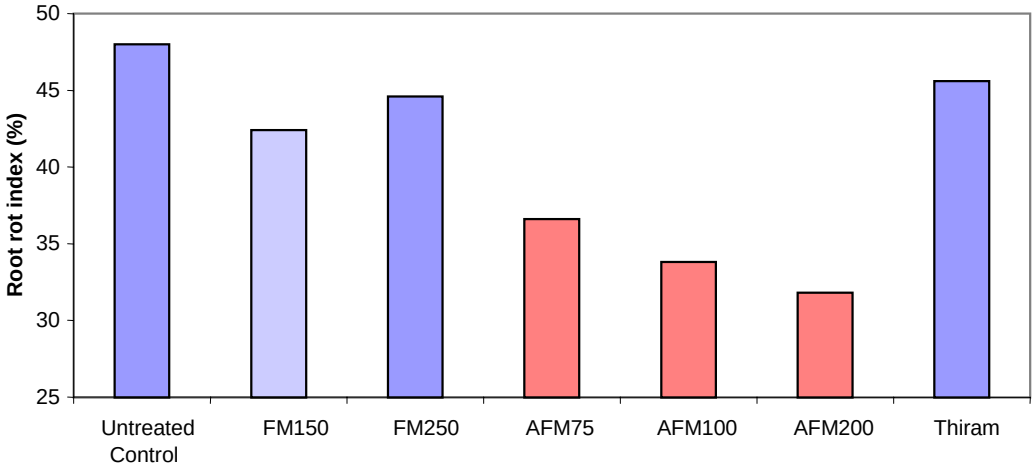


Table 2.3: Mean fresh shoot weight, plant wilting incidence and severity, and tap root rot of beans in Trial 2.3

No.	Seed Treatment	Active ingredient concentration (g per 100 kg seed)	Wilting incidence (% plant affected) (47DAS)	Wilting severity index of affected plants (47DAS)	Average fresh shoot weight (g/plant) (49DAS)	Tap root rot incidence (% plants with rotten tap root) (49DAS)
1	Thiram Liquid	120	14.1 a	2.5	24.7 c	43 c
2	Apron XL + Maxim FS + Thx (+ Zinc)	70 + 20 + 80.5	0.6 b	2.0	20.4 b	19 a
3	Apron XL + Maxim FS + Thx	70 + 20 + 80.5	1.8 b	1.3	16.9 a	21 ab
4	Apron XL + Maxim FS	70 + 20	1.9 b	2.6	19.2 ab	29 b
p-value			< 0.0001	-	0.0012	< 0.0001

DAS = Days after sowing
Means within columns followed by the same letter are not significantly different at the 5% level according to LSD test.

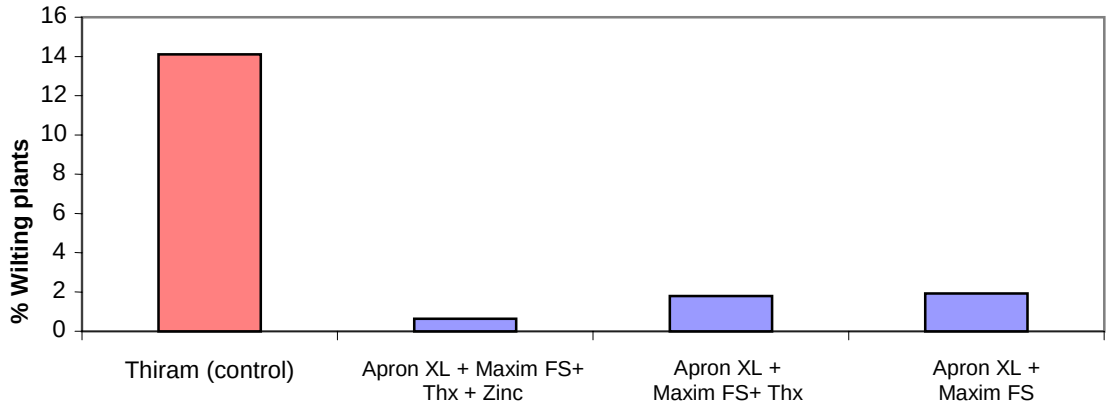
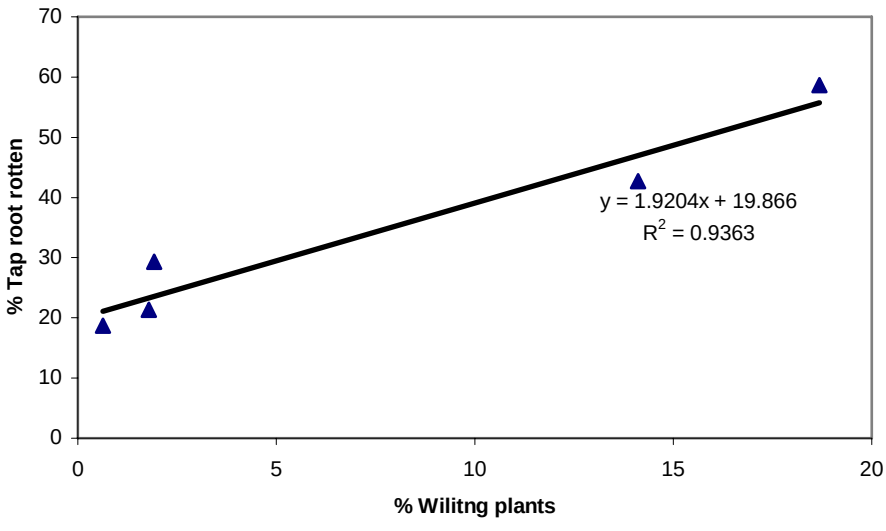


Figure 2.4: Seed treatment effects on the incidence of wilting plants at 47DAS

Figure 2.5: The relationship between tap root rot and incidence of wilting plants



DISCUSSION

Trial 2.1

The seedling emergence and survival rates were highly variable due to poor sandy soil and the relatively dry soil conditions. Therefore, in the analysis of variance, there were no significant differences in seedling emergence, survival, average fresh shoot weight, or root rot incidence (Table 2.1). Poor seedling growth in the trial study was mainly due to poor root establishment in poor soil. The root rot severity was considered to be mild. Although not significant, there was also a trend of lower root rot incidence on plants grown from fungicide treated seeds, in comparison to plants from untreated control seeds and the insecticide thiamethoxam treated seeds (Figure 2.1).

Trial 2.2

The seeds were planted under ideal field conditions, and rapid seedling emergence was noted. Although there were no significant differences in the seedling emergence and survival, there was a trend of slight improvements in seedling emergence and establishment due to the fungicide seed treatments in comparison to the untreated control (Table 2.2).

Rhizoctonia and *Fusarium* were the main causes of root rot in the trial. Most roots were affected by root rot, but the severity was considered to be mild to moderate. Only a small percentage of roots were completely free of root rot. There were significant differences between treatments in the percentage of healthy roots and root rot index. AFM seed treatments resulted in significantly higher incidence of healthy roots and lower root rot severity (Figures 2.2-2.3). This finding indicates that the combination of three fungicide active ingredients, azoxystrobin, fludioxonil and metalaxyl was more effective in protecting the seeds and reducing root rot, in comparison to the fludioxonil and metalaxyl combination and the standard thiram treatment.

There was also a trend of slightly lower average fresh shoot weight of plants produced from seeds treated with AFM. This result was consistent with the field observation of a slight delay in seedling emergence and consequently smaller plant size with the AFM seed treatments. The delay in seedling emergence appeared to be due to azoxystrobin.

Trial 2.3

Excellent seedling establishment and growth were noted in Trial 2.3. However, at the flowering crop stage, a relatively high percentage of bean plants in the paddock, both inside and outside the trial area, were wilting. With the standard thiram seed treatment, there was an average of 14% wilt affected plants (Table 2.3). The wilting symptoms ranged from temporary wilt to permanent wilt or complete desiccation of the plant.

There were significant differences in the plant wilt incidence and tap root rot incidence between the seed treatments (Table 2.3). All of the seed treatments with metalaxyl-M (Apron XL) and fludioxonil (Maxim FS) reduced plant wilt incidence by at least 87% in comparison to the standard thiram control treatment (Figure 2.4). Similarly, the incidence of plants with rotten tap root was reduced by at least 33% by the alternative seed treatments when compared to the thiram control. A higher percentage of tap roots on plants from the thiram seed treatment were completely rotten. There was a linear relationship between the tap root rot and incidence of wilting plants (Figure 2.5). This indicates that the rotten tap roots had resulted in poor water uptake, and hence wilting symptoms on the affected plants. *Rhizoctonia* and *Fusarium* were found in association with the tap root rot.

There were significant differences in the average fresh shoot weight between the seed treatments (Table 2.3). The seed treatments with Apron XL and Maxim FS, with and without thiamethoxam (thx), tended to result in lower fresh shoot weights. This indicates that the new seed dressing combinations could delay seed germination, and seedling emergence and growth. The addition of zinc (Treatment 2) appeared to help counter the adverse effect.

Conclusions

The new fungicide seed dressing combinations with azoxystrobin, fludioxonil and metalaxyl-M were suitable alternatives to thiram for general damping off and root rot control.

3. SCLEROTINIA CONTROL

SUMMARY

Two field trials were conducted in early 2005 within commercial green bean crops at Merseylea, Tasmania, in order to compare the alternative fungicides Amistar SC, Amistar WG and Filan to Sumisclex for *Sclerotinia* control. The potential of gypsum for *Sclerotinia* control, on its own and with Amistar or Filan, was also examined in the trials. A third trial was conducted in 2006 within a commercial green bean crop at Merseylea, Tasmania, to examine the potential of integrating biological control agents based on *Bacillus subtilis* and *Trichoderma harzianum* with fungicide treatments for *Sclerotinia* control.

The early timing of the first fungicide application at the flowering stage was critical for effective white mould control. Filan applied at 0.8 and 1.0 kg/ha gave effective white mould disease control on bean crops, and it is a suitable alternative to Sumisclex for *Sclerotinia* control. Amistar gave little or no white mould control. Gypsum alone did not reduce *Sclerotinia* infections on treated bean plants, but when applied with Filan 1.0 kg/ha, appeared to slightly improved *Sclerotinia* control compared to Filan 1.0 kg/ha alone. Further studies are needed to determine if Fulzyme® Plus could be used in alternation with fungicides for consistent improvement in disease control.

INTRODUCTION

Procymidone (sold as Sumisclex or Fortress) is regularly used for *Sclerotinia* control on bean crops for the control of white mould by *S. sclerotiorum*. In late 2004, procymidone was suddenly withdrawn from use on beans due to safety concerns. At the request of representatives from the Australian bean industry, emergency permits were issued for the use of the relatively new fungicide active ingredients boscalid (Filan) and azoxystrobin (Amistar) as fungicide alternatives to procymidone for white mould control. Although the effectiveness of Filan for white mould control has been established, there have been little or no evaluations on the efficacy of Amistar. Two field trials were, therefore, conducted in early 2005 within commercial bean crops to evaluate and compare the efficacies of Amistar and Filan to Sumisclex for white mould control. The potential of gypsum for *Sclerotinia* control, on its own and with Amistar or Filan, was also examined in the trials.

A third trial was also conducted in 2006 within a commercial green bean crops at Merseylea, Tasmania, to examine the potential of integrating beneficial biological products based on *Bacillus subtilis* and *Trichoderma* species with fungicide treatments for *Sclerotinia* control. *B. subtilis* and *Trichoderma spp.* are beneficial bacteria and fungal microbes that are also believed to be antagonistic to plant pathogens and may have activities in preventing *Sclerotinia* infections under low disease pressure. With high disease pressure, these products are believed to work better when applied in alternation with fungicides. This study was therefore conducted to determine if these biocontrol agents may help reduce disease levels when applied in alternation with Filan, and potentially reduce the number of fungicide applications.

MATERIALS & METHODS

Product List

Product Name	Active Ingredient (ai)	Concentration of ai	Formulation
Sumisclex SC	procymidone	500 g/L	Suspension concentrate
Amistar SC	azoxystrobin	250 g/L	Suspension concentrate
Amistar WG	azoxystrobin	500 g/kg	Water dispersible

			granule
Filan WG	boscalid	500 g/kg	Water dispersible granule
Gypsum (Micro-Gyp™)	calcium sulphate	21.6 % Ca, 17.3 % S	Wettable powder
Fulzyme® Plus	*Bacillus subtilis* *Amino acids*	1 x 10^{10} cfu/ml 13%	Liquid product
TRI-D25 Trichoderma	*Trichoderma koningii* *Trichoderma harzianum*	3 x 10^{7} cfu/g 2 x 10^{7} cfu/g	Wettable powder

Fulzyme® Plus contains the beneficial bacteria *B. subtilis* as well as selected amino acids designed to improve plant health.

