

Potato pink rot control in field and storage

E Oxspring; C Davoren;
T Wicks and B Hall
South Australian Research
and Development Institute

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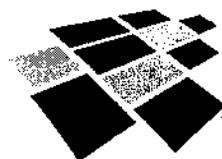
Sydney NSW 2000

Telephone: (02) 8295 2300

Fax: (02) 8295 2399

E-Mail: horticulture@horticulture.com.au

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POTATO PINK ROT CONTROL IN FIELD AND STORAGE

HORTICULTURE AUSTRALIA LIMITED FINAL REPORT

JUNE 2001

PROJECT PT97004

E.A. Oxspring, C.W. Davoren, T.J. Wicks, and B.H. Hall



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CONTENTS

INDUSTRY SUMMARY	3
TECHNICAL SUMMARY	4
TECHNICAL REPORT	6
LABORATORY EXPERIMENTS.....	7
(a) Identification of fungi isolated from infected tubers.....	7
(b) Optimum temperature for the growth of <i>P. erythroseptica in vitro</i>	8
(c) Optimum temperature for sporulation of <i>P. erythroseptica in vitro</i>	9
(d) Cultivar susceptibility	10
(e) Detection of <i>Phytophthora</i> in Field Soils	12
STORAGE EXPERIMENTS	19
IRRIGATION EXPERIMENT	22
FUNGICIDE CONTROL	24
(a) <i>In vitro</i> experiments	25
(b) Resistance of <i>P. erythroseptica</i> to Metalaxyl	29
(c) Drench experiment.....	32
(d) Biofumigation	35
(e) Shade house experiments	40
(f) Field experiments	46
TECHNOLOGY TRANSFER.....	61
RECOMMENDATIONS	63
ACKNOWLEDGEMENTS	63
REFERENCES	64

INDUSTRY SUMMARY

Investigations on various aspects of the disease Pink rot and the control of the Pink rot fungus *Phytophthora erythroseptica* were undertaken in laboratory, glasshouse and field experiments.

The main findings of these studies were:

- *P. erythroseptica* is the fungus most commonly associated with Pink rot throughout Australia.
- The fungus is most active at temperatures between 15-25°C.
- None of the 17 potato varieties or lines tested were resistant to the Pink rot fungus although Russet Burbank appeared to be the least susceptible.
- Several baiting techniques for detecting the Pink rot fungus in soil were tested. Floating discs of Camellia leaves were the most effective but the level of detection was not sensitive enough to detect *P. erythroseptica* in soil where low levels of Pink rot occurred at harvest.
- Spread in storage appears to be as a result of latent infection rather than transfer from infected to non infected tubers.
- Twelve fungicides were tested for the control of Pink rot and Ridomil (Metalaxyl) was the most effective.
- Sprays of Ridomil Gold MZ at 2.5kg/ha at tuber initiation and 14 days later were as effective as 20kg/ha Ridomil Gold (25G) granules applied at planting.
- In furrow sprays of Ridomil at planting controlled Pink rot but further evaluation of timing and rates is needed.
- Twenty isolates of the Pink rot fungus were tested for resistance to Metalaxyl and all were sensitive.

TECHNICAL SUMMARY

Isolations from diseased tubers, potato plants and soil showed that Pink rot was associated mainly with *Phytophthora erythroseptica* and occasionally with *P. cryptogea*, *P. megasperma* and *P. parasitica*. *P. erythroseptica* was recovered from tubers and soil from South Australia, Tasmania, Western Australia and Victoria, showing that the problem is widespread in Australia.

Six isolates of *P. erythroseptica* grew on artificial media at temperatures ranging from 5°C to 30°C with optimum growth rate between 20°C to 25°C. No isolate grew at 35°C.

Optimum temperatures for sporulation ranged from 15-25°C.

The relative susceptibility of 17 potato cultivars and breeding lines was evaluated by artificially inoculating tubers and measuring the extent of infection after 7 days incubation. No tubers were resistant to *P. erythroseptica*, although differences in susceptibility were detected.

A number of studies were undertaken to evaluate methods for detecting *P. erythroseptica* in soil. These involved baiting soil samples with either discs of camellia leaves, potato leaves, juniper needles or tomato seedlings. Camellia leaves were the most effective and convenient method of detecting the fungus in soil. This technique was used to test soil known to be heavily infested with *P. erythroseptica*. Of the 96 samples tested, 48% were positive for *P. erythroseptica*. The test was not sensitive enough to detect levels of *P. erythroseptica* that caused low levels of disease, as infected tubers were found in plots where the fungus was not detected.

In vitro studies were undertaken to evaluate fungicides for the control of *P. erythroseptica*. This was done by measuring fungal growth on fungicide amended agar. Fungicides evaluated were Ridomil, Shirlan, Patafol, Acrobat, Amistar, Zoxium and a coded material SZX722. Ridomil, Acrobat and SZX722 were the most effective as these inhibited mycelial growth by nearly 100% at 1ppm. The Strobilurin fungicide Amistar had little inhibitory effect on mycelial growth.

Twenty isolates of *P. erythroseptica* were tested for resistance to Metalaxyl and all were sensitive however variations in sensitivity were observed.

In vitro studies were also carried out to test the use of mustard meal and mustard pellets as biofumigants. These release isothiocyanates when wetted and could therefore be an alternative to fungicides for the control of Pink rot. These studies showed that as little as 0.01g of meal per plate was inhibitory to the growth of *P. erythroseptica* and *P. cryptogea*. However in one field experiment, mustard meal applied at 1 or 3T/ha at planting showed little effect on the level of Pink rot.

A number of experiments were set up to evaluate the efficacy of soil applied fungicides. *P. erythroseptica* inoculum was buried at varying depths in a soil column and the soil surface drenched with a fungicide suspension. After 7 days, the inoculum was removed and the viability tested. The results showed that Ridomil controlled *P. erythroseptica* completely at depths of 15cm and was more effective than Shirlan, Zoxium and SZX722.

Glasshouse studies were undertaken to evaluate several fungicides and the timing of spray applications for the control of Pink rot. Potatoes were grown in artificially inoculated soil which was flooded for 24 hours around tuber initiation. Pink rot developed in up to 61% of the control plants. Ridomil applied as a foliar spray at tuber initiation and again 14 days later was as effective as Ridomil granules applied at planting.

Similar results were obtained in 6 field experiments carried out on commercial properties. In these experiments yield increases of up to 6 to 17 tonnes per hectare were recorded following the application of Ridomil either as a spray or granules.

Large field experiments were carried out on commercial properties in 1999-2001 to evaluate Ridomil applied in furrow at planting and the use of Brassica meal. Pink rot did not develop in any of the control plots in 6 separate plantings set up on properties where the disease had previously been reported.

In one experiment at Lenswood, an in furrow treatment of 1.04kg/ha Ridomil at planting was as effective as 20kg/ha of Ridomil granules when both were applied at planting.

TECHNICAL REPORT

Pink rot is a serious soil and tuber borne disease of potatoes common to many of the potato growing areas of Australia. Infected plants wilt and collapse due to rotting of the crown area of the stem. Potato roots and stolons are also attacked by the fungus which often grows along the stolon into the tuber. Infected tubers are initially spongy and rubbery, with further breakdown occurring as a result of the development of secondary soft rot bacteria. Losses can occur both in the field and in storage.

In the South East of South Australia the disease has caused serious economic losses of up to 50% on some properties, with growers considering the problem to be increasing in all districts. Of particular concern is the possibility that the disease is being introduced into new areas on infected seed tubers. In addition, major losses occur during long term storage of potatoes destined for processing. All this has far reaching implications for the industry and could limit further expansion.

Field, glasshouse and laboratory experiments were undertaken to investigate sustainable methods of controlling Pink rot.

LABORATORY EXPERIMENTS

(a) Identification of fungi isolated from infected tubers.

A large number of *Phytophthora* isolates were recovered from potato tubers and roots exhibiting symptoms of Pink rot. Many were also recovered from soil using various baiting techniques.

Materials and Methods

Sections of potato tuber or root tissue exhibiting symptoms of Pink rot were plated onto P₁₀VP+, a selective media for the isolation of *Phytophthora* spp. (Tsao and Ocana, 1969). *Phytophthora* spp. were identified by mycelium morphology and growth pattern on P₁₀VP+ and transferred to V8 juice agar to encourage the formation of oogonia. Sporangia were induced by flooding plugs of mycelium growing on V8 juice agar with soil extract and incubating under white light for 24 hours. Isolates were identified to species using the key of Stamps *et al* (1990) and descriptions from Erwin and Ribeiro (1996). Type species were confirmed by either Michael Priest, Mycologist with New South Wales Department of Agriculture or Elaine Davidson, Curtin University, Western Australia.

Results and Discussion

P. erythroseptica is the predominant species responsible for causing Pink rot in Australia. Of the 87 different isolates of *Phytophthora* spp. recovered from potato tissues 29 isolates were identified as *P. erythroseptica* and one isolate as *P. cryptogea*. The remaining 57 isolates have not been formally identified, but most are morphologically similar to *P. erythroseptica*. *P. erythroseptica* has been isolated from potatoes grown in South Australia, Victoria, Tasmania and Western Australia.

In South Australia isolates of *P. erythroseptica* have been collected from the South East, Adelaide Plains and Adelaide Hills. The isolate of *P. cryptogea* was recovered from a potato tuber growing in the Adelaide Hills. The Victorian isolates were recovered from certified seed tubers.

(b) Optimum temperature for the growth of *P. erythroseptica* in vitro

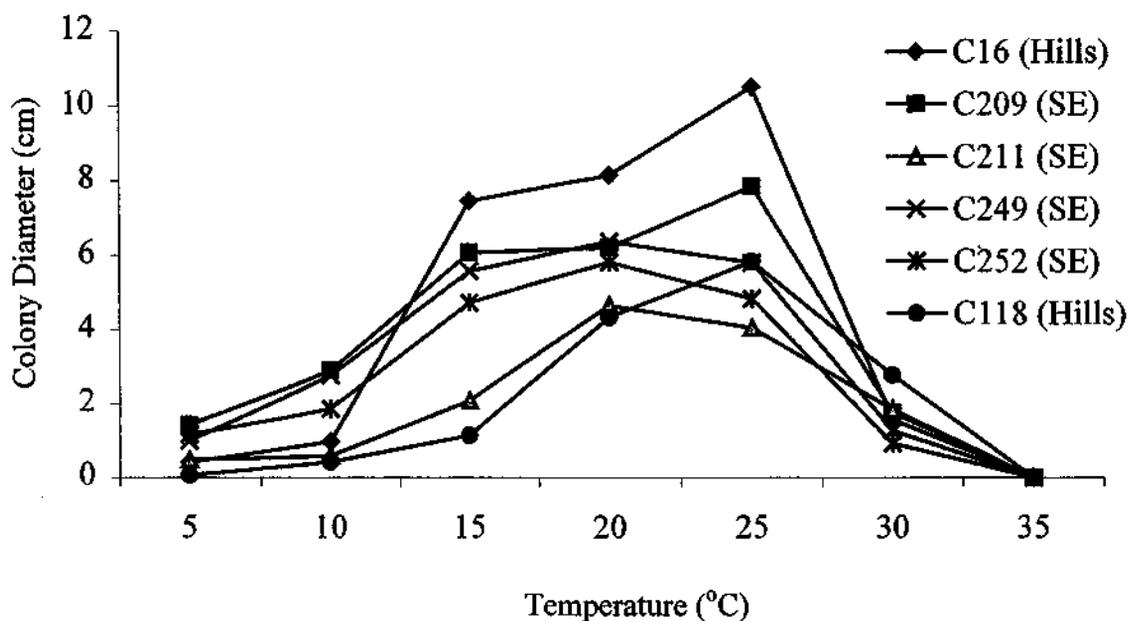
Materials and Methods

Isolates of *P. erythroseptica* recovered from potatoes were grown on corn meal agar (CMA). Plugs (5mm) were taken from the growing edge of cultures and transferred singly to the centre of fresh CMA plates. Plates were incubated in the dark at 5, 10, 15, 20, 25, 30 and 35°C with 4 replicates per isolate. After 7 days the diameter of mycelial growth was recorded and the growth rate calculated (mm/day).

Results and Discussion

All isolates except C118 showed some growth at 5°C. Growth rates increased with temperature until 20-25°C (Figure 1). The optimum temperature for growth was 20°C for isolates C211, C249 and C252 and 25°C for isolates C16, C118 and C209. At higher temperatures the growth rate was markedly reduced and no growth was observed at 35°C. The optimum temperature considered to favour disease development is 20-30°C (Erwin and Ribeiro, 1996). From these results it appears that this may be slightly high and 15-25°C is a more accurate range for optimum growth. There was no obvious reason for one set of isolates to have a higher optimum temperature than the other. All were from the South East (SE) or Adelaide Hills (Hills), which have similar climatic conditions, so we can only assume those differences are due to natural variation (Figure 1).

Figure 1. Effect of temperature on the growth rate of 6 isolates of *P. erythroseptica* *in vitro*



(c) Optimum temperature for sporulation of *P. erythroseptica* *in vitro*.