Trial 3.1 was conducted in January to February 2005, Trial 3.2 was conducted in February to March 2005, and Trial 3.3 was conducted in February to March 2006. All of the trials were conducted within commercial bean crops at Merseylea, Tasmania, a region that is ideal for bean crop production, as well as field conditions that favour *Sclerotinia* disease. The trial design for all the trials was randomised complete block with five replicates, and plot size was 4 plant rows x 5 m. Spray treatments were applied with a knapsack precision sprayer with fitted 1.5 m boom and conejet nozzles TX12, and sprays were applied at approximately 270 L water/ha at a pressure of 400 kPa.

Treatment list for Trial 3.1

No.	Treatment	Rate		Application Schedule
		Product/ha	ai/ha	
1	Untreated control	0	-	-
2	Amistar SC	0.5 L	125 g	3 sprays at 55, 62 and 69 days after sowing. 1st spray at 70-80% flowering.
3	Amistar SC	0.6 L	150 g	
4	Filan	0.8 kg	400 g	
5	Filan	1.0 kg	500 g	
6	Gypsum	2.5 kg	-	
7	Amistar SC + gypsum	0.6 L + 2.5 kg	-	
8	Filan + gypsum	1.0 kg + 2.5 kg	-	

Treatment list for Trial 3.2

No.	Treatment	Application Rate		Application Schedule
		Product/ha	ai/ha	
1	Untreated control	Nil	-	-
2	Amistar WG	0.3 kg	150 g	3 sprays at 50, 57 and 64 days after sowing. 1st spray at 20-30% flowering.
3	Sumisclex	1.0 L	500 g	
4	Filan	1.0 kg	500 g	
5	Filan + gypsum	1.0 kg + 2.5 kg	500 g + 2.5 kg	

Treatment list for Trial 3.3

No.	Treatment	Product Rate/ha	Application schedule
1	Untreated control	-	
2	Nil, Filan 1.0 kg, Nil*	1.0 kg	3 sprays at 47, 55 and 62 days after sowing. 1st spray applied at 10-20% flowering
3	Filan 0.8 kg	0.8 kg	
4	Filan 1.0 kg	1.0 kg	
5	Filan 0.8 kg + gypsum	0.8 kg + 2.5 kg	
6	Filan 1.0 kg + gypsum	1.0 kg + 2.5 kg	
7	Fulzyme® Plus, Filan 1.0 kg, Fulzyme® Plus *	2.0 L, 1.0 kg, 2.0 L	
8	TRI-D25 Trichoderma, Filan 1.0 kg, TRI-D25 Trichoderma*	2.0 kg, 1.0 kg, 2.0 kg	

Fulzyme® Plus and TRI-D25 Trichoderma are beneficial biological products based on *B. subtilis* and *Trichoderma* spp.
* Alternate spray applications

Disease assessments

Plants were assessed for *Sclerotinia* incidence and severity at close to commercial harvest, 73-74 days after sowing. The numbers of plants infected by Sclerotinia in each plot were counted in the two middle plant rows and 3 m along the rows. The disease incidence was tabulated as the percentage of the total number of plants assessed.

The disease severity was assessed according to the following severity rating:
1 = mild - infection of single stem, leaf or bean pod
2 = moderate - infection of multiple stem branches
3 = severe - infection affecting whole plant

Disease severity index was then tabulated according to the formula:

$$\text{Disease index} = \frac{[(1 \times \text{no. plants in rating 1}) + (2 \times \text{no. plants in rating 2}) + (3 \times \text{no. plants in rating 3})]}{(3 \times \text{total plants})} \times 100$$

Statistical Analysis

Analysis of variance was conducted on the data set using Statgraphics Plus 2.0, and pairwise comparisons were made of the mean values using Least Significant Difference Test (LSD).

RESULTS

Table 3.1: Treatment effects for white mould control on bean plants at harvest in Trial 3.1 (73 DAS)

No.	Treatment	*Sclerotinia* incidence	*Sclerotinia* severity (% Plants with each disease rating)			
		% Plants infected	% Mild	% Moderate	% Severe	Disease severity index (%)
1	Untreated control	64 cd	43	18	3	29 cd

2	Amistar SC 0.5 L	61 cd	33	19	9	33 d
3	Amistar SC 0.6 L	49 bc	37	9	3	22 abcd
4	Filan 0.8 kg	30 ab	25	4	2	12 ab
5	Filan 1.0 kg	39 ab	25	10	4	19 abc
6	Gypsum 2.5 kg	70 d	48	19	3	32 d
7	Amistar SC 0.6 L + gypsum	49 abc	30	12	8	25 bcd
8	Filan 1.0 kg + gypsum	26 a	22	4	0	10 a
p-value		0.0016	-	-	-	0.0034

Means within columns followed by the same letter are not significantly different at the 5% level according to LSD test.
DAS = Days after sowing

Figure 3.1: Treatment effects on white mould incidence in Trial 3.1

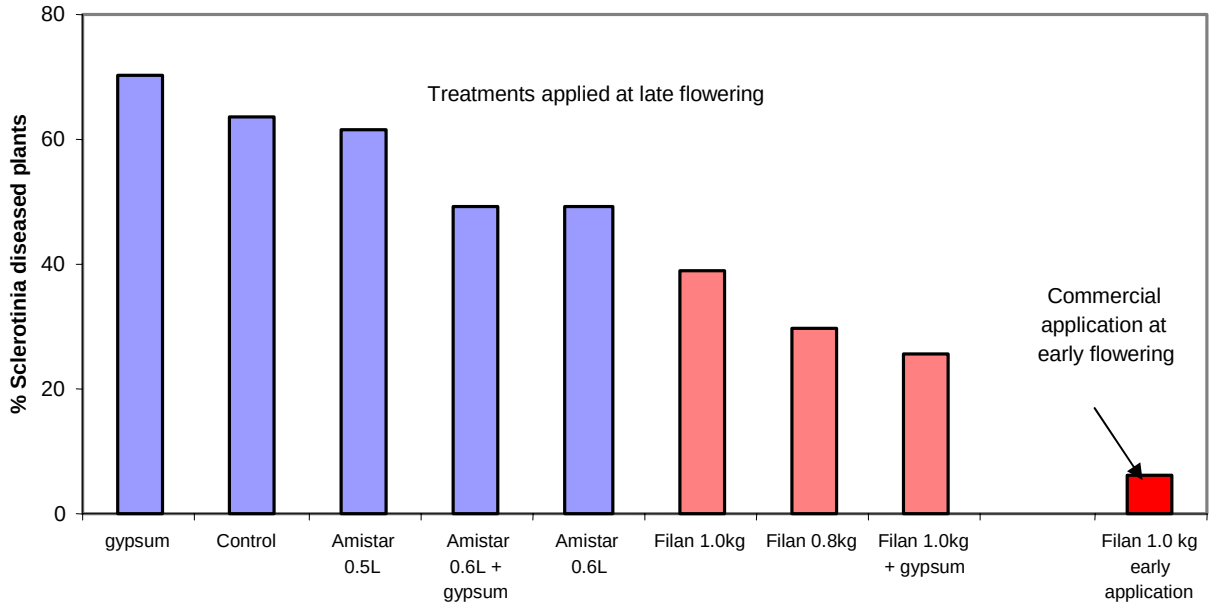


Table 3.2: Treatment effects for white mould control on bean plants at harvest in Trial 3.2 (73 DAS)

No.	Treatment	*Sclerotinia* incidence	*Sclerotinia* severity (% Plants with each disease rating)				*Botrytis* incidence (% plants infected)
		% Plants infected	% Mild	% Moderate	% Severe	Disease severity index (%)	
1	Untreated control	39.4 b	35.2	3.2	1.0	15.2 b	14.6 b
2	Amistar WG 0.3 kg	27.6 b	24.6	2.8	0.2	10.6 b	3.4 ab
3	Sumisclex 1.0 L	6.8 a	6.6	0.2	0.0	2.5 a	2.1 a
4	Filan 1.0 kg	5.5 a	5.3	0.0	0.2	2.1 a	1.3 a
5	Filan 1.0 kg + gypsum 2.5 kg	5.6 a	5.2	0.2	0.2	2.0 a	2.0 a
p-value		< 0.0001				< 0.0001	0.0113

Means within columns followed by the same letter are not significantly different at the 5% level according to LSD test.
DAS = Days after sowing

Table 3.3: Treatments effects for white mould control on bean plants at harvest in Trial 3.3 (74 DAS)

No.	Treatment	*Sclerotinia* incidence	*Sclerotinia* severity (% plants with rating)			
		% Plants infected	% Mild	% Moderate	% Severe	Disease severity index (%)
1	Untreated control	18.1a	10.5	6.5	1.1	8.9a
2	Nil, Filan 1 kg, Nil	9.1 b	6.3	2.5	0.2	4.0 b
3	Filan 0.8 kg	3.8 bc	2.1	0.4	1.3	2.2 b
4	Filan 1.0 kg	3.4 bc	1.1	1.8	0.5	2.1 b
5	Filan 0.8 kg + gypsum	4.2 bc	2.7	0.8	0.6	2.1 b
6	Filan 1.0 kg + gypsum	2.4 c	1.8	0.5	0.0	1.0 b
7	Fulzyme® Plus, Filan 1.0 kg, Fulzyme® Plus	5.3 bc	4.2	0.5	0.5	2.3 b
8	TRI-D25 Trichoderma, Filan 1.0 kg, TRI-D25 Trichoderma	7.2 bc	4.2	2.3	0.6	3.6 b
p-value		0.0002	-	-	-	0.0005

Means within columns followed by the same letter are not significantly different at the 5% level according to LSD test.
DAS = Days after sowing

DISCUSSION

Trial 3.1

The first fungicide spray applications were applied at the late flowering period, when all plants were flowering, and approximately 70-80% of the flowers were opened. At close to harvest, white mould incidence was very high, with approximately 64% *Sclerotinia* infected plants in the untreated control plots (Table 3.1). Outside the trial area, Filan 1.0 kg/ha was applied commercially in three fungicide applications at 7-day intervals and at early flowering, nine days before the first fungicide applications in the trial area. An assessment of plant rows immediately outside the trial area showed that the average disease incidence and severity index was 6% compared to 19% in the trial area for the same treatment with Filan (Figure 3.1). These differences show that the timing of the first fungicide application is critical in order to provide early protection of flowers from *Sclerotinia* infections, and subsequently, prevent secondary infections from the infected flowers onto plant leaves, stems or pods at close to harvest.

Filan at 0.8 kg/ha and 1.0 kg/ha significantly reduced the percentage of plants infected by *Sclerotinia (*Table 3.1, Figure 3.1). There was no significant difference between the two Filan rates of 0.8 kg/ha and 1.0 kg/ha. Amistar SC applied at 0.5 and 0.6 L/ha gave no significant disease control when compared to the untreated control. Amistar SC appeared to be more effective at the higher rate of 0.6 L/ha compared to 0.5 L/ha.

Gypsum alone did not reduce *Sclerotinia* infections on treated bean plants, but when applied with Filan 1.0 kg/ha, appeared to slightly improve *Sclerotinia* control compared to Filan 1.0 kg/ha alone. No improvement in disease control was noted in the Amistar + gypsum mixture.

Trial 3.2

In Trial 3.2, the first fungicide spray applications were applied at the early flowering period, when only 20 to 30% of the flowers were opened, at the same timing as the commercial Filan applications outside the trial area. The level of disease control inside the trial area by Filan was similar to that outside the trial area. At close to harvest, white mould incidence was moderate, with approximately 39% *Sclerotinia* infected plants the untreated control plots (Table 3.2).

Filan was found to be as effective as Sumisclex for *Sclerotinia* control (Table 3.2). At 9 days after the last treatment application, Filan significantly reduced *Sclerotinia* incidence by 86% compared to the untreated control. In contrast, Amistar WG applied at 300 g/ha did not control *Sclerotinia* disease when compared to the untreated control.

Botrytis infections were also noted on some leaves, pods and stems. Most of the plants infected by *Botrytis* were rated as mild in disease severity, with the infection usually confined to a single leaf, stem or pod. Filan and Sumisclex treatments significantly reduced the percentage of plants infected by *Botrytis*. Amistar WG also appeared to be effective in reducing *Botrytis* infections.

Trial 3.3

In Trial 3, the first fungicide spray applications were applied at the early flowering period, when only 10 to 20% of the flowers were opened. *Sclerotinia* disease levels in the crop were considered to be low to moderate, with approximately 18% *Sclerotinia* infected plants in the untreated control plots (Table 3.3).

All Filan applications, alone or in combinations with gypsum, Fulzyme® Plus or TRI-D25 *Trichoderma,* significantly reduced *Sclerotinia* incidence and severity (Table 3.3). Due to the relatively low disease incidence, there were no significant differences in the *Sclerotinia* incidence between all the treatments with Filan applications. Three spray applications of Filan (Treatments 3-4) appeared to consistently result in lower disease incidence compared to one application of Filan Treatment 2). Gypsum applied with Filan 1.0 kg/ha appeared to slightly improve *Sclerotinia* incidence and severity compared to Filan 1.0 kg/ha alone. Two applications of Fulzyme® Plus in alternation with one application of Filan appeared to slightly improve disease control compared to a single application of Filan.