Materials and Methods

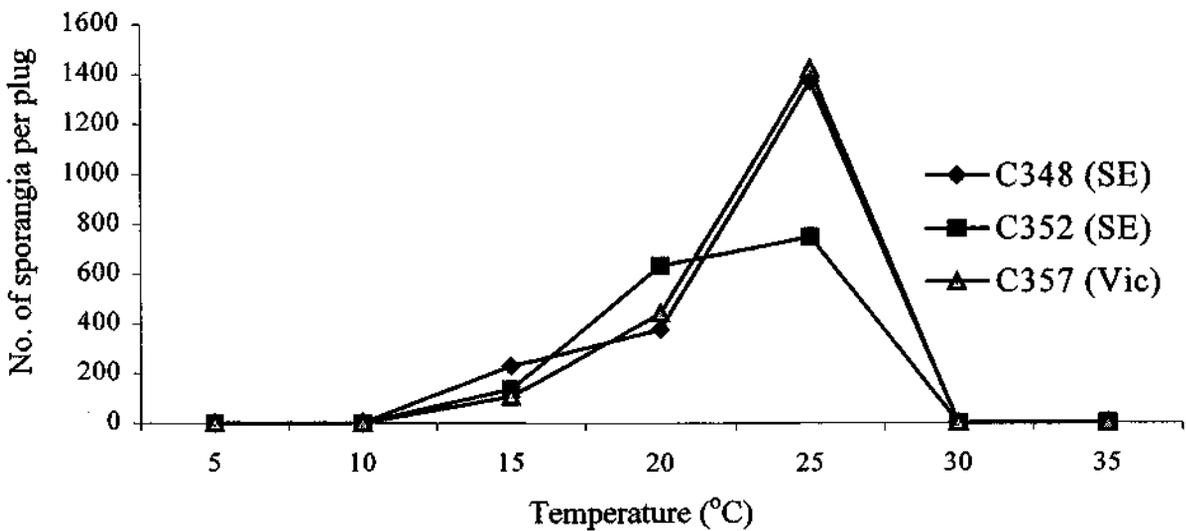
Three isolates of *P. erythroseptica* isolated from potato tubers were cultured on V8 juice media. Five plugs (3.5mm) were taken from the edge of 2 day old cultures and placed in 9cm plastic petri plates with 5 replicates for each temperature tested. Soil extract (10ml) was added to each plate and plates incubated in the dark at 5, 10, 15, 20, 25, 30 or 35°C for a period of 40h. After incubation a plug was removed from each plate, squashed onto a microscope slide and the number of sporangia per plug counted.

Results and Discussion

No sporangia were observed on plugs of any isolate incubated at 5, 10, 30 or 35°C (Figure 2). Most sporangia were produced at 25°C and least at 15°C. These results, and those on the

mycelial growth, indicate that the optimum of 20-30°C reported elsewhere as favourable for disease development (Erwin and Ribeiro, 1996) may be too high for Australian isolates. Optimum conditions for both growth and sporangia development were 15-25°C and this may partly explain why the disease is more prevalent in cooler climates of the South East of South Australia and Tasmania.

Figure 2. Number of sporangia produced per plug, after incubation at different temperatures



(d) Cultivar susceptibility

The relative susceptibility of potato cultivars was tested by artificially inoculating tubers of equal physiological age.

Materials and Methods

P. erythroseptica recovered from a potato from Tasmania was grown for 3 days on CMA before being used for inoculations.

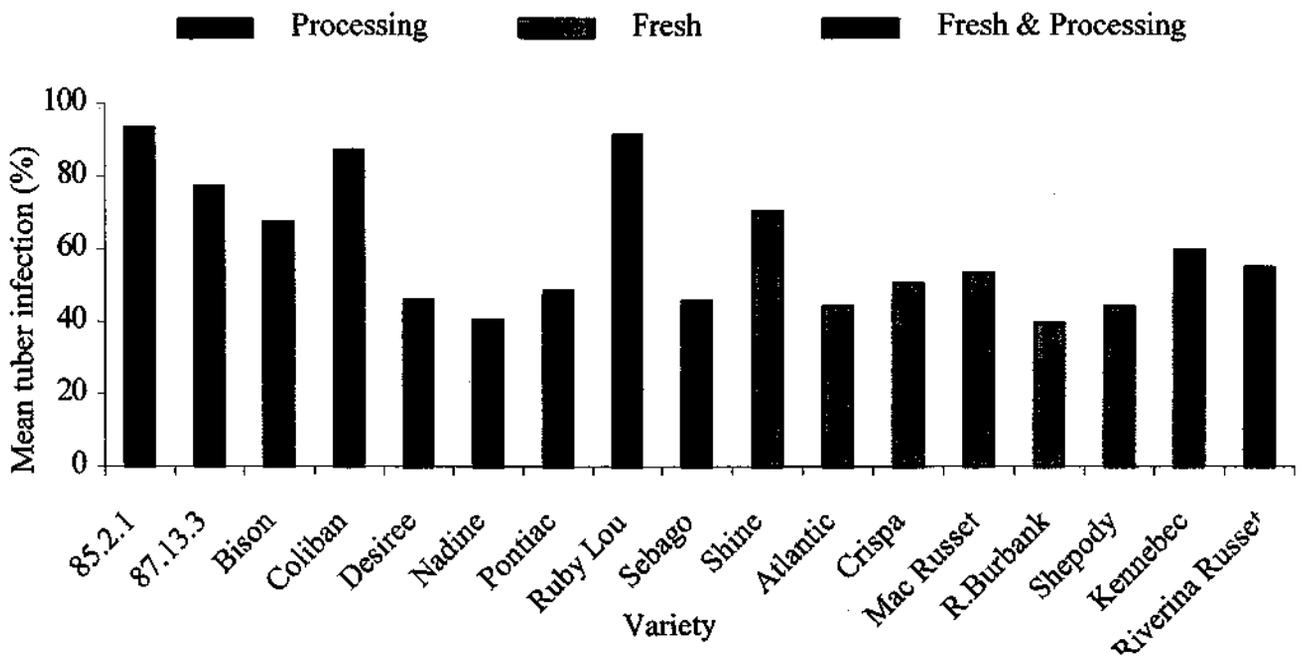
Cultivars tested included Atlantic, Bison, Coliban, Crispa, Desiree, Kennebec, Mac Russet, Nadine, Pontiac, Ruby Lou, Riverina Russet, Russet Burbank, Sebago, Shine, Shepody and the breeding lines 87.13.3 and 85.2.1. Ten tubers of each variety were surface sterilised in a 0.4% chlorine solution for 15 minutes, rinsed with deionised water and sprayed with 70% alcohol. A 6mm plug of the fungus was removed and placed in a hole 15mm deep at the end of each tuber opposite the stolon. Tubers were placed in sealed plastic bags and incubated in the dark at 22°C for 7 days before being cut in half lengthways and left for at least 1 hour. This ensured diseased tissue turned pink before measuring the percentage surface area infected.

Results and Conclusions

All tubers were infected by *P. erythroseptica*, however the area of infection varied between cultivars indicating differences in susceptibility. Of the fresh varieties, Nadine were the least susceptible and the breeding line 85.2.1 the most susceptible, with 40% and 93% of the tuber area infected respectively (Figure 3). Of the processing varieties, Russet Burbank was the least susceptible with 40% of the tuber area infected. Kennebec and Riverina Russet, used for both fresh and processing markets, showed 59% and 55% tuber infection respectively.

Further investigations are required to assess whether stems, stolons and roots are as susceptible as the tubers.

Figure 3. Mean comparative susceptibility of potato cultivars artificially inoculated with *P. erythroseptica*.



(e) Detection of *Phytophthora* in Field Soils

Several experiments were conducted to evaluate different methods for detecting *P. erythroseptica* in soils. In experiments 1-3 a number of different baits and baiting techniques were tested for their ability to detect *Phytophthora* under various incubation regimes. A further experiment was then carried out to determine whether baiting, with one of the best techniques, could be used to detect *Phytophthora* at various times of the year in a paddock known to have a history of Pink rot. This experiment also tested whether the incidence of detection was related to the amount of Pink rot in tubers at harvest.

Experiment 1

Materials and Methods

Four bait types were tested, *Camellia japonica* and potato leaf discs (6mm diam), *Juniper conferta* (common Juniper) needles and tomato *Lycopersicon esculentum* cv. Grosse Lisse seedlings. Ninety five soil samples were collected at a depth of 0-15cm from a potato field (Lenswood, South Australia) where Pink rot was detected at harvest. In a method similar to Ferguson and Jeffers (1997), two 60g sub samples were either air dried then re-moistened three days before flooding, or baited from a moist condition (as collected). Six leaf discs or needles, previously surface sterilised in 0.4% sodium hypochlorite solution, were floated on 75ml of deionised water added to the soil.

The baiting vessels (300ml opaque plastic cups with lids) were incubated at 25°C under white light. At 24 and 72h half the baits were removed, blotted dry on paper towel and placed on P₁₀VP+.

Two tomato seedlings, grown for 4 weeks in pasteurised vermiculite, were planted into 200g of moist soil in 300ml baiting tubs. The tubs were incubated in a glass house at 22°C, with the moisture maintained for 5 days, before 100ml deionised water was added. After 24h one seedling was wounded by pinching the stem just below water level with sterile forceps. At 48h this seedling was removed, dried on paper towel and plated onto P₁₀VP+ media. The remaining seedling was flooded for a further 9 days before it was removed from the soil,

washed with deionised water and dried on paper towel. Root sections with lesions were then plated onto P₁₀VP+ media incubated at 22°C for 3-5 days plates and examined for the presence of *Phytophthora* spp. The tomato root baiting was repeated using 8 days of flooding.

Results and Discussion

Drying the soil prior to baiting did not improve recovery of *Phytophthora* as only two positive isolations were obtained. This procedure was therefore omitted from the analysis. Camellia leaf discs were the most effective leaf baits tested as they showed *Phytophthora* in 41% and 40% of soils at 24 and 72h incubation respectively (Table 1). Potato leaf discs and Juniper needles resulted in significantly less isolations regardless of the baiting duration. Tomato stems achieved 30% positive isolations which was not significantly different to the Camellia leaf discs. One of the tomato root bioassays provided the best overall baiting method as *Phytophthora* spp. were recovered from 63% of the soils. This method was however difficult and time consuming and as the results were inconsistent was discarded.

Table 1. Recovery of *Phytophthora* spp. using different baits and incubation times.

Bait method	% +ve isolations
Camellia 24 h	41 b
Camellia 72 h	40 b
Potato 24 h	17 d
Potato 72 h	12 d
Juniper 24 h	8 d
Juniper 72 h	0 cd
Tomato stem	30 bc
Tomato roots (9days)	63 a
Tomato roots (8days)	—

Numbers followed by the same letter are not significantly different (P>0.05)

Experiment 2

As zoospores are the most likely infective unit when baiting *Phytophthora* from soil (Duniway 1975) an experiment was set up to determine whether pre wetting for 24 hours would increase detection levels by increasing zoospore releases.

Materials and Methods

Twenty five soil samples were collected three months after harvest at a depth of 0-15cm from a potato field where 25% of tubers were infected with Pink rot (Woodside, South Australia). Two 100g sub samples of the soil were flooded with 100ml deionised water in baiting tubs. In one sub sample 8 Camellia leaf discs were floated in the baiting tubs and incubated at 25°C under white light. After 24h half the baits were removed, blotted dry on paper towel and placed on PARPH-V8 media, a selective media modified by Ferguson and Jeffers (1999). Four fresh leaf discs were added, distinguishable from the remaining discs by a pinprick in the centre of each fresh disc.

To the remaining sub sample four Camellia leaf discs were added and the lids replaced and incubated as above. After 24h, four fresh leaf discs were added, the tubs chilled at 4°C for 60 minutes and incubated at 25°C for a further 23h. The baits were sampled as previously described.

Results and Discussion

Camellia leaf discs incubated for a period of 48h was the most effective of the baits used to detect *Phytophthora* in soil (Table 2).

Erwin and Ribeiro (1996) found that a period of chilling followed by re-warming encouraged zoospore release and increased detection. In this experiment a period of chilling at 4°C followed by re-warming to 25°C did not significantly improve the detection of *Phytophthora* from field soil. Fresh baits added 24h after flooding produced significantly fewer isolates

than discs added initially. This indicates that the greatest number of sporangia were formed and zoospores released soon after flooding.

Table 2. Recovery of *Phytophthora* spp. from naturally infested soil using Camellia discs.

Bait method	%+ve isolations
Camellia Discs	
24h incubation, fresh soil	24 ab
48h incubation, fresh soil	28 a
Fresh discs after soil flooded 24h	4 c
Fresh discs after soil flooded 24h, chilled	0 c
24h incubation, chilled, 24h incubation (48h)	28 a

Numbers followed by the same letter are not significantly different ($P > 0.05$)

Experiment 3

To ascertain the optimum duration of baiting, three soils naturally infected with *Phytophthora* were baited with Camellia leaf discs for various lengths of time.

Materials and Methods

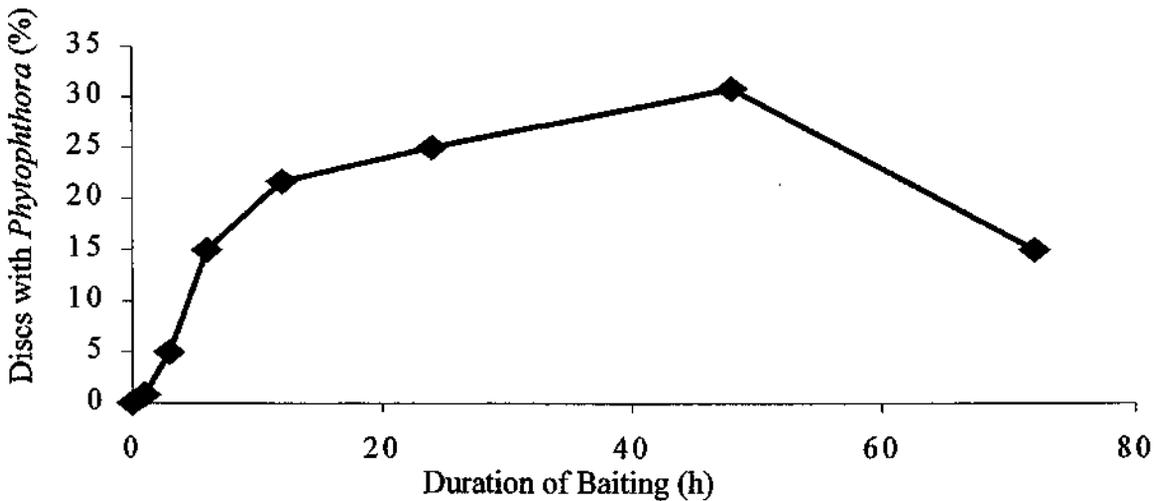
The equivalent of 100g oven dried soil, either air dried or moist (as collected) was flooded with 100ml deionised water before 28 Camellia discs were added. Baiting tubs were incubated at 25°C under white light using six replications for each treatment. The technique was also repeated using six 5mm mycelium plugs of both *P. erythroseptica* and *P. cryptogea* in baiting tubs. Soil extract was used instead of water to promote sporangia production. Four discs were removed to P₁₀VP+ media at 1, 3, 6, 12, 24, 48 and 72h.

Results and Discussion

Phytophthora spp. were not recovered from air dried and re-wet soils regardless of the duration of baiting even though pre-drying of soil has been shown to improve the detection of homothallic *Phytophthora* spp. (Erwin and Ribeiro, 1996; Jeffers and Aldwinkle, 1987).

Most *Phytophthora* spp. were recovered after 48h incubation but this was not significantly different from the recovery at 24h (Figure 4). *Phytophthora* was detected in baits incubated for as little as 1h and the level of detection steadily increased, plateaued and then began to decline. Twenty four to 48h is generally accepted as the optimum duration for baiting many species of *Phytophthora* (Ferguson and Jeffers 1997) and from these results appears to be appropriate for the detection of *P. erythroseptica*. It is likely the reduction in recovery at 72h was due to contamination of baits by other micro-organisms. Recovery varied among soil and liquid cultures with *P. cryptogea* plugs in soil extract providing the highest level of isolations.

Figure 4. Experiment 3: - Recovery of *Phytophthora* spp. after different incubation times.



Experiment 4

Soil known to be infected with Pink rot was sampled from an area at the Lenswood Research Station, 30km east of Adelaide, South Australia. This site had been planted to potatoes annually for the past 4-5 years. The levels of Pink rot in tubers from various plots was compared to determine if there was any correlation with incidence of detection in soil samples. Samples were also taken at various times to determine the most effective sampling time.

Materials and Methods

The 25.6m wide and 60m long area, known to be infected with *Phytophthora*, was split into 96 plots. Tubers harvested in May 2000 from each plot were assessed for the incidence of Pink rot. Soil was sampled from each plot in July, September and November 2000. Soil samples, collected at a depth of 0-15cm, were mixed before two 60g sub samples were removed and placed into 300ml baiting tubs with 75ml of deionised water. Ten *Camellia japonica* leaf discs (6mm diam), previously surface sterilised in 0.4% sodium hypochlorite solution, were floated on the water.

After incubation at 22°C for 48h the *Camellia* discs were removed, blotted dry on paper towel and placed on P₁₀VP+. Plates were then examined for the presence of *Phytophthora* after a further 3-5 days incubation at 22°C.

The sub sample was defined as positive when *Phytophthora* was detected from at least one of the *Camellia* discs.

Results and Discussion

Soil sampled in July 2000 showed *Phytophthora* was detected most frequently from soils where the highest number of tubers were infected with Pink rot. However tubers with Pink rot were also found in soils where *Phytophthora* was not detected (Table 3). The highest number of positive samples were found in the first sampling two months after harvest (July

2000) where *Phytophthora* was detected in 75% of the samples compared to 13% and 34 % in September and November respectively. The experiment shows that even though Camellia leaf discs are convenient and useful to use as soil baits, the technique does not always detect the low levels of *Phytophthora* which are sufficient to cause disease. Timing of soil sampling may also contribute to variations in the level of detection and needs further exploration. The lowest level of detection in this experiment was after rain when much of the area was waterlogged. This may have had a similar effect as pre wetting, reducing the number of zoospores available for release.

Further work is required to establish minimum levels of detection and to develop molecular techniques to detect and identify *Phytophthora* in soil. This may help determine more accurately the levels of the fungus in soil and therefore assist in predicting disease development.

Table 3. Incidence of *Phytophthora* in soil samples and number of Pink rot tubers found at harvest.

Detection of <i>Phytophthora</i> *	Number of plots in each <i>Phytophthora</i> detection group			Number of Pink rot tubers at harvest (%) (May)
	July	September	November	
++	39	8	9	409 (5.3)
+-	33	4	24	240 (4.1)
--	24	84	63	106 (2.4)

* ++ *Phytophthora* detected in both sub samples

+ - *Phytophthora* detected in one of two sub samples

-- *Phytophthora* detected in neither sub samples

STORAGE EXPERIMENTS

The aim of these experiments was to determine if Pink rot spreads in storage from infected to non infected tubers and whether previous fungicide treatments influence the resistance of tubers to infection.

Materials and Methods

Experiment 1

Coliban tubers retrieved from the control plots of a field trial were surface sterilised in a 0.4% sodium hypochlorite solution for 15 minutes, rinsed with deionised water and sprayed with 70% alcohol. A 6mm plug of *P. erythroseptica* was removed from an actively growing culture and placed in a hole 15mm deep at the end of each tuber opposite the stolon. One inoculated tuber was placed in a humidity tray in contact with four uninoculated tubers. Tubers were placed in sealed plastic bags and incubated in the dark at 22°C for four weeks before they were assessed for Pink rot. Five replicates were used.

Experiment 2

Russet Burbank tubers harvested from a pot trial were used in this experiment. Infected Pink rot tubers, retrieved from inoculated pots, were placed in 11cm x 6cm tubs with tubers from uninoculated pots. Each tub contained one infected tuber in contact with four uninfected tubers. Four replications were used. The tubs containing the tubers were stored in the cold room at 3°C (relative humidity approximately 96%) for 11 weeks and visually assessed for Pink rot. The tubers were then placed in the glasshouse for a further 8 weeks and incubated at 25°C before being cut open to determine if they were infected with Pink rot.

Experiment 3

Summer Red tubers retrieved from a fungicide pot trial where treatments of Ridomil granules (20kg/ha), Ridomil Gold MZ (2.5kg/ha), Ridomil Gold MZ (5kg/ha) and Ridomil Gold MZ (2.5kg/ha) plus Ridomil granules (20kg/ha) had been applied were inoculated with *P. erythroseptica* as in experiment 1. Tubers from each treatment were kept separate and stored at 4°C for 4 weeks. Six replicates were used for each treatment.

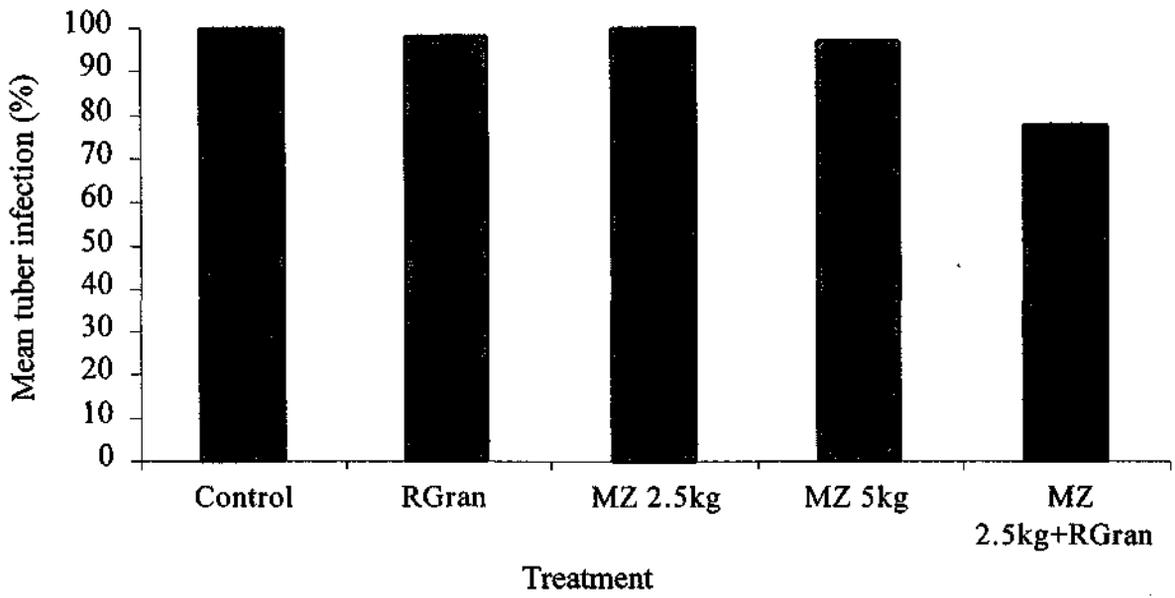
Results and Discussion

Pink rot developed extensively in tubers that had been previously infected but the rotting did not extend into adjacent tubers that were in direct contact with the infected tubers. A single tuber in one control tub developed Pink rot but this may have had a low level of infection when the trial was established. There was no evidence of disease spread from infected to uninfected tubers in storage. Infections that developed in storage are most likely due to either latent infection, or infection that developed from inoculum present in soil adhering to the surface of the tubers.

In experiment 3 only the combined treatment of Ridomil Gold MZ (2.5kg/ha) plus Ridomil granules (20kg/ha) reduced the level of infection by over 20% (Figure 5). Carryover of fungicide on or in tubers reduces their susceptibility to Pink rot which could prevent carryover of infection in storage.

This suggests that residues of Metalaxyl sufficient to inhibit mycelial growth were present in the tubers one month after harvest.

Figure 5. Experiment 3: - Susceptibility of tubers artificially inoculated with *P. erythroseptica* after pre treatments.



IRRIGATION EXPERIMENT

As soil moisture plays an important part in the development of Pink rot, an investigation was set up to determine the role irrigation has on disease incidence. In this experiment three different watering regimes were used, each applying the same amount of water at different intervals. Disease incidence was then assessed to determine if there was a treatment effect.

Materials and Methods

This trial was established at the Lenswood Research Station, South Australia, in an area known to be infected with *P. erythroseptica*. Treatment plots consisted of 4 rows each 2.5m long with the outer two rows acting as buffers. Certified Russet Burbank tubers were planted on 13th November 1998 at a density of 7 plants per row and a row spacing of 80 cm. Treatments were randomised with a total of 4 replicates. The irrigation system was set up using variable flow drippers located between each plant. Each dripper delivered approximately 500ml per minute and the volume of water varied by adjusting the time of irrigation using a multi station controller and solenoids. The treatments applied were a six day treatment, where the plots were watered once every six days with the equivalent of 25mm of rain, a three day treatment where the plots were watered once every three days with 12.5mm and a daily treatment where the plots were watered every day with 4.2mm. Irrigation was initiated 28 days after planting and finished at 118 days. At harvest the number of plants were recorded and assessments made from the centre two rows of each treatment. Both healthy and diseased tubers were counted and weighed and a statistical analysis carried out using a multi-factorial ANOVA(plot* row* treatment). The means were compared by LSD.

Results and Discussion

Pink rot developed in all plots, however there was a significant difference between the number of Pink rot tubers in all three treatments (Table 4). Most Pink rot developed in plants that were watered every six days. The number, weight and percentage of tubers with Pink rot

was significantly greater to all other treatments. There was no significant difference in the incidence of Pink rot tubers in treatments that had been watered once every three days or daily. This shows that dry periods followed by wet periods are more conducive to the development of disease than continuous periods of soil wetness.

Table 4. Number and weight of tubers recovered from plots treated with different watering regimes.

Irrigation interval	No. healthy tubers	Weight. healthy tubers	No. Pink rot tubers	Weight Pink rot tubers	%. Pink rot tubers
Six Days	45.8	5.28	9.8 a	0.78 a	15.0 a
Three Days	48.4	5.91	5.6 ab	0.36 b	6.4 b
Daily	50.6	5.32	3.6 b	0.36 b	6.6 b

Numbers followed by the same letter are not significantly different ($P>0.05$)

FUNGICIDE CONTROL

Control of Pink rot with fungicides or biofumigants were evaluated *in vitro*, *in vivo* and with shade house and field experiments. The fungicides used in these experiments were Acrobat MZ (90g/kg Dimethomorph combined with 600g/kg Mancozeb – BASF Australia Pty Ltd.), Amistar (500g/kg Azoxystrobin – Syngenta, formerly Novartis Crop Protection Australasia Pty Ltd), Dithane M45 (800g/kg Mancozeb – Crop Care Australasia Pty Ltd), Foli-R-Fos 200 (200g/L Phosphonic acid neutralised with equal amounts of KOH - U.I.M Agrochemicals (Aust) Pty Ltd. Rocklea, Queensland), Patafol (500g/kg Ofurace (Phenylamide) - formerly manufactured by Schering), Ridomil 50G (50g/kg Metalaxyl granules – Syngenta), Ridomil Gold 25G (25g/kg Mefenoxam granules – Syngenta), Ridomil Gold MZ (40g/kg Mefenoxam combined with 640g/kg Mancozeb – Syngenta), Ridomil Gold 480 EC (480g/L Metalaxyl-m - Syngenta) and Shirlan (500g/kg fluazanim – Crop Care Australasia Pty Ltd.), SZX 722 (80% a.i. - Bayer) and Zoxium (80% a.i. - Rohm and Haas Company). The biofumigants Mustard Meal (100% cold pressed *Brassica juncea* – Yandilla Seeds, NSW) and Mustard Pellets (25% cold pressed *Brassica juncea* – Yandilla Seeds, NSW) were also used.

Application methods for shade house and field experiments.