Conclusions

The early timing of the first fungicide application was critical in order to provide early protection of flowers from *Sclerotinia* infections. Filan applied at 0.8 and 1.0 kg/ha gave effective white mould disease control on bean crops, and it is a suitable alternative to Sumisclex for *Sclerotinia* control. Amistar was not effective for white mould control. Gypsum alone did not reduce *Sclerotinia* infections on treated bean plants, but when applied with Filan 1.0 kg/ha, appeared to slightly improve *Sclerotinia* control compared to Filan 1.0 kg/ha alone. Further studies are needed to determine if Fulzyme® Plus could be used in alternation with fungicides for consistent improvement in disease control.

4. ROOT ROT MANAGEMENT

SUMMARY

There are no effective fungicides for *Aphanomyces* root disease control. Effects of the soil treatments within commercial bean crops with fungicides, biofumigants or biocontrol agents for root rot management in bean crops were inconclusive, and further investigations under controlled conditions are required.

INTRODUCTION

A pot trial study was conducted in 2005 to evaluate fungicides for *Aphanomyces* root disease control. In 2005 to 2007, three field studies were conducted within commercial bean crops to investigate the use of soil treatments using green manure biofumigant crop (BQ-Mulch), Fulzyme® Plus and TRI-D25 *Trichoderma* biocontrol products based on *Bacillus subtilis* and *Trichoderma* spp. for root rot management.

MATERIALS & METHODS

Trial 4.1 - *Aphanomyces* root rot control

A pot trial was conducted in 2005 to evaluate the effects of various fungicides for the control of *Aphanomyces* root rot on green beans. Green bean seeds (cv Celtic) were treated by coating seeds with suspensions of fungicide seed dressing at the appropriate rates, and then air-dried. Field soil collected in a paddock where severe bean root rot due to *Aphanomyces* had been identified, was used in the study. Ten seeds were sown per pot in 6 L soil. The trial design was randomised complete block with four replicates. Seedling emergence was assessed at 13 days after sowing, and survival was assessed at 36 and 49 days after sowing. At 49 days after sowing, seedlings were also examined for root rot incidence and severity.

The root rot severity was rated according to the following disease rating:

0 = no rot,
1 = < 2%,
2 = 2-10%,
3 = 11-50%,
4 = >50% discolouration and decay
5 = plant dead or dying

Seed treatments in Trial 4.1

No.	Seed Treatment Code	Active ingredient	Active Ingredient Rate (g per 100 kg seed)	Product Rate (per 100 kg seed)
1	untreated control	N/a	N/a	N/a
2	A	azoxystrobin	5	50 mL
3	F	fludioxonil	5	50 mL
4	MF	metalaxyl-M + fludioxonil	5.63 + 3.75	150 mL
5	FM	fludioxonil + metalaxyl-M	3.75 + 1.5	150 mL
6	DM	difenconazole + metalaxyl-M	11.96 + 2.99	130 mL
7	AFM	azoxystrobin + fludioxonil + metalaxyl-M	7.5 + 1.25 + 3.75	100 mL
8	Thiram	thiram	400	500 g

Trial 4.2 - Non-chemical control

A field study was conducted within a commercial bean crop in 2005/06 at Sunnyside, Tasmania, to evaluate the effects of biological products (Fulzyme® Plus and TRI-D25 *Trichoderma*) in soil applications. Previously, the paddock was divided into two halves: with half sown with BQ-Mulch and another half sown with ryegrass. Therefore, the effects of the previous green manure crops on the subsequent green bean crop growth and levels of root rots were also examined by carrying out a trial within an area previously planted with BQ-Mulch and duplicating the trial in an area previously planted with ryegrass. The trials were set up after bean seeds (cv Flavor Sweet) had been sown in the paddock. The biological products were applied with 8 L water per plot (equivalent to 8,000 L water/ha) using a watering can, at 4 days after sowing, and a second application was applied at 39 days after sowing. The trial design was randomised complete block with four replicates and the plot size was 2 m x 5 m. At 60 days after sowing, plant densities were recorded and twenty consecutive plants per plot were examined for root rot severity and fresh shoot weights. At 74 days after sowing, the levels of plant wilt and root rot severity were rated as described in Trial 4.1.

Treatment list for Trial 4.2

No.	Treatment	Product Rate/ha
1	Untreated control	-
2	Fulzyme® Plus - one application	2 L
3	Fulzyme® Plus - two applications	2 L
4	TRI-D25 *Trichoderma* - one application	4 kg
5	TRI-D25 *Trichoderma* - two applications	4 kg

Trial 4.3 - Voom, a liquid biofumigant formulated product

A field study was conducted within a commercial bean crop in 2005/06 at Merseylea, Tasmania, to examine the potential use of Voom, a biofumigant extract from mustard, for root rot control. The trial design was randomised complete block with four replicates and the plot size was 2 m x 5 m. At eleven days prior to sowing, Voom was applied at 50 L/ha. The product was sprayed onto the soil

surface with 530 L water/ha and then incorporated into top soil (10 cm deep) with a rotary hoe. The trial design was randomised complete block with four replicates and the plot size was 6 m by 4 m. At 24 days after sowing, 20 consecutive plants in middle row of each plot were collected, and their total fresh shoot weights and root rot incidence and severity were recorded as described in Trial 4.1.

Treatment list for Trial 4.3

No.	Pre-plant soil treatment	Product Rate
1	Untreated control	n/a
2	Liquid biofumigant (Voom™)	50 L/ha

Trial 4.4 - Fungicide soil treatments

A field study was conducted within a commercial bean crop in 2005/06 at Wesley Vale, Tasmania, to examine the efficacy of fungicide soil treatments for root rot control. Soil treatments were applied after seeds had been sown into dry soil and the soil surface rolled. Fungicides were first applied onto gypsum granules as a carrier and mixed thoroughly to ensure an even coating onto the granules. The fungicide treated gypsum was then broadcast onto each plot at 200 kg/ha and raked into topsoil to a depth of approximately 5 cm. The trial design was complete randomised block, with four replicate plots. The plot size was 5 m x 2 m, and the paddock was irrigated soon after the treatment applications in order to drench in the fungicide products.

Treatment list for Trial 4.4

No.	Treatment	Product Rate/ha	Active Rate/ha	Application Method
1	Untreated control	N/a	N/a	Soil raked
2	Amistar	2 L/ha	500 g	Soil raked soon after broadcasting of fungicide treated gypsum at 200 kg/ha
3	Filan	1 kg/ha	500 g	
4	Rizolex	1 L/ha	500 g	
5	Thiram	1 kg/ha	800 g	

Assessments for seedling emergence and survival were conducted at 28 days after sowing and 21 days after soil treatments, by recording the number of seedlings in 2 plant rows x 3 m in each plot. At 74 days after sowing and 67 days after soil treatments, 20 consecutive plants in middle row of each plot were collected, and their total fresh shoot weights were recorded. The roots of the 20 plants were washed and rated for root rot severity. The root rot severity was assessed according to the following severity ratings:

0 = no root rot
1 = no hypocotyl rot, slight root discolouration
2 = < 10 % hypocotyl rot, some root discolouration
3 = 11-30% hypocotyl rot, root discolouration
4 = 31-60% hypocotyl rot, root discolouration
5 = > 60% hypocotyl rot, root discolouration

Roots were also rated for black root rot incidence due to *Thielaviopsis* and calculated as a percentage of the 20 roots assessed.

RESULTS

Table 4.1: Seed treatment effects in *Aphanomyces* infected soil in Trial 4.1

No.	Seed Treatment Code	Product Rates (per 100 kg seed)	13DAS	36DAS	49DAS		
			% Emergence	% Survival	% Survival	Disease incidence (%)	Disease severity index (%)
1	Untreated control	0	60	35	35	100	90
2	A	50 mL	58	48	43	100	85
3	F	50 mL	65	48	40	100	88
4	MF	150 mL	60	45	38	100	87
5	FM	150 mL	60	33	33	100	91
6	DM	130 mL	60	40	38	100	92
7	AFM	100 mL	53	65	60	100	72
8	Thiram	500 g	78	58	55	100	83
	p-value		0.1605	0.2578	0.4533	-	0.1770

DAS = Days after sowing

Table 4.2: Effects of green manures and biological control agents in Trial 4.2

No.	Green manure	Treatment	60DAS			74DAS
			Shoot weight from 20 plants (g)	% Roots with root rot	Root rot severity index (0 - 5)	% Wilting plants
1	Ryegrass	Untreated control	644	99	2.1	7
2		Fulzyme® Plus - one application	554	95	2.1	7
3		Fulzyme® Plus - two applications	658	100	2.0	9
4		TRI-D25 *Trichoderma* - one application	576	100	1.9	6
5		TRI-D25 *Trichoderma* - two applications	565	98	2.0	11
p-value			0.5271	0.5897	0.3876	0.3925
6	BQ-Mulch	Untreated control	760	100 b	1.9	8
7		Fulzyme® Plus - one application	675	96 b	1.8	10
8		Fulzyme® Plus - two applications	695	98 b	1.9	6
9		TRI-D25 *Trichoderma* - one application	635	91 a	1.9	7

10		TRI-D25 *Trichoderma* - two applications	654	97 b	2.0	7
p-value			0.6690	0.0069	0.5897	0.3365

DAS = Days after sowing

Table 4.3: Effects of pre-plant soil treatment with Voom, a liquid biofumigant product, in Trial 4.3

No.	Pre-plant soil treatment	Product Rate	24DAS		
			Total fresh shoot weight (g/20 plants)	Root rot incidence (% roots infected)	Root rot index (%)
1	Untreated control	0	83	8 a	3a
2	Voom	50 L/ha	75	24 b	12 b
p-value			0.2292	0.0371	0.0167

DAS = Days after sowing

Table 4.4: Effects of fungicide soil treatments in Trial 4.4

No.	Treatment	28DAS	74DAS		
		Plant density	Average fresh shoot weight/plant	Root rot severity rating (0-5)	Black root rot incidence
1	Untreated control	112	105	3.4	65
2	Amistar	122	88	3.1	45
3	Filan	105	102	3.4	31
4	Rhizolex	104	99	3.3	54
5	Thiram	113	102	3.2	46
p-value		0.2478	0.3477	0.5340	0.1742

DAS = Days after sowing

DISCUSSION

Trial 1 - *Aphanomyces* root rot control

All seedlings were infected by *Aphanomyces*, which caused reduced seedling survival and severe root rots (Table 4.1). All infected plants were stunted. None of the fungicide seed treatments had any significant effects in preventing infections, improving seedling emergence or survival, or in reducing root rot incidence and severity. This indicates that none of the fungicide active ingredients, including thiram or metalaxyl-M, were effective for *Aphanomyces* control.

Trial 2 - Non-chemical control methods

Bean plants in the area of the paddock previously planted with BQ-Mulch were generally more vigorous in growth compared to the other half of the paddock, which was previously planted with ryegrass. The increase in growth may be related to the higher levels of organic matter and nutrients incorporated into soil due to the large BQ-Mulch plants compared to ryegrass, which was grazed by sheep. The differences in plant growth were noticeable with the generally higher total fresh shoot weight in the BQ-Mulch trial area (Table 4.2).

The soil treatments with the biological control agents (*Bacillus* and *Trichoderma*) did not cause any significant differences in the fresh shoot weights or reduced root rot severity. Although there was a significant difference in Treatment 9 with one application of *Trichoderma* in the BQ-Mulch area, the root rot incidences were still generally high, ranging from 91% to 100% root system affected. Root rot mainly occurred on the tap roots, causing constrictions on some root systems, which resulted in the wilting of top parts of plant foliage at close to crop maturity. There were no obvious differences in the levels of wilting plants between all the soil treatments.

Trial 4.3 - Soil treatment with liquid biofumigant

Crop establishment and growth in the trial area and most of the paddock were excellent. There was little root disease in the bean crop. Soil treatment with Voom, the liquid biofumigant, had no obvious effect on plant growth. Although there was little root rot, there were significant increases in the root rot incidence and severity due to the soil biofumigant soil treatment. However, due to the low levels of root rot and lack of any obvious differences in plant growth, before and at close to harvest between the treated and untreated plots, no conclusions could be made.

Trial 4.5 - Fungicide soil treatments

Crop establishment and growth in the trial area were excellent. Although all roots of plants had root rots, their severity was considered to be mild to moderate and appeared to have little or no obvious impact on plant growth.

Two main types of root diseases were noted in this paddock: brown root discolouration due to *Rhizoctonia* and black root rot due to *Thielaviopsis basicola*. *Thielaviopsis* appeared to cause greater root rot severity compared to *Rhizoctonia*. The fungicide soil treatments appeared to have no obvious impact on plant densities, or on root rot severity and black root rot incidence. This study was conducted in 2007, an unusually dry season and water shortages, which might affect the fungicide efficacies and impact of the root diseases.