Granular formulations of Ridomil were applied by placing the required amount in the furrow beneath or adjacent to the tubers at planting and watered in with normal irrigation practices. Ridomil Gold 480 EC was used as an in furrow drench and applied at a rate of 300L/ha. The required amount was applied using nozzles directed onto the tubers before the furrows were closed. Foliar fungicides were applied at a rate of 1000L/ha using either a hand operated knapsack sprayer on the shade house experiments or a motorised backpack sprayer on the field experiments. Although fungicides were directed onto the foliage in the field experiments, plants were irrigated by overhead sprinkler irrigation every 2-6 days to enhance the leaching of the fungicide deposit from the foliage onto the soil. Pots were watered overhead by hand 2-3 days after fungicide application to aid the movement of fungicides into and through the soil. Mustard Meal was applied by hand over plots directly before planting.

Flooding.

To induce high levels of disease shade house pots were flooded on two occasions by placing them in plastic bags and filling with water to submerge the top of the pot. Pots were flooded for 24h and then allowed to drain. Flooding was imposed 2 and 3 days after the first and second spray applications respectively in experiment 1, and 6 days after the initial spray application in experiment 2.

Disease assessment and analysis

At harvest, tubers were washed, separated into healthy and infected, counted and weighed. The incidence of Pink rot was expressed as the percent by weight of diseased tubers. A random sample from each treatment was plated onto P₁₀VP+, a selective media to confirm the presence of *Phytophthora* (Tsao and Ocana, 1969). Unless otherwise indicated, results were analysed using analysis of variance (ANOVA) and means compared by LSD on the raw data.

(a) *In vitro* experiments

Materials and Methods

Three experiments were undertaken to test the sensitivity of *P. erythroseptica* and *P. cryptogea* to fungicides *in vitro*. Corn Meal Agar (CMA) was amended with various fungicides at 0.01, 0.1, 1, 5 and 10ppm active ingredient. Five replicate plates were used for each concentration. Fungicides and formulation used in these experiments are shown in Table 5. The plates were dried in a laminar flow cabinet for 30 minutes before a 6mm plug of mycelium from an actively growing culture of either *P. erythroseptica* or *P. cryptogea* was placed in the centre of each plate. The plates were sealed with parafilm® and incubated at 22°C for 4-5 days before the diameter of mycelial growth was measured. The sensitivity of the fungus was evaluated by calculating the percentage inhibition of mycelial growth on CMA amended agar compared to CMA without fungicides.

Table. 5. Fungicides and formulations evaluated against mycelial growth of *P. erythroseptica* and *P. cryptogea*.

Fungicide	Active Ingredient	Experiment
Ridomil®	Metalaxyl-L (250g/kg)	1, 2 & 3
Shirlan®	Fluazinam (500g/L)	1 & 2
Patafol®	Ofurace (500g/kg)	1
Acrobat®	Dimethomorph (500g/kg)	1 & 3
Amistar	Azoxystrobin (500g/kg)	1
Zoxium®	Zoxamide (80% a.i.)	2 & 3
SZX 722	50% a.i	2 & 3

Results and Discussion

Of the seven fungicides tested Metalaxyl, Dimethomorph, SZX 722 and Zoxamide were the most inhibitory to *P. erythroseptica* and *P. cryptogea* and Azoxystrobin and Fluazinam the least inhibitory. Complete inhibition by Metalaxyl varied between 1 and 10ppm, which may be caused by variations in sensitivity of the isolates tested. All the fungicides except Fluazinam provided complete inhibition of *P. erythroseptica* at 10ppm. SZX 722 was the most effective with complete inhibition of *P. erythroseptica* at 0.5ppm (Figure 8 and 9).

Both *P. erythroseptica* and *P. cryptogea* were inhibited at similar levels when grown on fungicide amended media (Figures 6 and 7). Azoxystrobin is rarely effective when tested *in vitro*, and the lack of sensitivity was not unexpected.

Figure 6. Experiment 1: - Effect of different fungicides and concentrations on mycelial growth of *P. erythroseptica*.

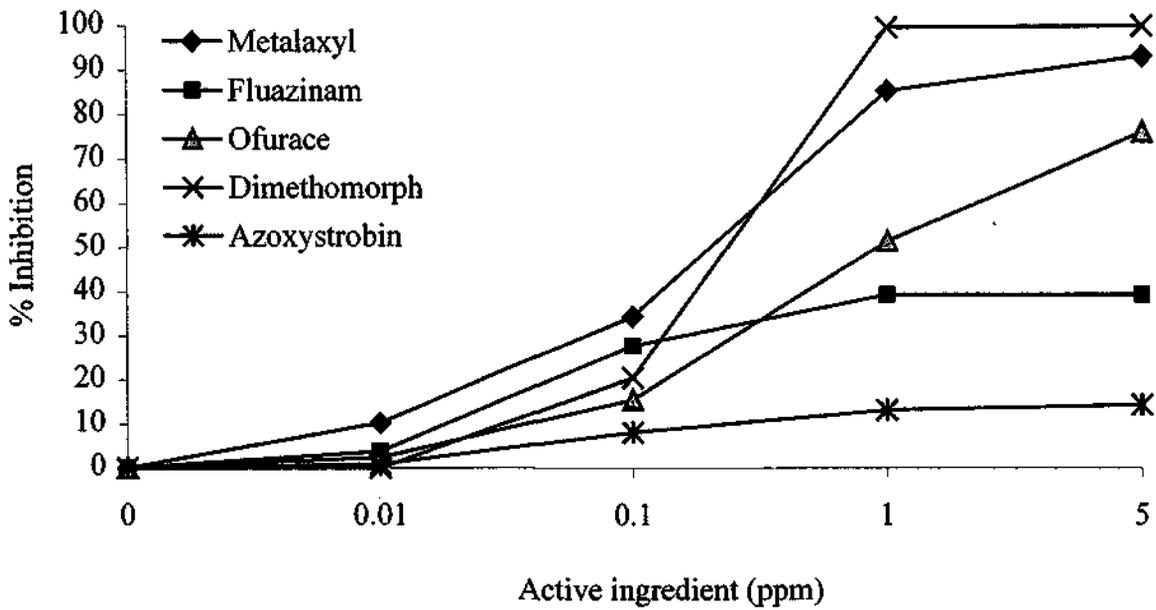


Figure 7. Experiment 1: - Effect of different fungicides and concentrations on mycelial growth of *P. cryptogea*.

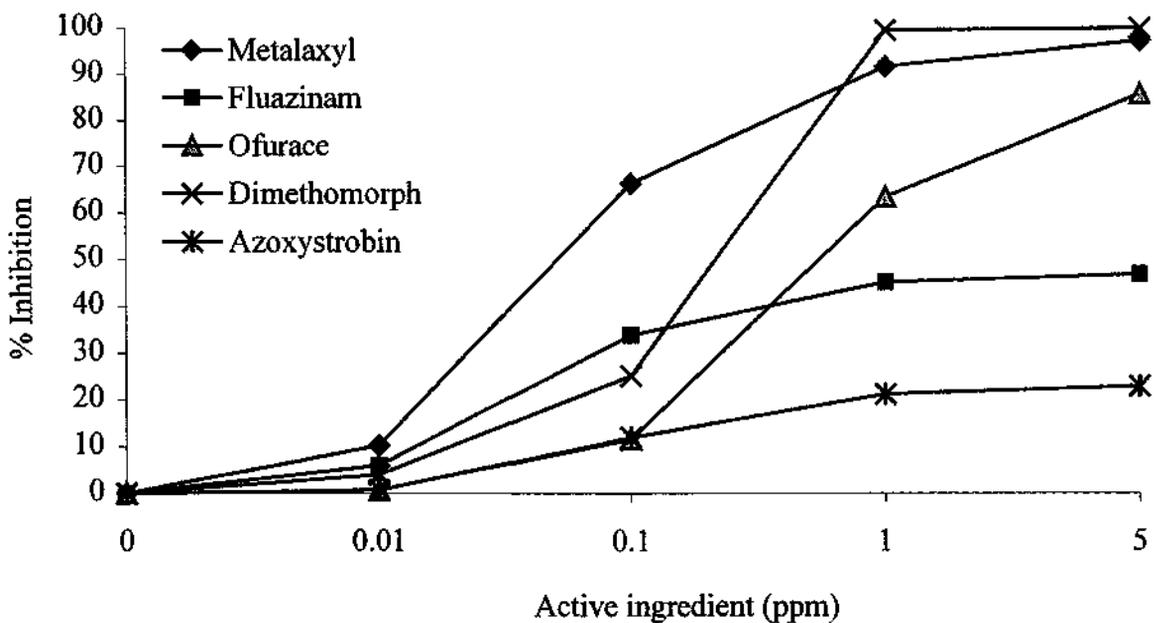


Figure 8. Experiment 2: - Effect of different fungicides and concentrations on mycelial growth of *P. erythroseptica*.

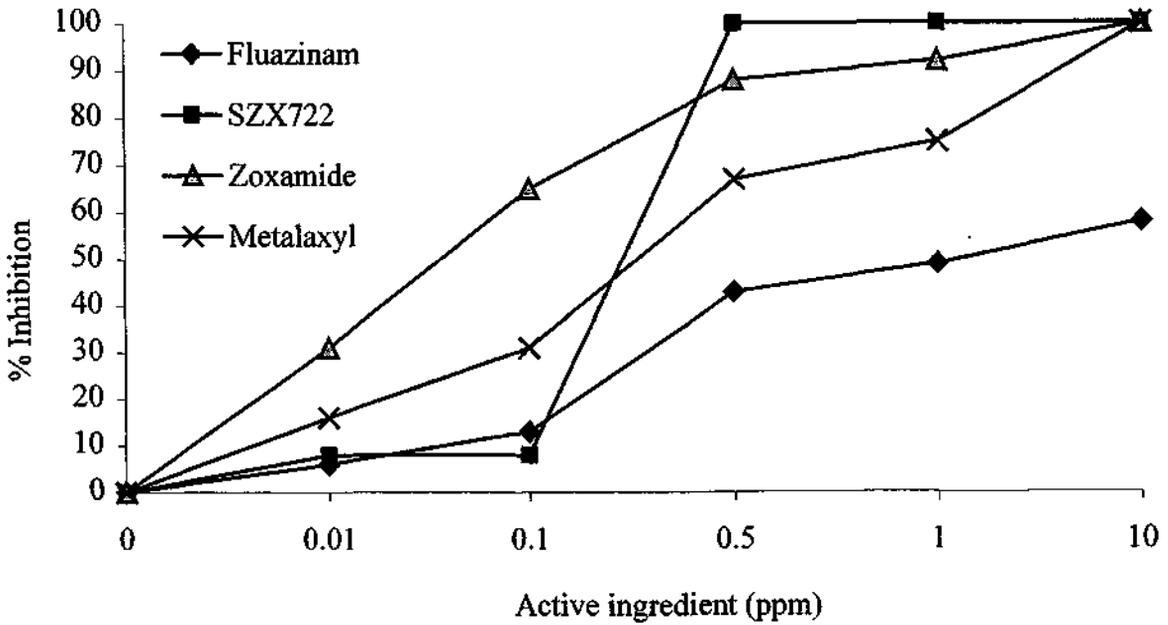
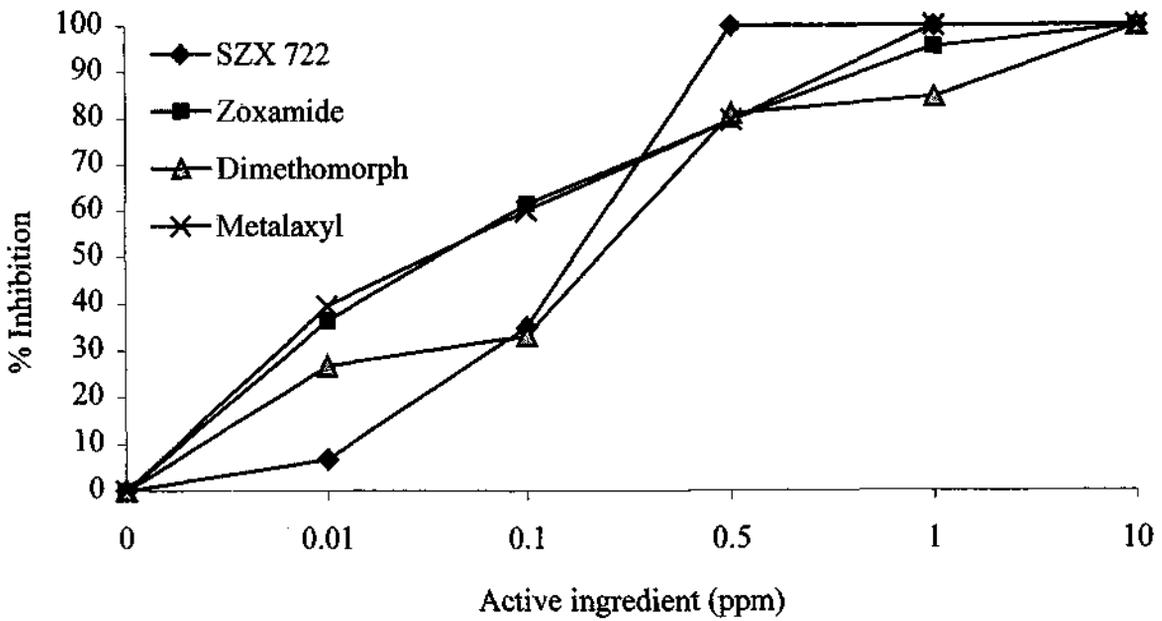


Figure 9. Experiment 3: - Effect of different fungicides and concentrations on mycelial growth of *P. erythroseptica*.



(b) Resistance of *P. erythroseptica* to Metalaxyl

In America strains of *P. erythroseptica* insensitive to Metalaxyl have been found. This experiment details investigations carried out to determine the sensitivity of Australian isolates of *P. erythroseptica* to Metalaxyl and to determine if resistance is present in Australia.