Conclusions

Currently, there are no effective fungicides for *Aphanomyces* root disease control. There were also no obvious beneficial effects shown by the various soil treatments with fungicides, biofumigants or biocontrol agents evaluated for root rot management in bean crops.

QUEENSLAND RESEARCH ACTIVITIES.

Queensland Final Report component
for

NSW Department of Primary Industries
HAL Project VG03002

by
John D. Duff
Queensland Department of Primary Industries and Fisheries

Queensland Government
Department of
Primary Industries
and Fisheries

QUEENSLAND REPORT SUMMARY

Bean red root rot and Sclerotinia rot are two major causes of crop loss in fresh market beans and are most common during the winter growing period of Queensland's production regions, in particular the Gympie region.

Red root disease is caused by a complex of soil fungi (*Fusarium solani* and *Fusarium oxysporum*, *Rhizoctonia solani* and *Thielaviopsis* species). *Aphanomyces euteiches* and *Pythium* spp were not isolated from bean plants on this occasion although they have been found on previous occasions in the Gympie region of Queensland. Pathogenicity tests carried out on the above soilborne pathogens, found *Rhizoctonia* and *Thielaviopsis* to be highly pathogenic exhibiting typical lesions around the collar of the young plants while the two *Fusarium* species were not wildly pathogenic.

A fungicide seed dressing trial was conducted on a property known to have red root disease issued. Unfortunately, the severity of this disease was very low with no significant differences in yield between the various treatments used to help manage this problem compared to what the grower would normally be doing. It is possible that the dry conditions favoured plant establishment and root development as no *Pythium* or *Aphanomyces* were recovered from any plants during the trial. The presence of *Fusarium, Rhizoctonia* and *Thielaviopsis* on the lower stem and roots did not appear to have any adverse effects on the plants as very few plants died during this trial with the plants still producing marketable pods.

Captan did however perform consistently better than any of the other treatments used which may suggest this product could be used as an alternative seed dressing, but would need to be investigate in more detail. Its broad spectrum of activity may lend it to being more effective at managing bean red root disease than most other products currently in use.

Sclerotinia sclerotiorum or commonly called white mould or nesting, affects bean crops from late autumn and early winter, due primarily to the environmental conditions, warm days and cool night temperatures, high humidity, showery weather, short day length and increased leaf wetness, coupled with susceptible varieties. The failure of the fungicides registered for use against this disease has resulted in procymidone being brought back under permit but with restrictions to its use, namely only 2 applications per crop. Another avenue of control was to look at plant spacings. This in combination with fungicide usage was investigated to determine if by reducing the plant spacings within the rows, this would allow for better penetration of fungicide sprays and thus better control of the disease. This trial found that there is the possibility of using plant spacings to help in the management of *Sclerotinia* rot in green beans but needs additional research on the full benefits attributed to such a change in grower practice. Increasing the plant spacing to twice the grower standard of around 7cm, there was a trend towards less disease being found in the crop in conjunction with fungicides. Even if this were only carried out during the period of the growing season when *Sclerotinia* rot is most prevalent and combined with the appropriate fungicides in a rotation program, crops losses could be reduces to a more acceptable level for the grower.

RED ROOT DISEASE OF GREEN BEANS

INTRODUCTION

Bean red root rot can be a major cause of crop loss in fresh market beans and is most common during the winter growing period. This disease is caused by a complex of soil fungi (*Fusarium solani* and *Fusarium oxysporum*, *Rhizoctonia solani*, *Pythium* spp. and *Thielaviopsis* species). *Aphanomyces euteiches* was not isolated from bean plants on this occasion although it has been found on previous occasion in the Gympie region of Queensland.

Bean root rot can occur in all major growing regions of Queensland, Lockyer Valley, Gympie and the Burdekin and is most severe during the winter crops of the Gympie district. The severity of this disease has been shown to be reduced by sowing the seed at a depth of 2.5cm as opposed to the standard practice of 5cm (HRDC Project VG024). No other control measures where shown to be as effective at managing this disease in the field due to its complexity of pathogens.

This disease is still considered a major cause of plant stunting and death predominantly in the Gympie region of Queensland during the late autumn early winter period of production and so warranted additional work carried out on it as part of HAL project VG03002.

Pathogen Identification

Survey 1
Plants with disease symptoms were collected from various bean farms in the Gympie area at the end of 2004. Various fungal organisms were isolated including *Fusarium oxysporum*, *Pythium* sp *Macrophomina phaseolina*, *Sclerotium rolfsii*, *Phytophthora* sp and *Rhizoctonia.*

Survey 2
Plants were collected from Goomboorian close to Gympie, Qld, by digging out plants that were starting to show signs of yellowing and wilting of the leaves. These plants were typically 1-2 weeks out of the ground and grown in a paddock with a history of red root rot disease as seen in photograph 1 below.

Photograph 1. Sample of infected plants.

A number of possible pathogens were isolated from the bean samples including *Fusarium oxysporum* and *F. solani*, *Rhizoctonia solani*, and *Thielaviopsis* species. Other known pathogens isolated in previous years have included *Pythium* and *Aphanomyces*.

Pathogenicity Testing

Each isolate of *Fusarium oxysporum* and *F. solani*, *Rhizoctonia solani*, and *Thielaviopsis* species was used to inoculate 3 pots of bean seedlings (seedlings inoculated at stage of 2nd true leaf emerging). Beans were grown in 5 inch pots in UC mix. Pots were seeded with 3 seeds/pot.
Fungal isolates were applied to the pots as mycelium. For each pot, 1/3 agar culture plate was macerated and incorporated into the UC mix of each pot. In addition, for each of these isolates, a sterile needle was used to insert a small amount of fungal mycelium into the lower stem of each plant – just above the soil line. Three pots of each isolate were then placed in 3 CEC cabinets (15C, 25C, 35C). The base of each pot was enclosed in a plastic bag and the plants were watered to saturation, daily.

For ratings, each plant was removed from the pot and its roots were thoroughly washed. The roots and stems were cut with a scalpel and examined for obvious signs of disease infection: root discolouration and rot, crown/stem discolouration and rot.

RESULTS AND DISCUSSION

None of the *Fusarium* species were pathogenic, but *Thielaviopsis* and *Rhizoctonia* all produced typical symptoms as shown below.

Photograph 2. Thielaviopsis symptoms at the bottom and healthy plants at the top. These plants were grown at 25ºC.

Symptoms from this fungal pathogen were more pronounced at 25ºC than at the other temperatures tested which could indicate that this is more of a cooler climate disease issue or when the crop is grown in parts of Queensland during the winter months.

Photograph 3. *Rhizoctonia* symptoms at the bottom and healthy plants at the top. These plants were grown at 35ºC.

Symptoms were still present at 25ºC but were more pronounced at the higher temperature. The 25ºC temperatures had more roots on the inoculated plants as well as the brown basal stem discolouration.

The research carried out by Wright (1997) found both *F. oxysporum* and *F. solani* to be pathogenic causing very distinct symptoms on the bean plants. The bean variety used by Wright (1997) was not

stated which could have had a bearing on the symptoms developed as a result of the fungal pathogens. The variety of beans used in these pathogenicity tests was ‘Matador’.

References

Wright, D. (1997). Bean root rot – etiology and control. HRDC Project Final Report VG024.

FUNGICIDAL CONTROL OF BEAN RED ROOT DISEASE 2006

INTRODUCTION

Bean red root disease is still considered a severe problem in the Gympie district of Queensland during the winter growing season. It is especially severe when conditions are cold and wet. A field trial was established at Goomboorian June 2006 to examine the use of chemicals to control this disease by incorporating them in the seed furrow at planting.

MATERIALS AND METHODS

A known site of red root disease was selected for this trial at Goomboorian and planted on the 27th June 2006 using the growers 2 row planter. The bean variety used was 'Valentino'.

Treatments applied were:

Fungicide Treatment	Active ingredient	Rate per 10m row
Grower standard (Thiram treated seed only)		N/A
Rizolex	tolclofos-methyl	0.12ml
Thiram	thiram	7g
Terraclor	quintozene	15g
Captan	captan	20g
Previcur	propamocarb	2.6ml
Amistar	azoxystrobin	10g
Spinflo	carbendazim	0.4ml
Ridomil Gold	metalaxyl	0.375ml

The treatments were applied at planting in the furrow created by the planter and covered over as part of the planting operation and were replicated 4 times.
Plots consisted of 4 rows that were 5m long. The trial area was maintained using normal grower practices and included regular watering and fertiliser applications and insect pest management.

Assessments:

A 3m length of row was marked out per plot and used for the following 2 assessments. The crop was assessed on the 20th July when plants had fully emerged and again on the 2nd August, 2 weeks latter, for red root symptoms.

Numbers of sick (yellowing, stunting and wilting) plants but still alive were counted as well as obvious dead plants and also the number of healthy looking plants to help calculate the number germinated. A number of plants were also sent to a diagnostician to determine the extent of the fungal pathogens still being found in individual treatments.

Five plants from each plot were carefully removed from the ground on the 16th August to include as many of the roots as possible and cut off about 5cm above the ground. The roots and lower stem was then placed into paper bags and placed into a drying oven in order to determine to average dry weights. Plants were observed through to harvest on the 4th September, at which time a 1m length of row from one of the middle 2 rows was harvested by picking all the marketable pods and weighing them.

The data collected was statistically analysed using the analysis of variance as part of the Genstat 8th Edition program supplied by the Queensland Department of Primary Industries and Fisheries.

RESULTS AND DISCUSSION

There was very little difference between the number of germinated plants and the number of healthy plants on the first assessment date of the 20th July. It was not until the 2nd August that plants were observed to be sick (that is yellowing, stunting and wilting). There was no significant difference between the treatments although Captan can be seen in Fig. 1 to have an improved percentage of healthy plants and less sick plants when compared to a number of other treatments, in particular Rizolex, Quintozene and Ridomil. This is only a trend and so would need more work to show any true relationship of management of this disease problem.

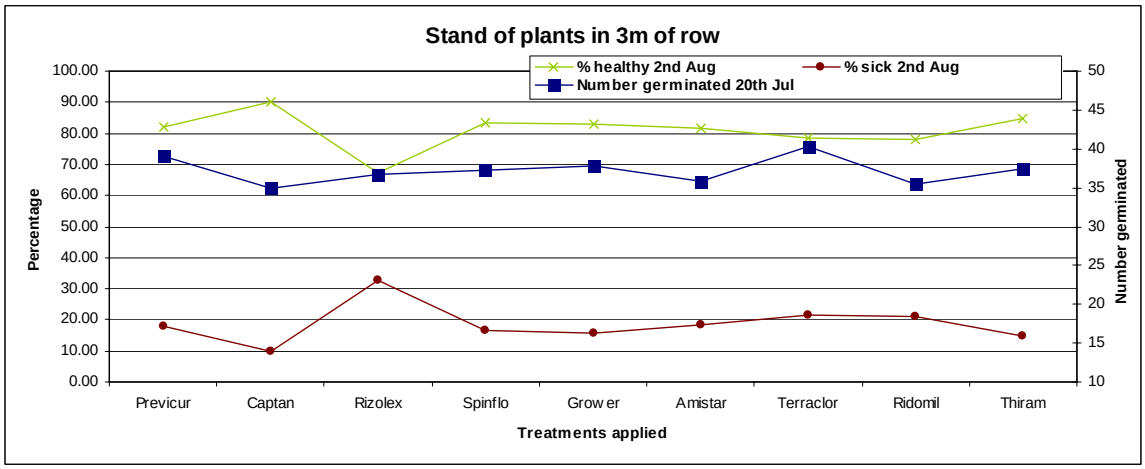


Fig. 1. The percentage plants that were sick and healthy as at the 2nd August 2007.

As in the percentage healthy and sick plants, the root and lower stem dry weights were not significantly different from one another. Captan however did show in Fig. 2 a higher value than the other treatments with Rizolex and Ridomil the worst performers.