Materials and Methods

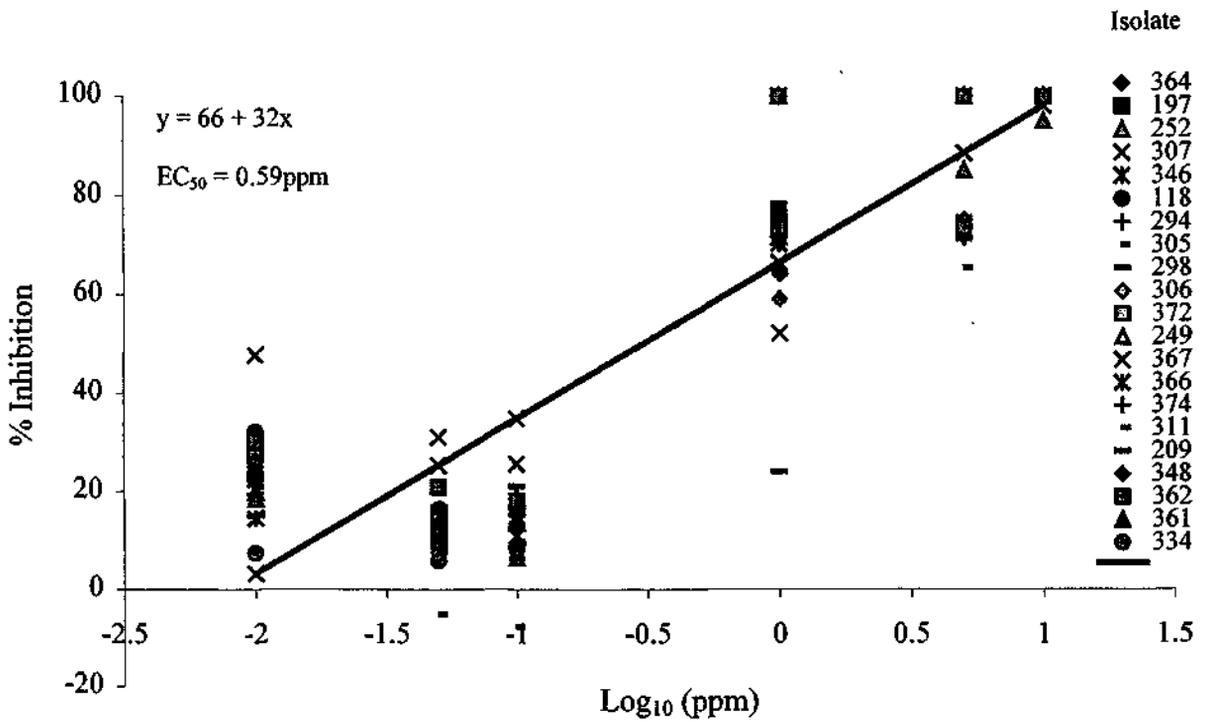
Experiment 1

Twenty one Australian isolates obtained from potato tubers and soil from South Australia, Victoria and Tasmania were used in this experiment. The isolates were grown on CMA amended with Metalaxyl at 0.01, 0.05, 0.1, 1, 5 and 10ppm. After three days at 22°C radial growth was measured and percentage inhibition to Metalaxyl calculated.

Results

All isolates were sensitive to Metalaxyl at concentrations above 1ppm with complete inhibition achieved at 10ppm. Based on a regression analysis the EC₅₀ value (the concentration required to kill 50% of the isolates) was 0.59ppm Metalaxyl (Figure 10).

Figure 10. Percentage inhibition of 21 *P. erythroseptica* isolates to Metalaxyl



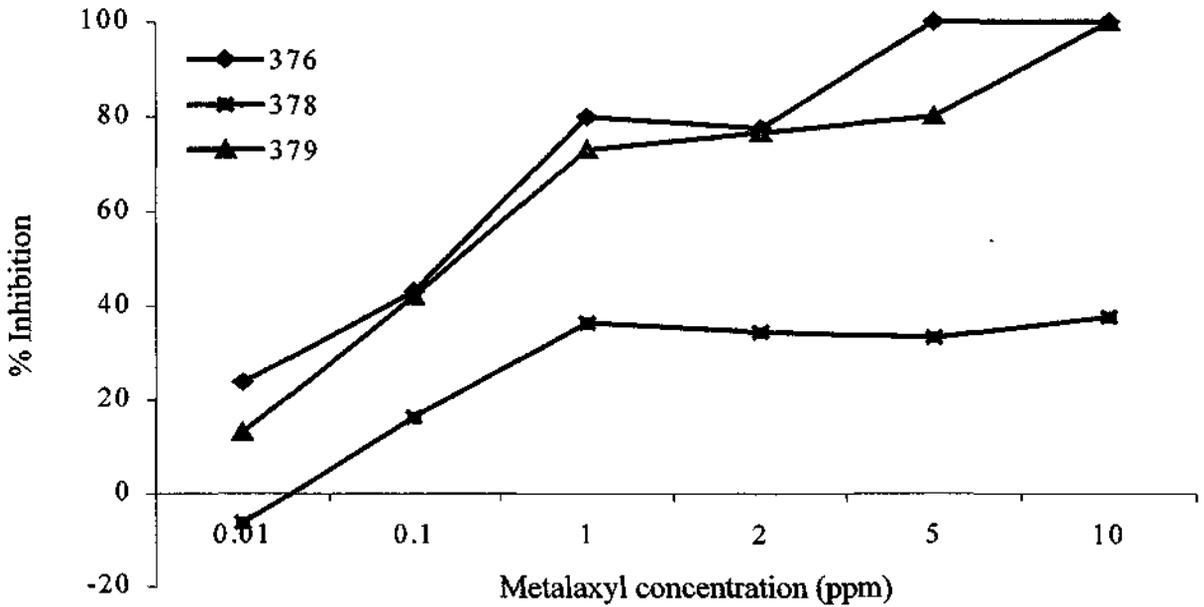
Experiment 2

Three *P. erythroseptica* isolates, collected from tubers from the South East of South Australia prior to harvest, were grown on amended agar as in experiment 1 and percentage inhibition to Metalaxyl calculated. Isolate 376 was retrieved from a tuber where no Metalaxyl had been applied to the site, isolate 378 from a site where the granular application of Metalaxyl was applied at planting and isolate 379 from a site where the foliar application of Metalaxyl was applied at tuber initiation and 14 days later.

Results

Isolate 376, retrieved from a site where no Metalaxyl had been applied, was most sensitive to Metalaxyl at all concentrations whereas isolate 378, from the site where Metalaxyl granules was applied was the least sensitive (Figure 11).

Figure 11. Percentage inhibition of 3 *P. erythroseptica* isolates to Metalaxyl retrieved from sites where different formulations of Metalaxyl were applied.



Discussion

As there are few effective alternatives to Metalaxyl for the control of Pink rot work is required to monitor the resistance of isolates, especially those retrieved from paddocks where Metalaxyl is applied.

Testing *P. erythroseptica* isolates for fungicide sensitivity is necessary to detect populations of the fungus developing resistance to Metalaxyl and to implement management strategies to prevent resistance becoming widespread in a field. Investigations are also required to determine whether granules, which slowly release the fungicide into the soil over a period of time, provide a long period of selective pressure encouraging the build up of resistance.

(c) Drench experiment

These experiments were set up to simulate the control achieved when fungicides are applied to the soil surface and leached through the soil by rain or overhead irrigation. Four fungicides applied to soil containing *P. erythroseptica* at various levels were evaluated.

Materials and Methods

PVC storm water columns (35cm high and 7cm in diameter) were filled with a UC soil mix. Each column was inoculated 5, 15 and 25cm below the surface with 1g of vermiculite, previously been treated with V8 juice (Erwin and Ribeiro, 1996), and inoculated with *P. erythroseptica*. The inoculum was placed in muslin layers to ensure detection and removal. Deionised water (200mls) was added to each column and incubated at room temperature overnight. Four replicate columns were used for each treatment. Metalaxyl, Zoxium, Fluazinam and SZX 722 were applied as a 200ml drench of 10, 50, 100 or 500ppm. Deionised water was used for the control. A further 200mls of deionised water was applied to the surface of the columns a week later and the muslin bags of inoculum removed the following day. Fungal viability was evaluated by taking thirty pieces of vermiculite from each depth and placing them on P₁₀VP⁺ selective media. After 7 days incubation at 20°C pieces were considered viable if microscopic examination showed mycelial growth typical of *P. erythroseptica*.

Results and Discussion

The response of *P. erythroseptica* to drenches of all four fungicides is shown in Figures 12-15. Differences in the activity of all the fungicides were seen with Metalaxyl and SZX 722 showing the best control of *P. erythroseptica* (Figures 12 and 15). Metalaxyl showed the most consistent control throughout all depths and completely inhibited growth at 100ppm and 500ppm (Figure 12). The poor activity of SZX 722 and Zoxium was unexpected as both these fungicides showed good activity *in vitro* (Figures 14 and 15). SZX 722 showed good activity at 500 ppm, almost completely inhibiting the growth of *P. erythroseptica*, whereas Zoxium showed the least activity at all concentrations and depths with just over 45%

inhibition at 500ppm. Soil may have been an inhibitory effect on the action of these fungicides and much higher rates may be necessary for control. The relatively poor activity of Fluazinam was consistent with the *in vitro* responses (Figure 13).

Figure 12. Viability of *P. erythroseptica* buried in soil columns at various depths and drenched with Metalaxyl.

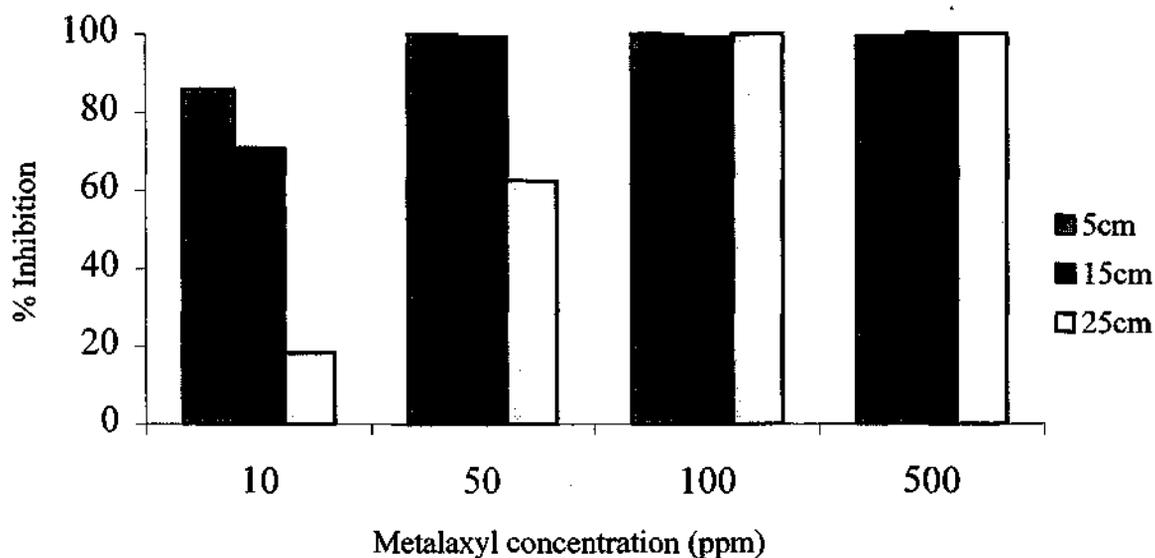


Figure 13. Viability of *P. erythroseptica* buried in soil columns at various depths and drenched with Fluazinam.

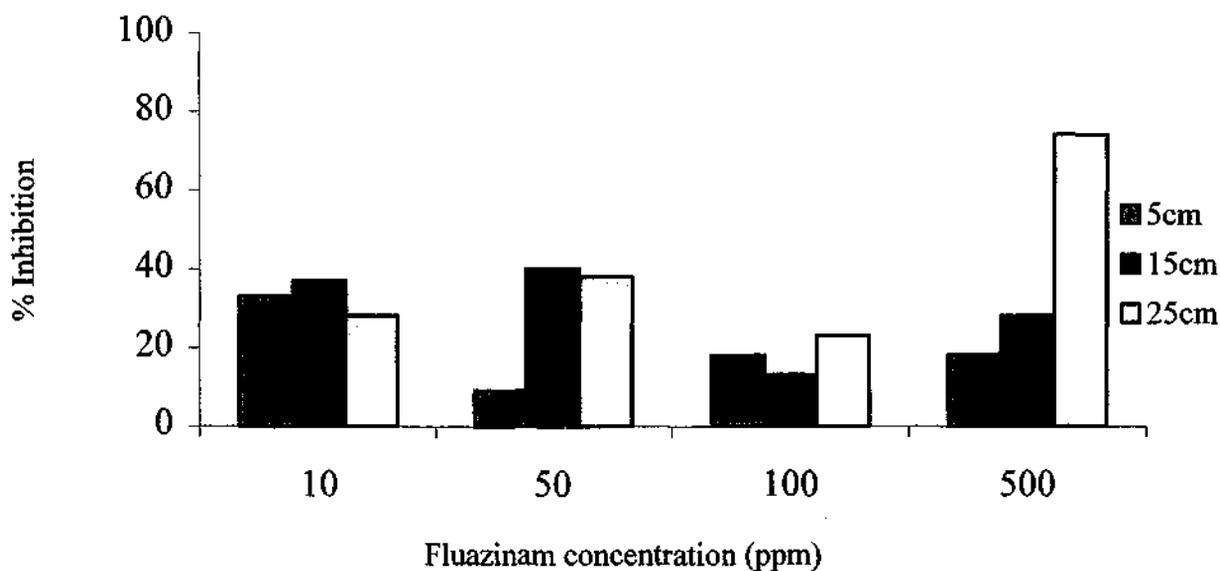


Figure 14. Viability of *P. erythroseptica* buried in soil columns at various depths and drenched with Zoxium.

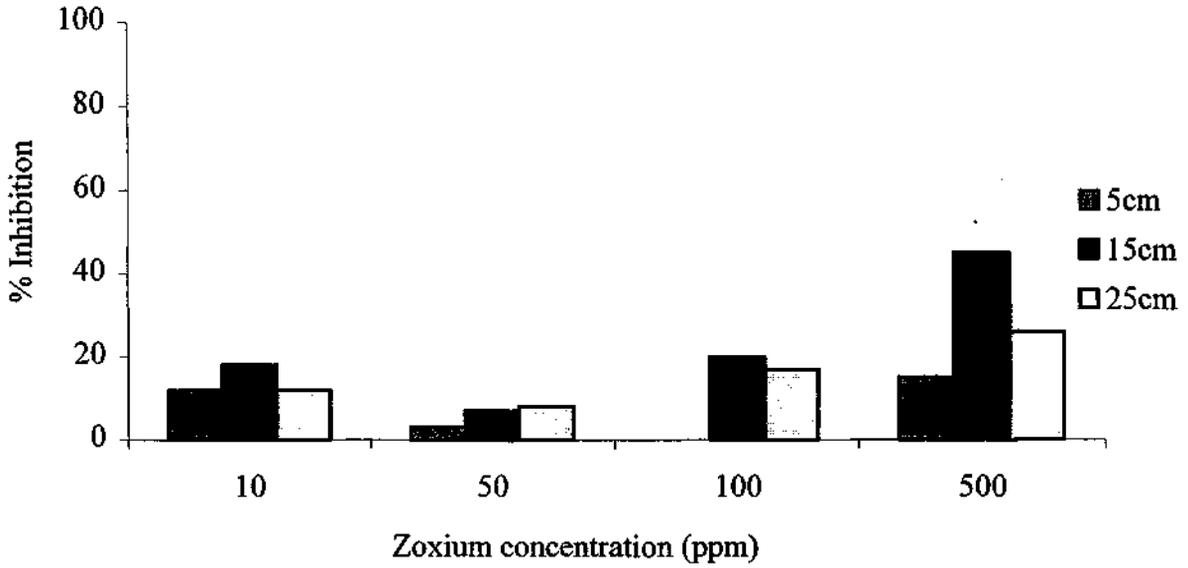
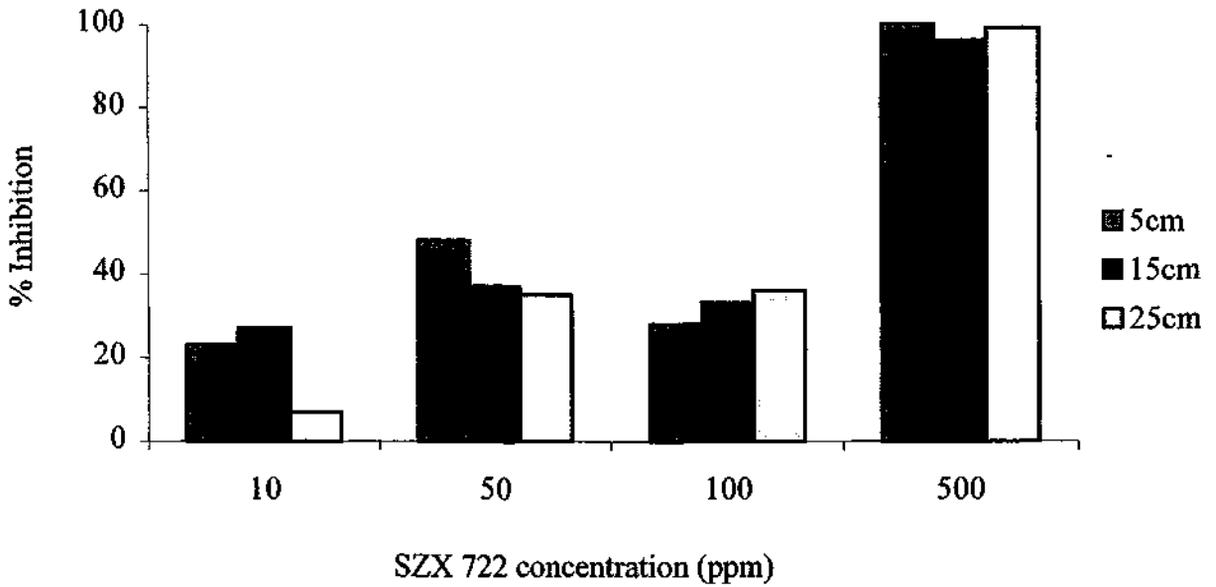


Figure 15. Viability of *P. erythroseptica* buried in soil columns at various depths and drenched with SZX 722.



(d) Biofumigation

Two *in vitro* experiments were undertaken to evaluate Mustard Meal and Mustard Pellets as biofumigants to control Pink rot. When moistened these are known to release isothiocyanates (ITCs), chemicals similar to the highly biocidal soil fumigant metham sodium.

Experiment 1

Materials and Methods

Isolates of *P. erythroseptica* and *P. cryptogea* were grown on CMA for three days before 6mm mycelial plugs were removed from the growing margin and placed onto fresh CMA plates. These plates were inverted over small containers of either meal or pellets at 0.0025g, 0.005g, 0.0075g, 0.01g, 0.025g, 0.075 and 0.1g. The meal and pellets were moistened with deionised water added at equivalent rates of 200 μ l/0.1g before the plates were sealed with parafilm®. After 4 days incubation at 25°C mycelial growth was measured. Five replicates were used for each treatment.

Results and Discussion

Isolates of *P. erythroseptica* and *P. cryptogea* were sensitive to volatiles from Mustard Meal and Mustard Pellets, with inhibition increasing with increasing concentration (Figures 16 and 17). Greater inhibition of *P. erythroseptica* was obtained using Mustard Meal with complete inhibition occurring at 0.025g of Mustard Meal compared to 0.05g of Mustard Pellets (Figure 16). The reverse was true for *P. cryptogea* as mustard pellets inhibited growth at higher concentrations than Mustard Meal however the results were slightly more variable (Figure 17).

Figure 16. Experiment 1: - Percentage inhibition of *P. erythroseptica* to Mustard Meal and Mustard Pellets

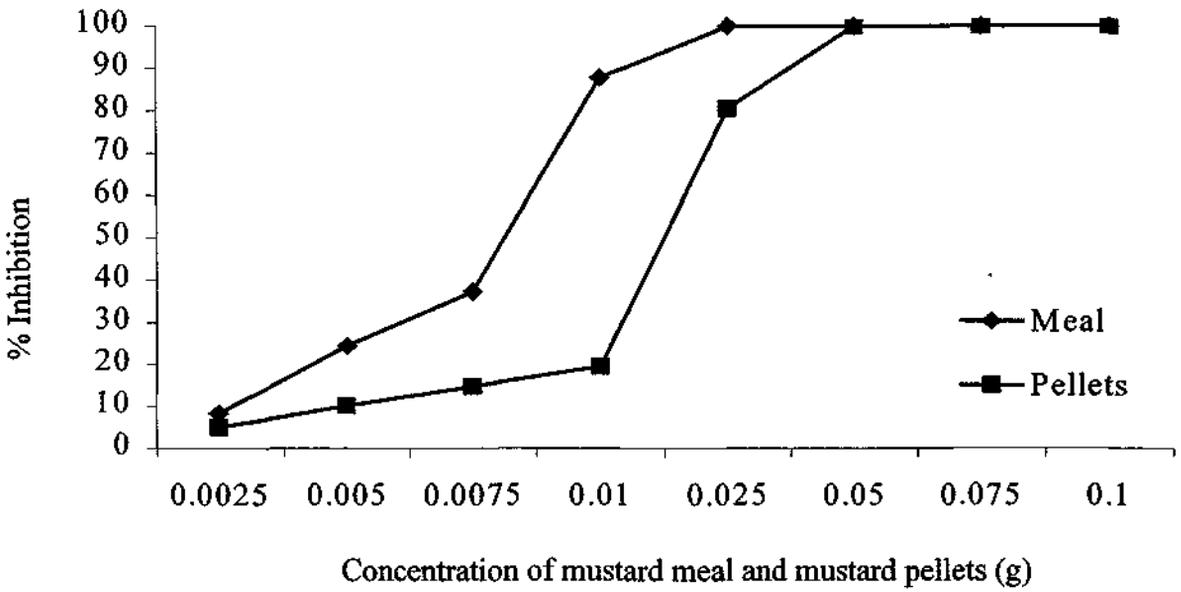
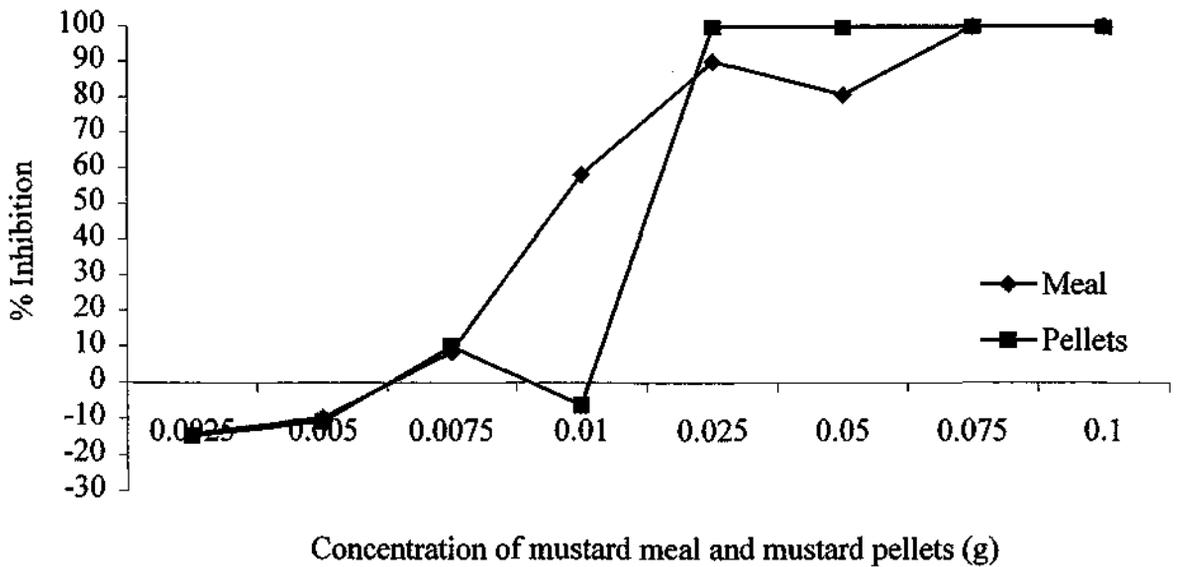


Figure 17. Experiment 1: - Percentage inhibition of *P. cryptogea* to Mustard Meal and Mustard Pellets



Experiment 2

Materials and Methods

Experiment 1 was repeated using concentrations of meal and pellets at 0.005g, 0.025g and 0.05g. The mycelial plugs of each isolate were exposed to the biofumigants for 6, 12, 24, 48 and 96h. After each exposure the biofumigants were removed and incubated for a further 4 days before measuring colony diameter and calculating percentage inhibition.

Results and Discussion

Both *P. erythroseptica* and *P. cryptogea* were completely inhibited at concentrations of 0.025g or above regardless of the time of exposure (Figures 18 and 19). Inhibition using mustard pellets was dependent on the length of time exposed (Figure 20 and 21).

These experiments show that both meal and pellets of *Brassica juncea* are inhibitory to *P. erythroseptica* and *P. cryptogea* if the concentration is maintained for the required time.

Figure 18. Experiment 2: - Percentage inhibition of *P. erythroseptica* to Mustard Meal after different periods of exposure.

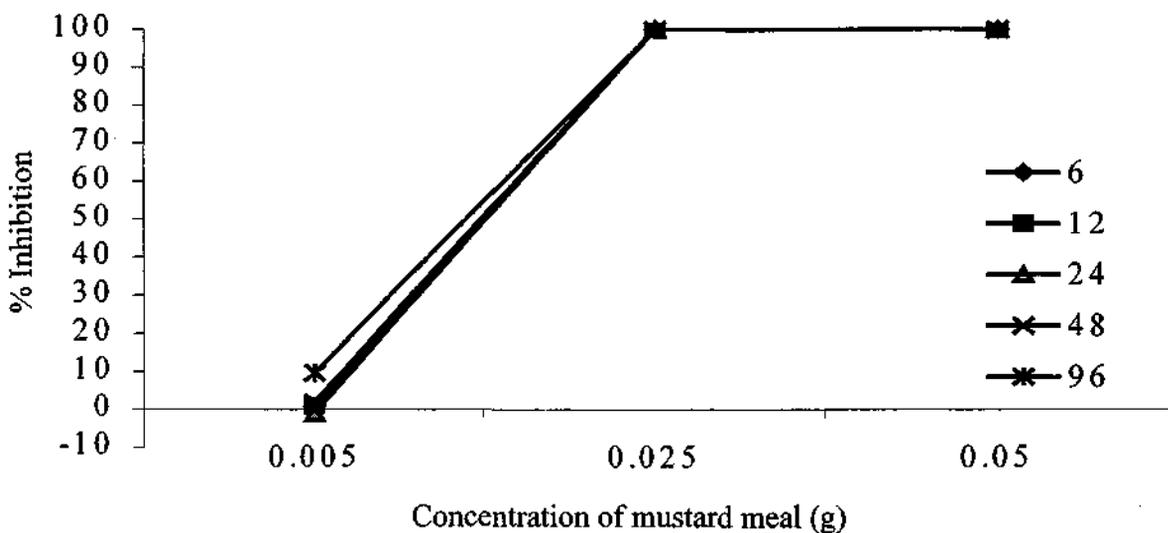


Figure 19. Experiment 2: - Percentage inhibition of *P. cryptogea* to Mustard Meal after different periods of exposure.