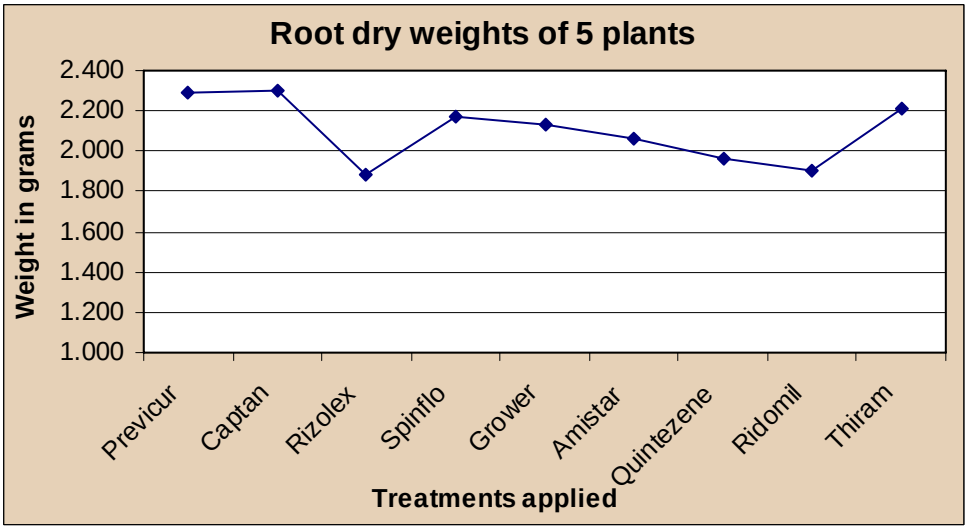


Fig. 2. Dry weights of 5 plants collected from the field on the 16th August 2007.

Captan again performed the best of all the treatments when it came to harvesting the marketable pods as seen in Figure 3 below. Although the values of each treatment were not significantly different from one another, Captan did produce a greater weight of pods from 1m or row.

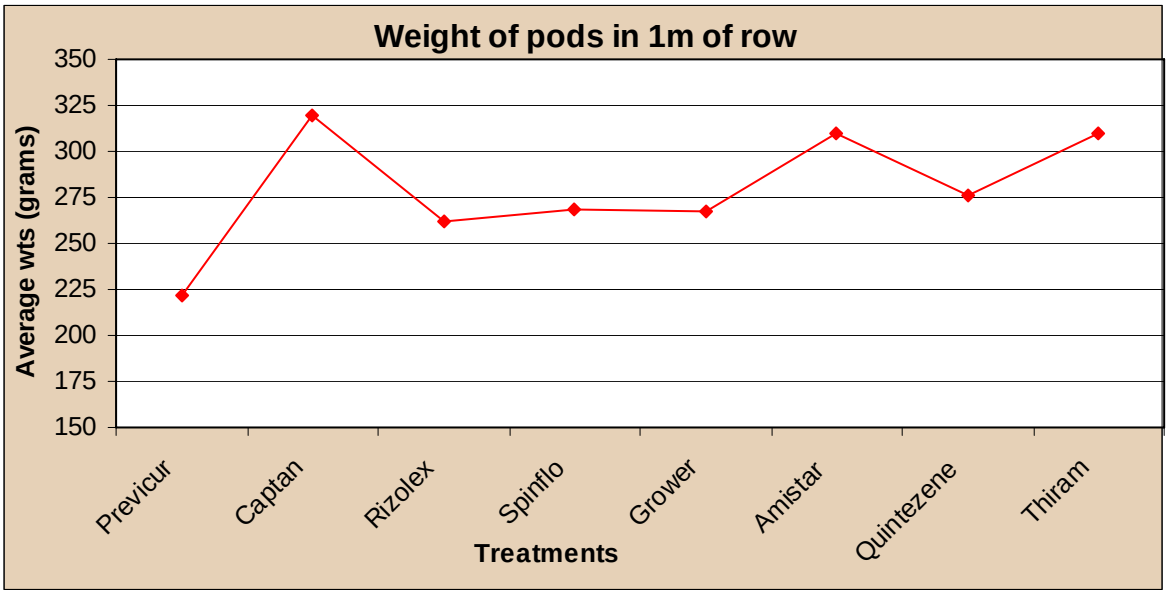


Fig. 3. Weights of pods from 1m of row harvested on the 29th August 2007.

The plants that were sent away for analysis failed to find any sign of *Pythium* or *Aphanomyces*. *Fusarium* species, *Thielaviopsis*, *Rhizoctonia* and even *Macrophomina* were the only fungal pathogens recovered from lower stem lesions and root browning.

CONCLUSIONS

Although this crop was planted into a known red root diseased paddock, the severity of this disease was very low with no significant differences in yield between the various treatments used to help manage this problem compared to what the grower would be doing. It is possible that the dry conditions favoured plant establishment and root development as no *Pythium* or *Aphanomyces* were recovered from any plants during the trial. The presence of *Fusarium*, *Rhizoctonia* and *Thielaviopsis* on the lower stem and roots did not appear to have an adverse effect on the plants as very few plants died during this trial and as the yields indicate in Figure 3, the plants were still producing marketable pods.

Although Captan did consistently perform better than any of the other treatments used, it would be appropriate to investigate Captan's effectiveness in more detail. A seed dressing of this product may be more appropriate than the current use of Thiram. Its broad spectrum of activity may lend it to being more effective at managing bean red root disease than most other products currently in use

FUNGICIDE CONTROL OF *SCLEROTINIA* ROT AUTUMN 2007

INTRODUCTION

Sclerotinia sclerotiorum or commonly called white mould or nesting is a severe disease of green beans in the Gympie region of Queensland affecting the crop from late autumn and early winter. This disease is most severe during this time due primarily to the environmental conditions, warm days and cool night temperatures, high humidity, showery weather, short day length and increased leaf wetness, coupled with susceptible varieties. Due to a lack of tolerant/resistant varieties, fungicides are the only viable options available to growers for managing this disease. Over the past few years growers have found that the fungicides registered for use against this disease have failed to control it to an acceptable level which has resulted in procymidone being brought back under permit but with restrictions to its use, namely only 2 applications per crop. Another avenue of control that has not been investigated is plant and row spacings. This in combination with fungicide usage was therefore investigated in this trial to determine if by reducing the plant spacings within the rows, this would allow for better penetration of fungicide sprays and thus better control of the disease.

MATERIALS AND METHODS

This trial was conducted on a grower property at Goomboorian just outside Gympie, Queensland, using the variety Valentino and grown for the fresh market. This trial was planted on the 12th March 2007 and harvested on the 9th May 2007. The fungicides used and when they were applied are listed in Table 1 below.

Table 1. Fungicide treatment and order in which they were applied.

Treatment no.	Fungicide	Product	Rate per Ha	Timing of treatment
1 RP	iprodione procymidone procymidone	Rovral Sumisclex Sumisclex	1.0 L 1.5 L 1.5 L	3 applications at 6-7 day intervals starting at 5% first flowers open
2 FP	procymidone boscalid procymidone	Sumisclex Filan Sumisclex	1.5 L 1.0 Kg 1.5 L	
3 FR	iprodione boscalid boscalid	Rovral Filan Filan	1.0 L 1.0 Kg 1.0 Kg	
4 LEMR1	penthiopyrad	LEM 17 Rate 1	1.0 L	3 applications at 6-7 day intervals starting at 5% first flowers open
5 LEMR2	penthiopyrad	LEM 17 Rate 2	2.0 L	
6	Untreated control			not applicable

Spray treatments were applied using a SOLO powered back pack sprayer with a 1.2m wide hand held boom with four equally spaced twin-jet nozzles. Treatments were applied at the equivalent rate of 570L/ha of water.

Plots were 4 rows wide and 5m long, with 4 replications per treatment. Three plant spacings were used per fungicide treatment, 7cm which was the grower standard, 13.5cm and also 22cm spacings.

Trial set up, spray dates and harvest date were as follows:

- Crop planted on the 12th March 2007

- 1st application applied on 20th April 2007
- 2nd application applied on 27th April 2007
- 3rd application applied on 3rd May 2007
- Harvest on 9th May 2007

At harvest all the plants in a 3m section of one of the middle 2 rows was assessed for Sclerotinia using a disease rating scale, where Rating 0 = no sign of the disease; Rating 1 = infection of single stem, leaf or bean; Rating 2 = infection of multiple stem branches; Rating 3 = infection affecting the whole plant.

Leaf wetness and temperature were recorded using Tinytag data loggers during the period from flowering until harvest.

RESULTS

Sclerotinia incidence in this trial site was low compared to previous years. At harvest only 19.5% of the trial site had any sign of Sclerotinia infection ranging from very minor infections of a leaf or pod to the whole plant being infected. Whole plant infections were mainly restricted to one side of the trial site and not evenly distributed across the field.

When analysing the data several possible models were fitted and the best overall model chosen for use in further analysis. The model used was a linear mixed model with arcsine-square root transformation on the response to the rating data, fixed treatment terms and random design terms. No attempt was made to account for spatial correlation structure. Analysis of the data found very little significant differences between the fungicide treatments, plant spacing and/or a combination of both. The analysis that was carried out did show a trend towards plant spacings of 13.5cm which was consistently better than the standard of 7cm and the greater spacing of 22cm at reducing Sclerotinia in the crop.

A graphical representation of these predicted means is useful for making comparisons, the following bar charts are provided with 5% LSD error bars. These figures are useful for making planned comparisons between different pairs of predicted means simply by checking to see if the error bars for the treatments of interest overlap or not. It should be noted though, that in order to guard against type II errors in multiple testing, the LSD error bars should only be used for testing if the Wald test (presented earlier) shows a significant effect (at 5% in this case) for the factor of interest. Here, for example, the Wald tests show significant effects for plant spacing ($p < 0.05$) and fungicide ($p < 0.05$), but not the interaction effect ($0.05 < p < 0.1$), so meaningful comparisons can be made for Figure 4 and Figure 5, but not Figure 6.

For Fig. 4 we see that the only fungicide treatment that is significantly different to the control is FR. However FR is not, in itself, significantly different from any of the other fungicide treatments (ignoring the control). What can be said is that the control treatment has the least proportion of plants with no infection while FR appears to have the highest proportion of uninfected plants on average, although this is not significantly more than any of the other fungicide treatments on average. The new product LEM performed better at the higher rate although this was still not significantly different from any of the other fungicide treatments. Note that these means are averaged over the levels of plant spacing and so represent overall means for the fungicide treatments as applied to the rating data.

For Fig. 5 we see that plant density 2 (13.5cm plant spacing) appears to perform best. It does significantly better than plant density 3 (22cm plant spacing) but the difference is not significant from plant density 1 (7cm plant spacing).

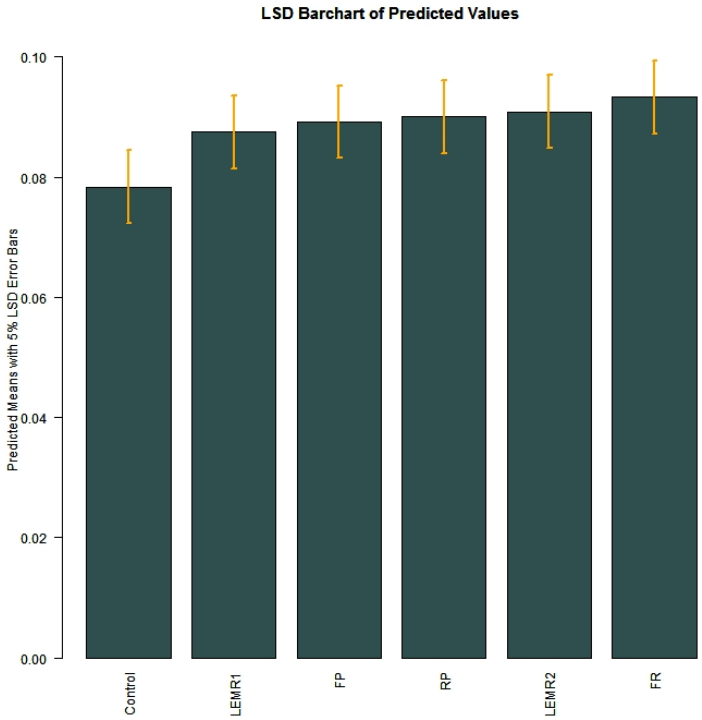


Fig.4. Predicted means of healthy plants by fungicide with 5% LSD error bars.
If the LSD error bars do overlap, then the treatment means are not significantly different at 5% but if they do not overlap, they are significant.

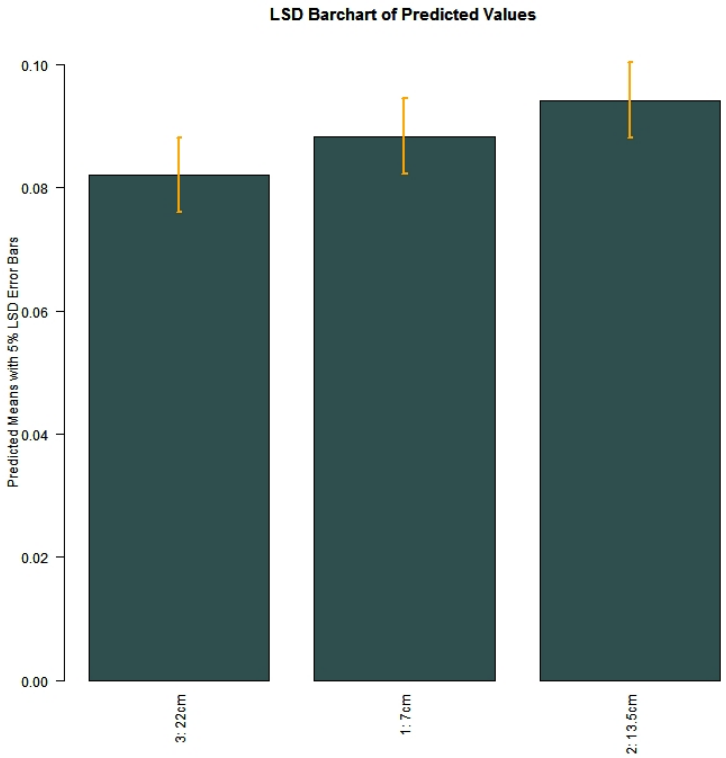


Fig. 5. Predicted means for healthy plants by plant spacing with 5% LSD error bars.
If the LSD error bars do overlap, then the treatment means are not significantly different at 5% but if they do not overlap, they are significant.