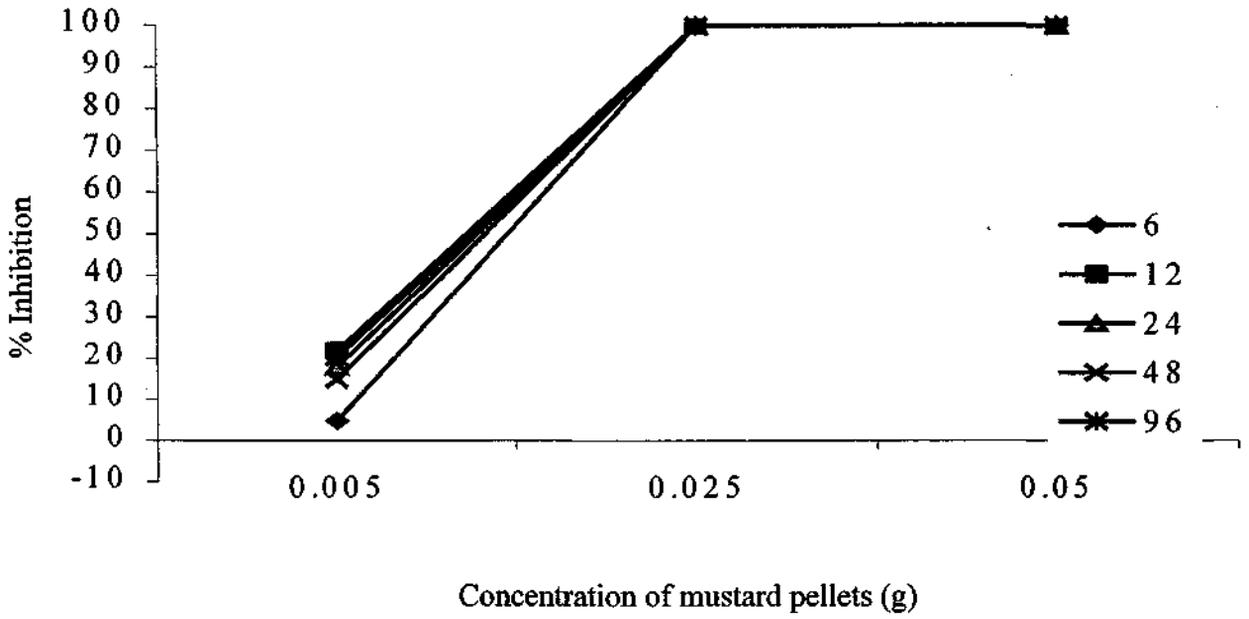


Figure 20. Experiment 2: - Percentage inhibition of *P. erythroseptica* to Mustard Pellets after different periods of exposure.

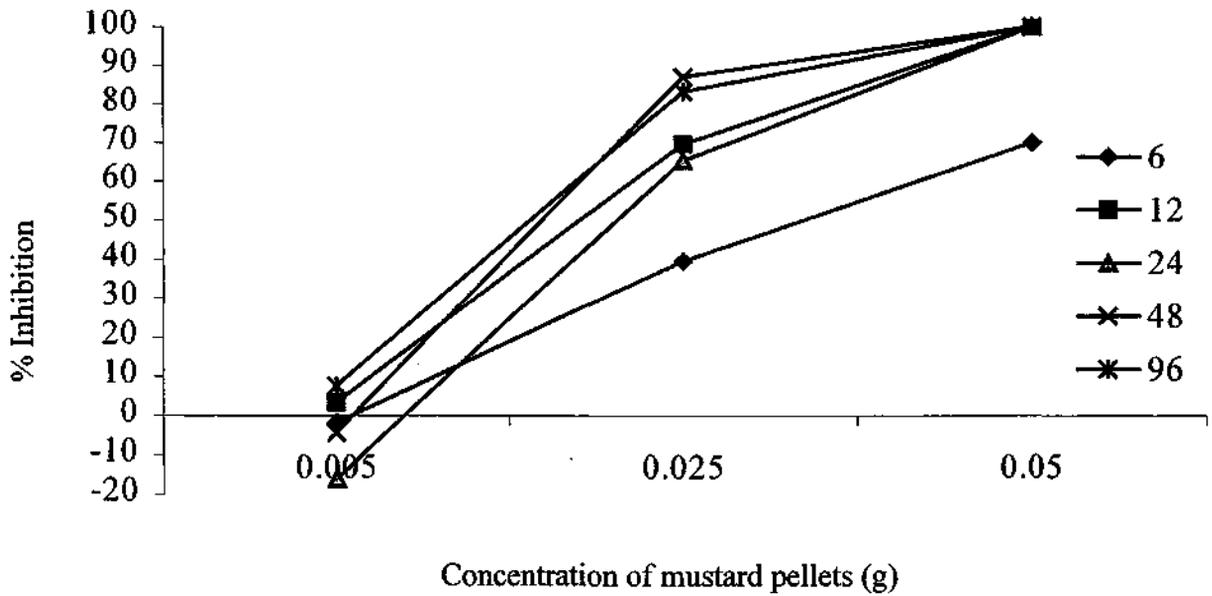
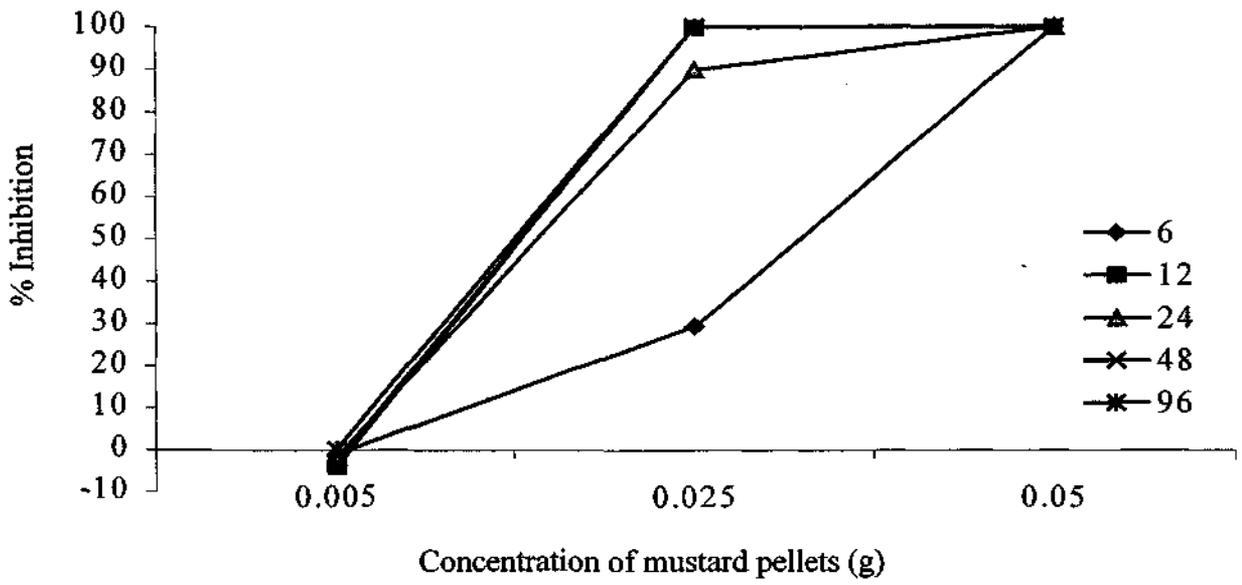


Figure 21. Experiment 2: - Percentage inhibition of *P. cryptogea* to Mustard Pellets after different periods of exposure.



(e) Shade house experiments

Experiments 1 and 2

Materials and Methods

Two shade house experiments were carried out to screen fungicides for the control of Pink rot. Plants were grown in 12L pots using either pasteurised recycled soil mix or UC soil mix (Baker, 1972). Each pot was inoculated with 2.5g of *P. erythroseptica* inoculum grown on vermiculite V8 juice media according to the method described in Erwin and Ribeiro (1996). This inoculum was placed in a layer in the lower third of the soil in each pot and tubers were planted several centimetres above. This enabled tubers to shoot and the plant to become established before infection. In previous experiments where inoculum was placed with the tuber the tuber rotted before emergence. Pots were randomised and maintained in a shade house receiving natural daylight and rainfall. After treatment additional irrigation was supplied through drippers every 2 days.

In experiment 1 whole potato tubers, cv. Summer Red were planted one per pot into either inoculated or uninoculated soil and harvested and assessed 109 days after planting. Treatments outlined in Table 6 were applied to individual pots considered as single replicates arranged in a randomised block and replicated ten times. Two control treatments were also included in both experiments with and without disease inoculum.

In experiment 2 tubers, cv. Russet Burbank were planted into infected soil as in the previous experiment with nine replicates used for each treatment (Table 6). Plants were harvested and tubers assessed 99 days after planting.

Table 6. Treatments and application times for Experiments 1 and 2.

Treatments	Rate/ha	Time of Application	Experiment
Dithane M45	4kg	Day 39 + 49 + 59	1
Foli-R-Fos 200	6L	Day 39 + 49 + 59	1
Foli-R-Fos 200	12L	Day 39 + 49 + 59	1
Foli-R-Fos 200	10L	Day 48 + 64	2
Ridomil Gold MZ	2.5kg	Day 39 + 49 + 59	1
Ridomil Gold MZ	2.5kg	Day 39 + 49 + 59	1
Ridomil Gold MZ	2.5kg	Day 48 + 64	2
Ridomil Granules	20kg	Planting	1+2
Ridomil Granules + Ridomil Gold MZ	20kg + 5kg	Planting +39 days	1
Ridomil Granules + Foli-R-Fos 200	20kg + 6L	Planting +39 days	1
Shirlan	4L	Day 48 + 64	2
Acrobat MZ	2kg	Day 48 + 64	2
Control (inoculated)			
Control (not inoculated)			

Results and Discussion

Pink rot did not develop in the uninoculated control plants whereas it was found in 61% and 50% of tubers in the inoculated control treatment in experiments 1 and 2 respectively. Similar or higher levels of Pink rot developed in the Dithane M45 and the Foli-R-Fos 200 treatments in experiment 1 (Table 7) unlike experiment 2 where all treatments reduced the incidence of Pink rot (Table 8). All Ridomil treatments significantly inhibited the development of disease compared to that of the control, with the Ridomil granule treatments

inhibiting the development of Pink rot completely (Table 7). The level of disease control in experiment 1 was reflected in the plant weight and yield of healthy tubers, as those treatments with the highest incidence of Pink rot had the lowest plant weight and tuber yield, and those with little or no Pink rot yielded the highest. Overall, *P. erythroseptica* reduced the fresh weight of Summer Red potatoes by 40% and the production of healthy tubers by over 90% (Table 7).

Table 7. Effect of fungicides on the development of Pink rot on Summer Red potatoes in potting soil artificially inoculated with *P. erythroseptica*.

Fungicide treatment rate of product ha	Healthy tubers g / pot	Plant weight g / pot	% Weight of tubers with Pink rot #
Dithane M45 – 4kg ^A	89 c*	228 d	71 a
Foli-R-Fos 200 - 6 L ^A	72 c	234 d	61 a
Foli-R-Fos 200 - 12 L/ha ^A	44 c	192 e	76 a
Ridomil Gold MZ- 2.5kg ^A	394 b	300 c	4 b
Ridomil Gold MZ- 5kg ^A	449 ab	334 bc	2 c
Ridomil granules – 20kg ^B	503 a	395 a	0 c
Ridomil granules – 20kg ^B plus Ridomil Gold MZ – 5kg ^A	473 ab	351 b	0 c
Ridomil granules – 20kg ^B plus Foli-R-Fos 200 6L ^A	483 a	357 b	0 c
Control (inoculated)	53 c	203 de	61 a
Control (not inoculated)	483 a	343 b	0 c
LSD (P=0.05)	82	35	#

*treatment means with the same letter are not significantly different from one another

data was analysed after natural log transformation to provide normality of data and analysed by standard ANOVA. Raw data means are shown, so no LSD is included

A = foliar sprays applied 39, 49 and 59 days after planting

B = soil treatments applied at planting

The control achieved with Foli-R-Fos varied considerably. In experiment 1 the level of Pink rot was higher than in the control, whereas in experiment 2 it was one of the most effective treatments (Table 8). In experiment 2 Foli-R-Fos was applied at 14 day intervals making the final spray later in the growing season, which may have had some effect. Acrobat MZ or Shirlan were the least effective of the fungicide treatments, with a Pink rot incidence of 31% and 26% respectively, compared to 16% in the Ridomil Gold MZ treatments and zero in the Ridomil granule treatment (Table 8). Although the inoculated untreated plots in experiment 2 produced the lowest yield of healthy tubers, no significant differences were detected between the treatments due to the variation in yields from each plant (Table 8).

Table 8. Effect of fungicides applied to soil or foliage on the development of Pink rot in Russet Burbank potatoes grown in potting soil artificially inoculated with *P. erythroseptica*.