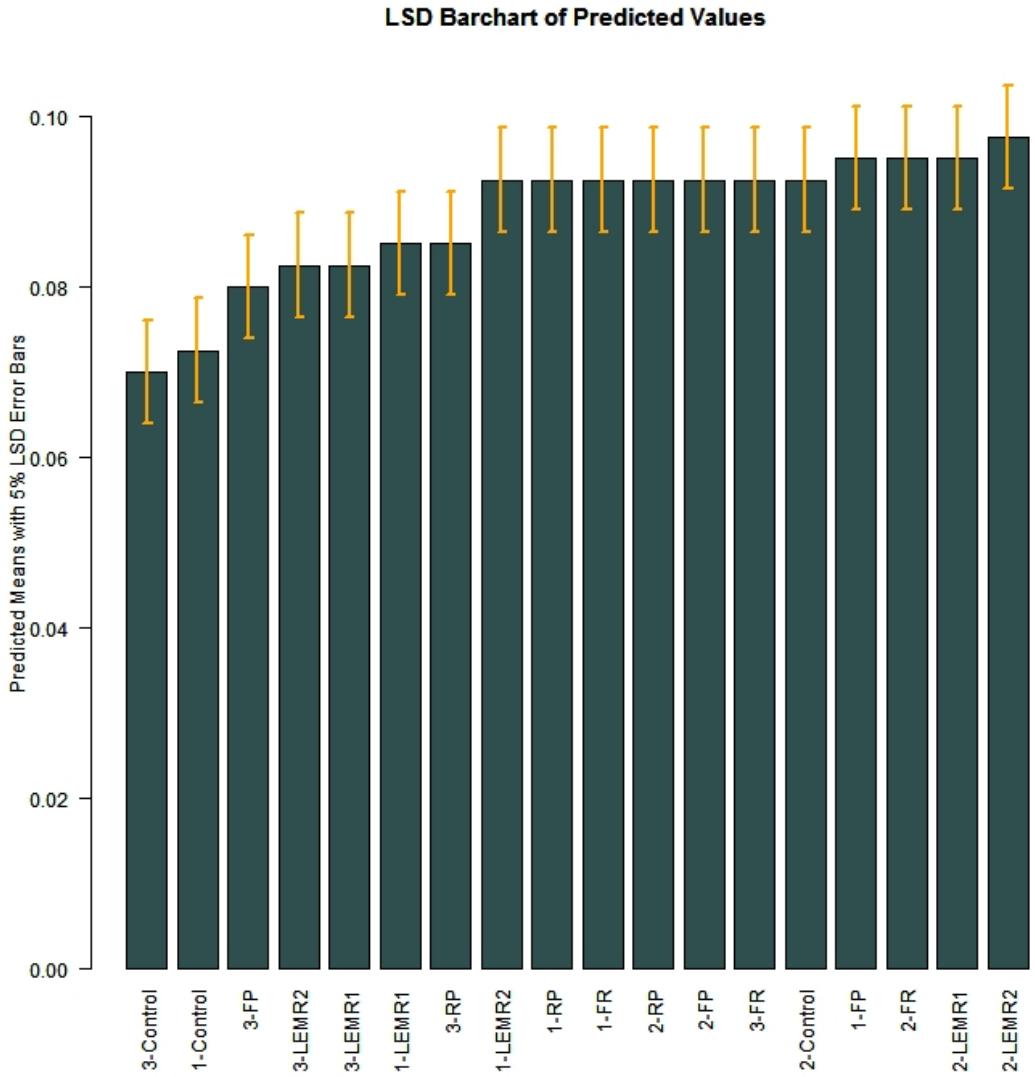


Fig. 6. Predicted means for healthy plants for interaction of plant spacing with fungicide along with 5% LSD error bars.
If the LSD error bars do overlap, then the treatment means are not significantly different at 5% but if they do not overlap, they are significant.

Fig. 6 is provided for general use, since the Wald test was not significant for the interaction between treatments, and so multiple comparisons are not valid. Only individual comparisons can be made between treatments. The control plots at 7cm and 22cm plant spacings were by far the worst treatments and were significantly different from the majority of treatments and in particular the treatments with the plant spacings of 13.5cm. There was a trend towards those treatments in the second plant spacing to perform better than the other fungicide treatments and plant spacing combinations although they were not always significantly different from one another. The higher rate of LEM was the better performer although not significantly different from most of the other fungicide treatments.

When looking at the data another way as in Fig. 7 below where the proportion of healthy and infected plants are graphed the trend towards the middle plant density is more obvious. It must be remembered that the significant differences between treatments were only minor but Fig. 7 does show that by increasing the plant spacings the grower can most likely improve the disease management of *Sclerotinia* in green beans. By doing nothing there was a marked improvement in control of this disease compared to the grower standard and the higher plant spacings.

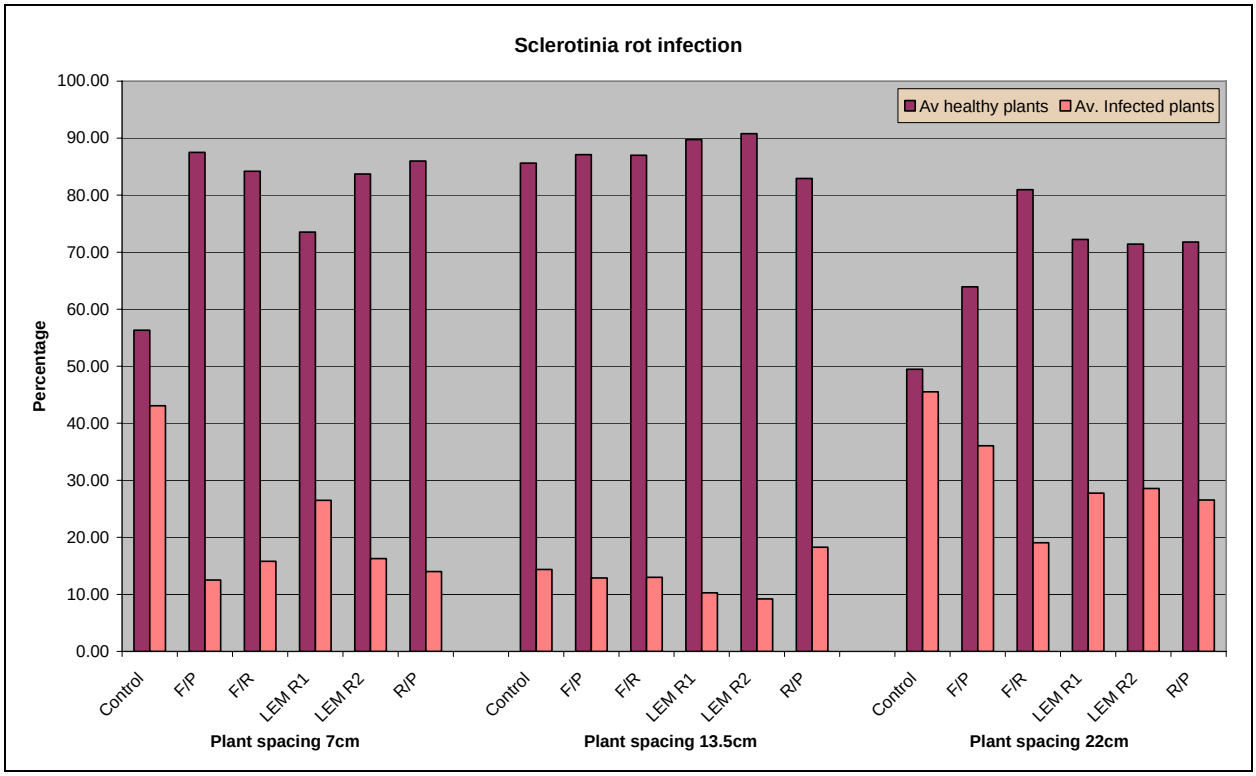


Fig. 7. Sclerotinia infection looking at the percentage of healthy plants and a total of infected plants as the 3 different plant spacings.

The leaves of the crop remained relatively wet for most of the day as seen in Fig. 8 below. On a number of days during the flower and pod fill period did the leaves not fully dry out, between the 26th and 28th April and again the 6th and 9th of May. The second application was made during a period of time when the leaf surface did not fully dry out for a day or more. The 3rd application also occurred during a similar such period of high moisture and coincided with cooler night time temperatures (Fig. 9) close to harvest.

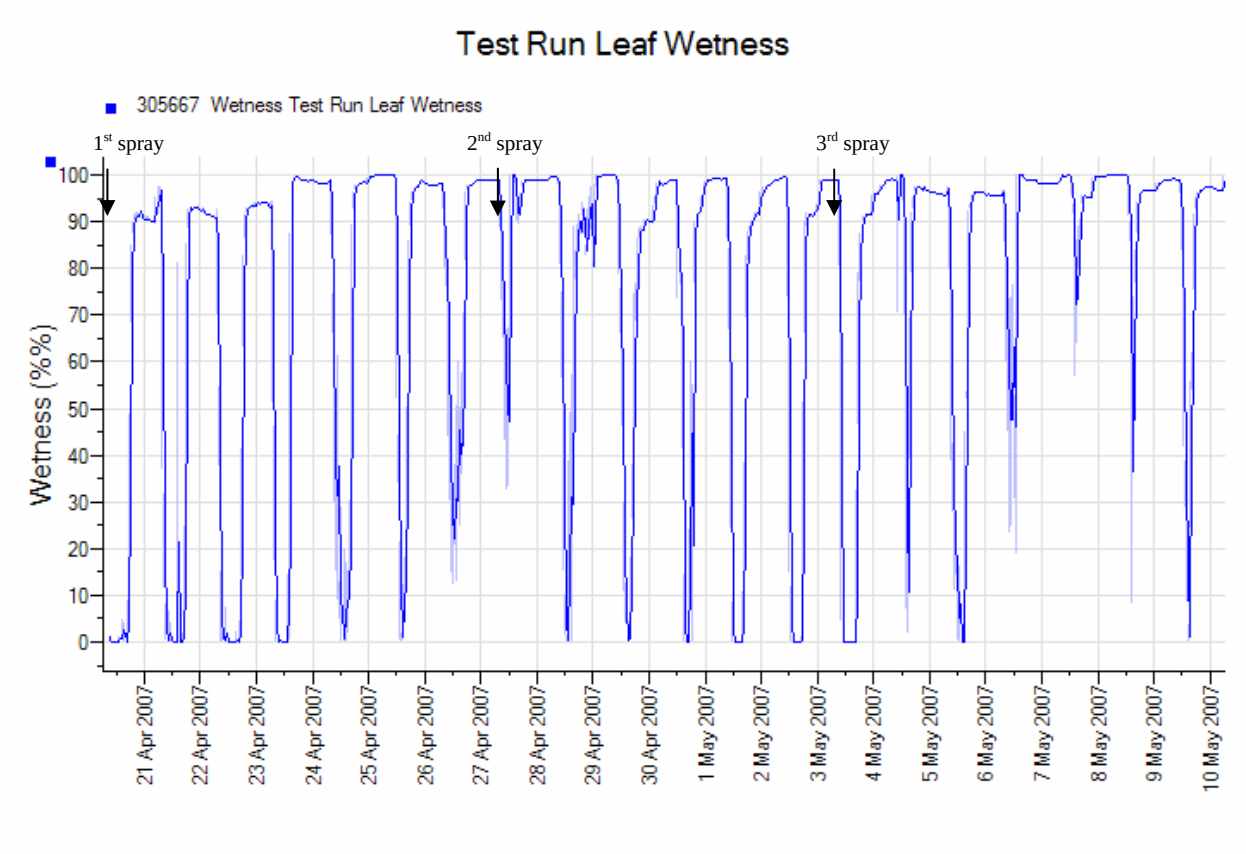


Fig. 8. Leaf wetness recorded from early flower until harvest using a Tinytag data logger. This sensor was placed in the standard plant spacing only.

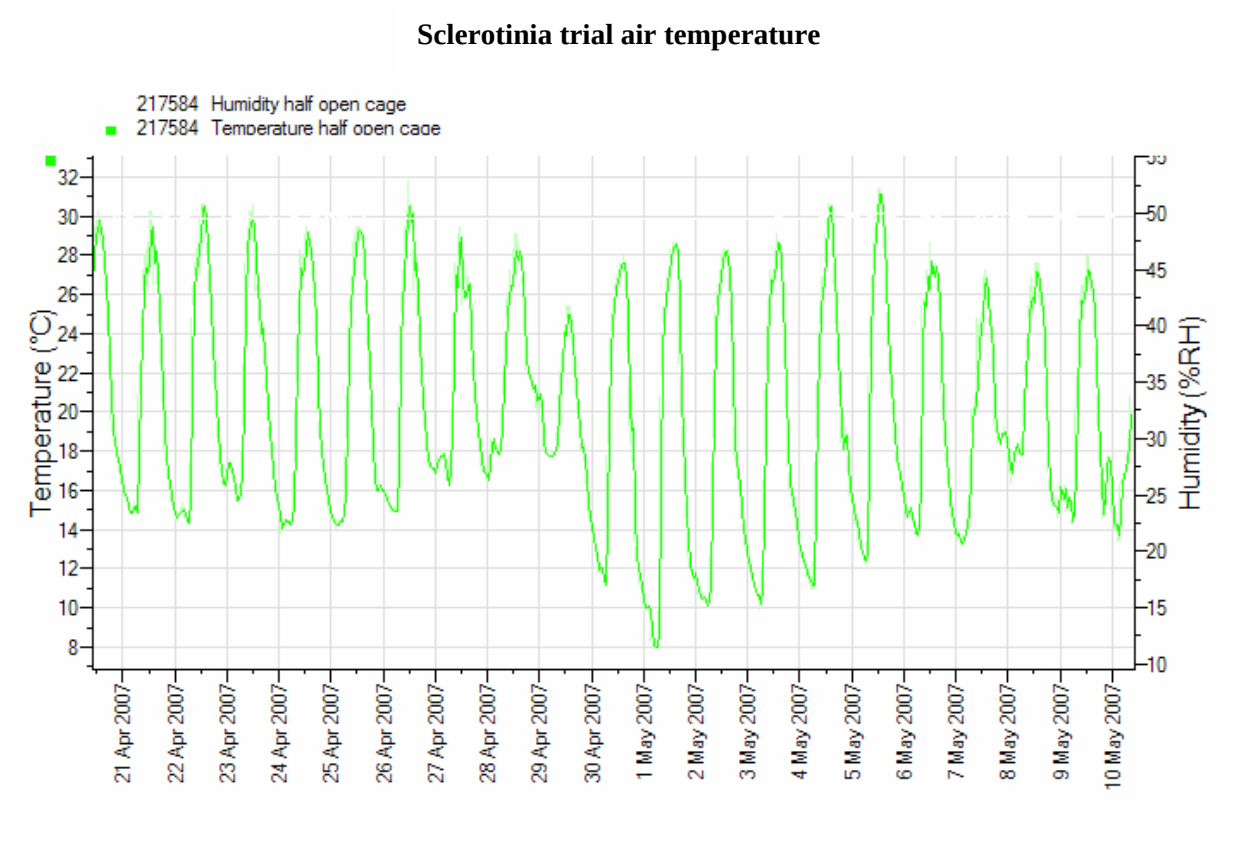


Fig. 9. Maximum and minimum temperature recorded at crop height from early flowering until harvest using a Tinytag data logger.

Bean yields were taken from a small number of plots from each plant spacing to give an indication of any reduction in weights with the increase in plant spacing. The grower standard plant spacing of 7cm returned the highest weight of pods (3320.67 grams) as shown in Figure 10 below. When the plant spacings was increased to 13.5cm, almost double the standard, there was just over 10% reduction in yield and a subsequent 6.2% when the plants were spaced at 22cm apart (2985.67 grams and 2779.75 grams respectively).

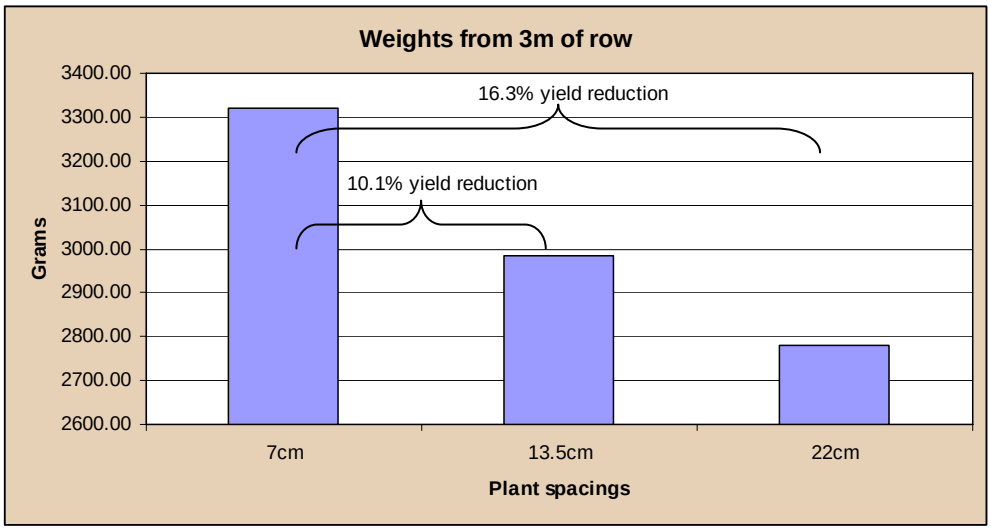


Fig. 10. Average weight of bean pods from 4 plots from each of the 3 plant spacings.

DISCUSSION

The effectiveness of the various fungicide treatments on the control of *Sclerotinia sclerotiorum* was not as clear as expected, due in part to the low inoculum levels found throughout the trial site which had an overall infection rating of approximately 19.5%. The analysis of the results showed very little significant differences between treatments as shown in Fig. 6, although doing nothing did result in the greater degree of infection, particularly in the standard plant spacing and the highest plant spacing treatments. This is reinforced when looking at the data in another format as in Fig. 7. The combination of Filan and Rovral tended to give a better control than any of the other treatments especially those that had procymidone in the rotation program. These are only trends and should not be considered as the norm. It is possible that the procymidone used was too old and may have lost some of its effectiveness as a previous trial in the Gympie region by Pung and Florissen (2006), found procymidone to be highly effective against this disease. It is also possible that the variety used in this trial (Valentino) is more open compared to other varieties such as 'Jade' allowing the fungicides such as Filan and Rovral to be more effective, whereas in the past they have not performed all that well in the Gympie region. This in itself could explain the lack of significant differences between the fungicide treatments and the fact that all the fungicide treatments were better than the untreated controls.

As shown in Fig. 5 and 7, the middle plant spacing of 13.5cm appears to perform the best. It is significantly better than the greatest plant spacing of 22cm but was not significantly different than the standard plant spacing of 7cm. This is further represented in Fig. 6 with the majority of the higher performing treatments coming from the middle plant spacing treatments. By opening up the crop canopy there is better air flow, allowing the crop canopy to dry out faster and also allowing better penetration of the fungicides into the crop and onto the plant parts that need protection from this disease. The plants at 13.5cm plant spacing would have also been close enough to help support one

another, stopping the plants from falling over, where as the higher plant spacings did result in more plants leaning or falling over which in themselves would have allowed the pods and leaves direct contact with the ground and perhaps increasing the likelihood of infection resulting from this action. Due to the lack of suitable leaf wetness sensors only one was used in the standard plant spacing row. If more were available it could have shown any differences in how fast the leaves may have dried out with the increase in plant spacings. This will be looked at in future trials.

The weights of pods revealed that by increasing the plant spacings there was a drop in the recorded weights. Whether this would change with a greater incidence of infection is not clear. The weights were taken from fungicide treated plots that consisted of procymidone in the rotation program. The result could have been quite different if taken only from the untreated control plots which showed a significant difference in the number of healthy plant as seen in Fig. 6, where the 13.5cm plant spacing control was significantly better than the standard plant spacing and the 22cm plant spacing controls. This will also be looked at in more detail in future fungicide trials.

CONCLUSIONS.

This trial has shown that there is the possibility of using plant spacings to help in the management of Sclerotinia rot in green beans but need additional research on the full benefits attributed to such a change in grower practice. Even if this were only carried out during the period of the growing season when *Sclerotinia* rot is most prevalent and combined with the appropriate fungicides in a rotation program, crops losses could be reduces to a more acceptable level for the grower.

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FUNGICIDE SEED DRESSING AND POT TRIAL FOR RED ROOT CONTROL

INTRODUCTION

Red root rot in green beans is a complex of soilborne pathogens making it difficult to manage by way of suitable fungicides. One effective way is by applying the fungicide direct to the seed protecting the plant as it germinates until it is established. The current use of Thiram, a broad-spectrum fungicide, has failed to give adequate control in the past and so al alternative is needed or a combination of suitable fungicides in order to effectively manage this disease. As such a range of fungicides were applied to green bean seeds to gauge their effectiveness at managing this disease.

MATERIAL AND METHODS

Green bean seeds were treated with a range of fungicides as shown in Table 2

Table 2. Fungicides used to dress bean seeds.

Seed dressings	**Active ingredient**	**mls or grams per 500grams of seed**
A	azoxystobin	0.25
F	fludioxonil	0.25
M F	metalaxyl + fludioxonil	0.75
FM	fludioxonil + metalaxyl	0.75
DM	difenconozole + metalaxyl	0.65
AFM	azoxystrobin + fludioxonil + metalaxyl-M	0.5
Thiram	thiram	2.5
Thiram	thiram	5
Thiram	thiram	10
Captan	captan	2.5
Captan	captan	5
Captan	captan	10
Washed seed untreated	N/A	N/A
Already treated Simba (Maxim XL)	fludioxonil + metalaxyl	Commercially treated.
Hymexazol	hymexazol	2.5

Three seed were plant into 10cm diameter pots on the 14th June and each treatment was replicated 4 times. The pots were placed on benches in the poly tunnel and watered using a drip irrigation system. The soil used in these pots was collect from a known red root paddock and had not previously been treated with any fungicides or fumigants. Temperature was recorded during the trial period both on the bench and in the pot using a temperature probe connected to Tinytag data loggers.

RESULTS AND DISCUSSION

The pot trial had very poor germination and so no data could be ascertained from the treatments. The temperatures dropped close to 0C and on most cases below 6C, which could have been too cold for the seeds to germinate.

If time permits this trial will be run again late August at a time when temperatures are hopefully not as cold.

ACKNOWLEDGEMENTS FOR ALL THE TRIALS

I would like to thank Peter Buchanan, green bean grower from Goomboorian, for allowing us the use of his land and crops in these fungicide trials and Caroline Church and Alan Duff for their help in setting the trials up and applying the various treatments. Also to Heidi Martin for helping with the diagnostics of the red root infected plants and carrying out the pathogenicity tests on the numerous isolates from the beans.

GENERAL DISCUSSION

The project conducted in the early 90's "Bean root rot-etiology and control" (VG024) was a thorough investigation of root diseases of beans from the Gympie and Bowen areas of Queensland. The organisms isolated from beans during that study included *Pythium*, *Rhizoctonia*, *Fusarium solani*, *F. oxysporum* and *Aphanomyces euteiches*. In pathogenicity tests with a combination of the fungi it was considered that *Pythium* was the main contributor to the disease in the field which had been termed "red root". The disease was more apparent in the Gympie growing area in the cooler months of the year. *Pythium sp.* commonly attack slow growing plants. The suggestion was to reduce the sowing depth which would assist faster plant establishment and reduce the plants exposure to pathogenic soil borne fungi. Isolates of *Pythium* collected varied in their pathogenicity but they were not identified to species, different species may have caused differing symptoms. In the same study *Rhizoctonia* was more aggressive at warmer temperatures; a similar result was reported in the current project in the Queensland report.

The Compendium of Bean Diseases (Hall 1994) lists the fungi as primary pathogens on their own i.e. *Fusarium* root rot (*F. solani*), *Aphanomyces* root rot (ARR), Black root rot (*Thielaviopsis*) (BRR), *Rhizoctonia* root rot (RRR) and *Pythium* root rot (PRR). Conclusions in this report prove similar but there are also cases where combinations of fungi may contribute to disease symptoms. Such as in Tasmania where *Thielaviopsis* and *Aphanomyces* may interact together to cause a root rot but may also cause individual symptoms.

In the NSW work, *Aphanomyces* was found to cause ARR especially in heavy rainfall situations; however it was also observed that the fungus infected bean roots when only normal irrigation was applied. When it does infect without excessive rainfall, symptoms are not as serious. Zoospores of the fungus only move short distances with free water (Papavizas and Ayers 1974), therefore the fungus requires old infected bean tissue in the soil close to current bean roots/hypocotyls. Observations during this project confirmed that old bean residue is the source of the fungus. It was observed that if a bean crop was planted on ground that contained old bean residue, plants that were away from any residue did not have symptoms of ARR whereas those near residue had symptoms. Beans cannot be grown on old bean ground for many years after the previous crop. This has been observed in other work (Sherwood and Hagedorn 1962). It appears that oospores left in the crop residue are the primary source of new infection and not from the fungus surviving in plant material as a saprophyte.

Using a pre planting assessment as identified in this report is a high priority for growers, where the potential of infection from ARR is high, as it provides important information on disease levels before planting.

Movement of zoospores is enhanced by heavy rainfall especially on sloping ground. Often large areas can be seriously infected. The graph below (Fig.1) highlights as an example the rainfall in the north coast bean growing areas of NSW (Coffs Harbour data) with both October and January having 300 mm. Fig.2 shows that mean monthly rainfall is highest in the Coffs Harbour region (close to bean growing areas) compared to other growing regions such as Bundaberg, Gympie and Devonport. Beans are not grown in Queensland growing regions in the mid summer months because the temperatures are too high. Tasmania has quite low rainfall for its growing period.

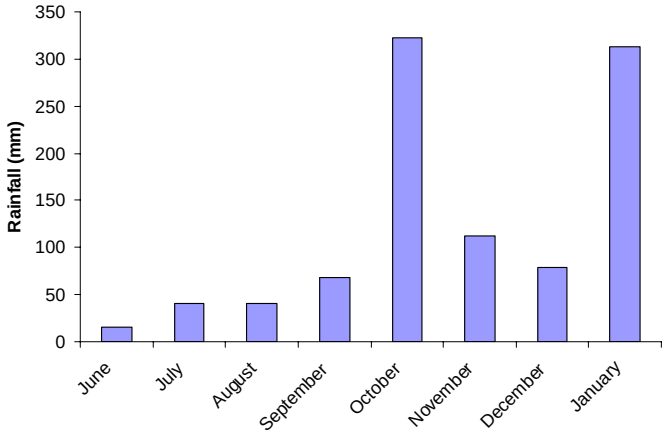

Fig.1. Coffs Harbour rainfall for 2004/2005

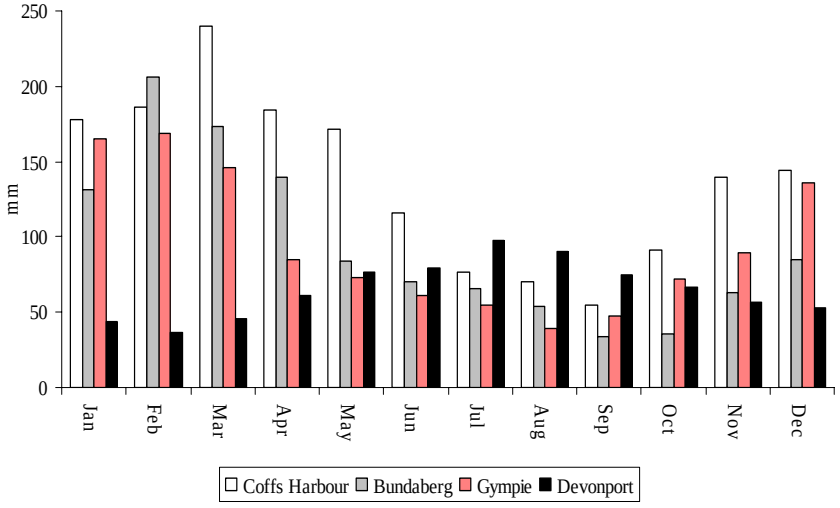

Fig. 2. Mean rainfall data for all the main growing regions in the study. Coffs Harbour has the highest rainfall of all the growing regions during the cropping period except for February in Bundaberg.

BRR is more severe at temperatures from 15-20^{0}C and ARR root rot at 20-28^{0}C (Hall 1994). BRR was isolated from autumn growing beans in Gympie and summer growing beans in Tasmania. The temperatures over these periods for both regions (Fig. 3) are similar, indicating that BRR could be an issue in both areas during their production times. However this does depend on cropping history etc.

ARR is ideally suited to conditions in NSW, with moist growing periods highlighted by heavy rainfall events. It would be suited to the growing periods of Gympie and Bundaberg also but it has not been found to be an issue at these sites. Rainfall is not as high in these areas compared to Coffs Harbour, so this may offer some explanation. ARR has been found to be an issue in Tasmania; it has the least rainfall compared to all the sites. But with work carried out in NSW once ARR levels build up the disease can be activated by normal irrigation practices.

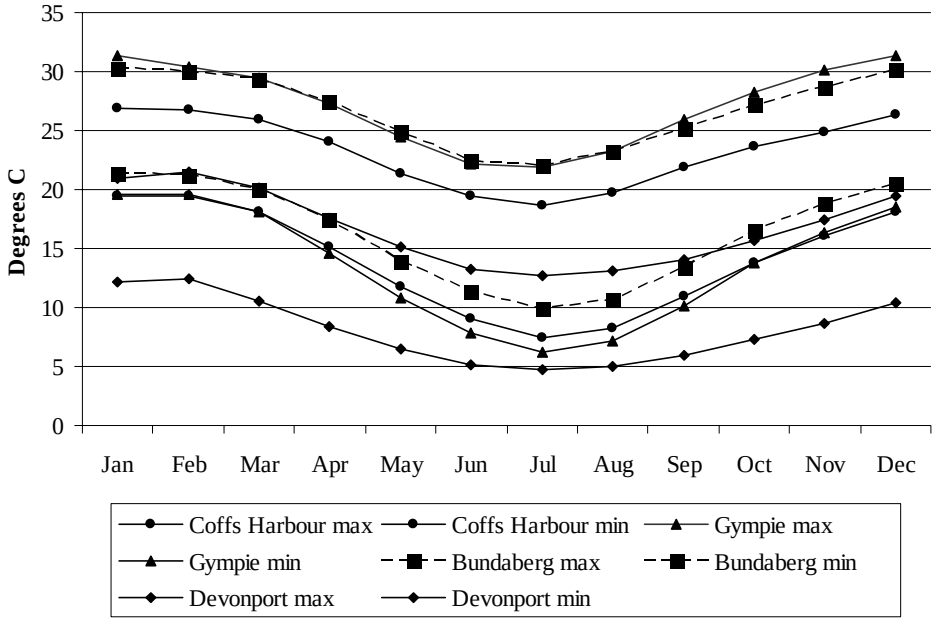

Fig.3. Mean maximum and minimum temperatures for the same sites.

VG024 was thorough in identifying causal organisms of red root rot. In this project (VG 03002) an aim was to distinguish if red root was the same as ARR. Red root is caused by a disease complex but is not the cause of the heavy losses experienced in NSW that are caused by ARR. This is confusing because some red root does occur in beans but it is not as devastating as ARR. The red colouration that is commonly seen on bean hypocotyls is most likely caused by *Fusarium oxysporum*. This fungus produces reddish pigmentation when plated onto media. It is commonly encountered in bean hypocotyls even without symptoms. *Fusarium oxysporum* colonises plant material quickly after other organisms cause initial damage. It was found in this report not to cause any primary damage.

The current status of soil borne diseases of green beans has been well established through this project. There are implications for the Tasmanian bean industry with the discovery of two new diseases of beans, BRR and ARR. BRR was also found in the Gympie region for the first time on beans and was shown to be pathogenic to beans in subsequent pathogenicity tests.

A number of *Pythium* species were isolated from plant material from all states. Some of these were identified to species but the majority were not. Some isolates grew well on *Aphanomyces* selective media indicating that there is a number of metalaxyl resistant isolates in the soil environment where beans are grown. Follow up on work should be done to establish all the *Pythium* species from beans from each region.

Hymexazol was successful at reducing symptoms caused by ARR. Hymexazol is marketed as Tachigaren® by the Sankyo Co. Ltd, Tokyo, Japan (now Daiichi Sankyo Co. Ltd.). This product was made available for the sugar beet industry in the USA (Harveson *et al*. 2007). Sugar beet is affected by *Aphanomyces cochloides* in many growing regions of the world and the industry successfully gained access to Tachigaren® as a seed dressing to aid in its control. Tachigaren® has registration on crops in Hungary including, cucumbers, green peppers, melons, onions, peas, rice, soybeans, sugar beet and tomatoes.

The possibility of having this product available in Australia should be investigated. It is the only product available for *Aphanomyces* control and also has some efficacy against *Pythium*. The main fungicide for *Pythium* is metalaxyl, to which some *Pythium* sp. are resistant. Hymexazol may offer some alternative to this fungicide.

Soil drenches including propamocarb and azoxystrobin also offered some control of ARR however they too are not registered for this purpose. Previcur (propamocarb) has registration on crops

in Hungary including cucumbers, green peppers, melons, onions, peas, rice, soybeans, sugar beet and tomatoes.

Fungicidal soil drenches have been identified as a management option for ARR however issues of fungicide availability, registration and costs of application make it unlikely to be adopted. Seed dressings however may offer the best option for ARR management.

Fumigation was successful, but would not be unlikely to be adopted because of cost and proximity to residential areas.

Crop residue removal or burning may offer some disease reduction. Currently crop residue is either incorporated or eaten by cattle. Oospores of ARR survive these treatments so are available for infection once beans are planted again. Increased tillage may assist in the breakdown of old bean plant material and reduce oospore survival.

Work in this project has identified fungicide options for control of ARR. However the problems of fungicide availability registration and the general decline in the acceptance of their safety makes the adoption of this disease management alternative highly unlikely. Avoiding old bean ground is becoming impossible and there are no resistant varieties.

Non-chemical management of *Aphanomyces* looks to be impossible from the habit of the fungus itself, its survival in plant tissue and its ability to survive on alternate hosts makes its management very difficult. Antagonistic bacteria may hold the key to controlling this fungus and more work should be considered in this area.

Further work on *Aphanomyces* needs to be carried out especially the genetic variability between isolates from each state and the variability between pea and bean isolates of the fungus in Tasmania.

Trials in NSW did not address disease issues relating to damping off. Damping off, which is accentuated by cool conditions, did not appear to be a problem during the course of the project in the northern growing regions. NSW and Queensland growers plant in warmer periods of the year and maybe less prone to damping off. Most bean seed available for growers is currently treated with the fungicides thiram, captan or Maxim/Apron XL. The Tasmanian section covers the alternatives that are potentially available as replacements for thiram for damping off management. The new seed dressings were combinations of fungicides such as azoxystrobin, fludioxonil and metalaxyl-M and were found to be suitable alternatives to thiram and reduced root rot and increased seedling establishment. When these were trialled in NSW they did not have any control on ARR. North coast growers have been recommended to use thiram instead of the current seed dressing (Maxim/Apron XL) because it had better activity against ARR.

Rotation and biofumigation crops did not control ARR in this project but a potential biocontrol organism showed promise in laboratory tests but this success was not transferred to the soil environment.

ARR management will still rely on the availability of new ground but other options such as seed dressings, soil drenches and the use of pre-planting assessments should be considered by industry.

Bean root and hypocotyl diseases can now be considered to be a complex of different fungi depending on each growing region. In some growing regions of Queensland and Tasmania, *Thielaviopsis*, *Aphanomyces*, *Rhizoctonia*, *Fusarium* and *Pythium* all provide some component to root/hypocotyl disease. In NSW it is mainly *Aphanomyces* but there is also some contribution by *Fusarium* and *Pythium* species especially as secondary or complementary invaders.

TECHNOLOGY TRANSFER

This project has been very grower based in all the growing areas covered in the project. Other activities are listed below.

- Watson A 2005 New research focus on bean and pea diseases Vegie Bites 32.
- Watson A (2006) Aphanomyces management in beans Vegie Bites 33.

- A talk was given at the Vegetable Industry Conference on the project in May 2006.
- Contribution to bean growers' field day Gympie November 2005
- Prime Fact "Disease of beans"- Completed but to be put on the web.
- Bean disease discussion night. Nambucca Heads August 2006.
- Collaboration between project members for the production of the Bean Pest/Disease Ute Guide (John Duff)

RECOMMENDATIONS

Further work on management of *Aphanomyces* root rot and root rots generally including:

- Further clarification on the role of Black root rot and *Aphanomyces* root rot on beans and also peas in Tasmania.
- Investigate biological controls of *Aphanomyces* root rot.
- Investigate genetic differences between isolates of *Aphanomyces* between states.
- Investigate the possibility of the industry having hymexazol or propamocarb available for ARR in Australia.
- If hymexazol does become available, then field trials should be set up for application rates etc.
- Assist bean growers on looking at alternative crops.
- A thorough examination of *Pythium* species should be undertaken for all bean growing regions.
- Breeding for resistance varieties is the optimum control option and should be investigated; however the cost to industry would be quite high.

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