Fungicide treatment rate of product ha	Healthy tubers g / pot	% Weight of tubers with Pink rot
Acrobat MZ – 2kg ^A	222	31 b*
Shirlan – 4L ^A	241	26 bc
Ridomil Gold MZ - 2.5kg ^A	279	16 bcd
Foli-R-Fos 200 - 10L ^B	301	13 cd
Ridomil Gold granule – 20kg ^C	291	0 d
Control (inoculated)	188	50 a
Control (not inoculated)	323	0 d
LSD (P=0.05)	n.s.	17.8

* treatment means with the same letter are not significantly different from one another

n.s. there are no significant differences between the treatments

A = foliar sprays applied at 48 and 62 days after planting

B = foliar sprays applied 48, 62 and 76 days after planting

C = soil treatments applied at planting

Growing potato plants in artificially inoculated soil and then flooding the plants for at least 24 hours around the time of tuber initiation was a reliable technique to induce the development of Pink rot. For example, in the experiments between 50-60% of tubers developed Pink rot in the inoculated control treatments compared to 6-21% that developed in

the field experiments with naturally infected soil. This technique was found to be a useful and reliable method to screen fungicides for the control of Pink rot. In general, fungicides that performed well in the pot test also controlled the disease in the field and those that had little or poor activity in the pot tests behaved similarly in the field.

Experiment 3

In this experiment a shade house study was carried out to examine the possible influence previous seasons fungicide treatments had on the susceptibility of seed tubers to infection by zoospores and the subsequent infection of plants.

Materials and Methods

Red la soda tubers from a site at Lenswood, previously sprayed with three applications of Ridomil Gold MZ at 5kg/ha (3 applications), Phosphonic acid 6 L/ha (3 applications) or no treatment were used.

The inoculum was prepared from cultures of *P. erythroseptica* and grown on V8 juice agar for 3 days. Twenty 4mm plugs were taken from the growing edge of cultures and placed in 5 petri dishes (per isolate) and flooded with 15ml of soil extract. Dishes were incubated under white fluorescent light for 48h at room temperature after which time they were placed at 4°C for 60 min. to encourage zoospore release. The number of zoospores was determined using a haemocytometer.

5×10^4 zoospores/ml were applied to tubers using a wide mouthed pipette at 1ml/seed. Tubers were then incubated for 24h in a sealed plastic bag at room temperature. Half were removed after 24h for planting and half incubated in the dark for a further 13 or 25 days at 27°C, with deionised water added after 4 (1ml) and 15 days (5ml). After 13 days tubers with Pink rot symptoms were removed, cut open and assessed for the characteristic pink colour change. The remaining tubers were incubated for a further 12 days before assessment. Control tubers without zoospores were inoculated with soil extract.

The tubers removed from plastic bags at 24h were planted into 25cm diameter plastic pots of moist UC soil mix, lightly watered and incubated in the glass house. At 35 days the pots were flooded for 24h to induce disease. Plants and tubers were assessed 50 days after planting. Root condition was rated for level of disease (% roots with lesions on a 0-4 scale with increasing disease), plant weight, healthy and diseased tuber number and weight. The presence of aerial tubers, top wilting and stem lesions was also noted.

Results and Discussion

Significantly less tubers were infected when the tubers were obtained from plants previously sprayed with Ridomil compared to the control and Phosphonic acid treatments (Table 9). This suggests that Ridomil residues persist at levels that continue to protect tubers after harvest and has important implications for the control of Pink rot in storage.

Table 9. Percentage, weight and number of healthy and infected tubers.

Treatment	Weight of healthy tubers g / pot	No. healthy tubers	% Infected with Pink rot	% Weight of Pink rot tubers
Zoospores Control	39.3 b	1.6 c	75a	63.4
Zoospores Phosphonic acid	67.9 b	4.6 b	64a	38.9
Zoospores Ridomil	69.1 b	3.4 bc	18b	52.7
Control	237.5 a	114.4 a	0*	0*
Phosphonic acid	213.1 a	10.4 a	0*	0*
Ridomil Gold MZ	212.5 a	10.0 a	0*	0*

treatments with the same letter are not significantly different from one another.

ns

* not included in analysis

Seed tubers inoculated with zoospores become infected with Pink rot resulting in a significant reduction in tuber weight and number (Table 9). Tubers from parent plants treated with

Ridomil and Phosphonic acid were not significantly different from the control, except where the Phosphonic acid treated plants produced more tubers than the control.

(f) Field experiments

A total of 12 field experiments were set up to evaluate various fungicide and biofumigant treatments for the control of Pink rot. In all field studies the application of fungicides, disease assessment and analysis was undertaken as described previously.

Field experiments were established at Lenswood Horticultural Research Centre approximately 30km east of Adelaide others were conducted on commercial potato grower's properties at Woodside approximately 50km east of Adelaide, Kalangadoo and Mount Gambier approximately 400km south east of Adelaide.

Experiment 1: Lenswood 1997-98

Materials and Methods

Whole seed potatoes, cv. Red la Soda were planted on the 4th December 1997 at 30cm spacing into single raised bed plots 2.5m long and separated 80cm apart. Seven replicates of each treatment were established in a randomised block design. Disease inoculum similar to that used in the pot experiments was placed around each seed at planting (0.5g/seed). Treatments consisted of 20kg/ha Ridomil granules applied around the tubers at planting or spray applications of either 6 or 12L/ha Foli-R-Fos 200, 5kg/ha Ridomil Gold MZ or 4kg/ha Dithane M45. Sprays were applied on three occasions, the first around tuber initiation at 40 days after planting, with two further applications at 14 day intervals. Plants were watered with overhead spray irrigation every 4-6 days. Tubers were harvested and assessed 139 days after planting.

Results

No uninoculated control was included in this experiment, nevertheless a significant increase in yield compared to the inoculated control was achieved in the treatments where Ridomil granules were applied at planting. None of the other treatments significantly improved the yield of healthy tubers. The Dithane M45 treatment produced significantly less yield than the control (Table 10). This was also reflected in the number of tubers with Pink rot, as nearly 7% were found in the Dithane M45 treatment compared to 5.3% in the inoculated control. The fewest Pink rot tubers (0.7 and 2.4%) occurred in the areas treated with Ridomil granules and Ridomil Gold MZ respectively, both significantly less than the level found in both the Dithane M45 and the higher rate of Foli-R-Fos. However, the variation in the incidence of Pink rot in each plot prevented the differences between the control and the Ridomil treatments from having statistical significance.

Table 10. Effect of fungicides on the development of Pink rot in Red la Soda potatoes planted in field soil artificially inoculated with *P. erythroseptica*, Lenswood 1997/98.

Fungicide treatment rate of product ha	Healthy Tubers kg / plot	% Weight of tubers with Pink rot #
Dithane M45 - 4kg ^A	5.5 c*	6.6 ab
Foli-R-Fos 200 - 6L ^A	6.8 bc	2.6 abc
Foli-R-Fos 200 - 12L ^A	7.0 bc	6.2 a
Ridomil Gold MZ- 5kg ^A	9.1 ab	2.4 bc
Ridomil granules - 20kg ^B	11.2 a	0.7 c
Control	8.4 b	5.3 abc
LSD (P=0.05)	2.5	#

*treatment means with the same letter are not significantly different from one another

data was analysed after natural log transformation to provide normality of data and analysed by standard ANOVA. Raw data means are shown so no LSD is included

A = foliar sprays applied 40, 54 and 68 days after planting

B = soil treatments applied at planting

Experiment 2: Kalangadoo 1997-98

Materials and Methods

This experiment was sited in a commercial potato crop, cv. Russet Burbank, and planted on the 27th October 1997 with a row spacing of 85cm and seed spacing of 28cm. The field had been planted to potatoes 6 years previously with pasture and cereal crops grown in the interim. Overhead irrigation was applied via a centre pivot delivering approximately 15mm every 2 to 3 days. After the plants had emerged, plots consisting of 4 rows 10m long were marked out with 6 replications of each treatment arranged in a randomised block design. Sprays of 2.5 or 5kg/ha Ridomil Gold MZ, 6L/ha Foli-R-Fos 200 or 4kg/ha Dithane M45 were applied at 10-20mm tuber size 52 days after planting and then at a further 18 days and 28 days later. Additional treatments of Foli-R-Fos 200 were included to determine if the time of application influenced the efficacy of the treatment; 6L/ha Foli-R-Fos 200 applied later at 70, 80 and 94 days after planting and a higher rate of 12L/ha Foli-R-Fos 200 applied on only one occasion at 52 days after planting. An untreated control treatment was also included. Tubers were harvested 133 days after planting by hand digging a 3m long section in each of the centre two rows of each plot.

Results

The highest level of Pink rot developed in the control treatment, where 6% of the tubers were infected (Table 11). Slightly less Pink rot developed in plots sprayed with Foli-R-Fos 200 or Dithane M45 but only the Ridomil Gold MZ treatments significantly reduced the incidence of disease compared to the untreated plots.

The yield of healthy tubers varied between 1.9 and 2.2kg per plant with no significant differences detected between treatments (Table 11).

Table 11. Effect of fungicides applied to the foliage on the incidence of Pink rot and the yield of Russet Burbank potatoes grown in naturally infected field soil, Kalangadoo 1997/98.

Fungicide Treatment rate of product/ha	Healthy tubers kg / plant	% Weight of Tubers with Pink rot #
Dithane M45 - 4kg ^A	2.2	3.6 a*
Foli-R-Fos 200 - 6L ^A	2.1	4.0 a
Foli-R-Fos 200 - 6L ^B	1.9	3.2 a
Foli-R-Fos 200 - 12L ^C	2.1	2.0 ab
Ridomil Gold MZ - 2.5kg ^A	2.2	0.6 bc
Ridomil Gold MZ - 5kg ^A	2.2	0.3 c
Control	1.9	5.6 a
LSD (P=0.05)	n.s.	#

data was analysed after natural log transformation to provide normality of data and analysed by standard ANOVA. Raw data means are shown, so no LSD is included

* treatment means with the same letter are not significantly different from one another

n.s. there are no significant differences between treatments

A = applied 52, 70 and 80 days after planting

B = applied 70, 80 and 94 days after planting

C = applied 52 days after planting

Experiment 3: Woodside 1998-99

Materials and Methods

Red la Soda tubers were planted on the 27th October 1998 with a row spacing of 80cm and seed spacing of 40cm. Single row plots, 5m long with 8 replications of each treatment were established in 2 rows with 2 buffer rows separating treatment rows. Treatments applied were 2.5kg/ha Ridomil Gold MZ, 12L/ha Foli-R-Fos 200, 4L/ha Shirian or 2kg/ha Acrobat MZ. Untreated control plots were also included for comparison. Sprays were applied 41 days after planting when tubers were 10-20mm diameter and again 16 days later. Tubers were dug by hand 99 days after planting from a 3m long section of each plot.

Results

Pink rot developed in all plots on this site, with 9.2% found in the untreated plots. Although the weight of tubers with Pink rot was the lowest in the Ridomil Gold MZ treatment (1.9%), the variation between plots was so great that no significant difference was detected between that treatment and others (Table 12). Yields were not significantly different between treatments except for that of the Ridomil Gold MZ treatment, which yielded the highest at 4.8kg per plot.

Table 12. Effect of fungicides on the incidence of Pink rot and the yield of Red la Soda potatoes grown in naturally infected field soil, Woodside 1998/99 (Expt. 3), Lenswood 1998/99 (Expt. 4).

Fungicide treatment - rate of product ha	Healthy tubers kg / plot		% Weight of tubers with Pink rot	
	Expt 3 ^A	Expt 4 ^B	Expt 3 ^A	Expt 4 ^B
Acrobat MZ - 2kg	3.4 b*	5.2 b	7.7	13.5 ab
Shirlan - 4L	3 b*	4.9 bc	11.2	11.4 ab
Ridomil Gold MZ - 2.5kg	4.8 a	5.3 b	1.9	4.5 bc
Ridomil Gold granules - 20kg ^C	na	7.4 a	na	0 c
Foli-R-Fos 200 - 12L ^A	3.0 b	na	10.6	na
Control	3.2 b	3.6 c	9.2	21.1 a
LSD (P=0.05)	1.2	1.6	n.s.	10.1

* treatment means with the same letter are not significantly different from one another

n.s. there are no significant differences between the treatments

na this treatments was not applied

A = foliar sprays applied 41 and 56 days after planting

B = foliar sprays applied 39 and 55 days after planting

C = applied to the soil at planting

Experiment 4: Lenswood 1998-99

Materials and Methods

Red la Soda tubers were planted on 29th October 1998 with a row spacing of 80cm and seed spacing of 40cm. Plots consisted of 4 rows each 4m long with 8 replicates per treatment arranged in a randomised block design. Sprays of 2.5kg/ha Ridomil Gold MZ, 4L/ha Shirlan or 2kg/ha Acrobat MZ were applied 39 days after planting and again 16 days later. Ridomil Gold granules at 20kg/ha were applied to the furrow at planting. At 119 days after planting, tubers were harvested by hand from 2m long sections of the centre two rows in each plot.

Results

In this experiment Pink rot developed in 21% of tubers in the untreated plots. All treatments reduced the level of disease, however only the Ridomil treatments significantly reduced the level of disease compared to the untreated plots (Table 12). No disease was found in the plots treated with the granular formulation of Ridomil Gold. This was reflected in the yield of healthy tubers, with 7.4kg/plot in the Ridomil granule treatment significantly greater than that of other treatments.

Experiments 5 and 6: Kalangadoo 1998-99

Materials and Methods

Field experiment 5 was planted to Russet Burbank in a dark loamy clay soil on the 26th October 1998. Experiment 6 was planted to Kennebec in a lighter, clay loam soil 5 days later. In both plantings rows were spaced 85cm apart and seed pieces 28cm apart. The field was last planted to potatoes 6 years previously and used for pasture and cereal crops in the interim. Overhead irrigation was applied via a centre pivot delivering approximately 15mm every 2 to 3 days. Treatment plots consisting of 4 rows each 10m long were marked out

within the field with 6 replications of each treatment set up in a randomised block design. Sprays of 1.25 or 2.5kg/ha Ridomil Gold MZ, 12L/ha Foli-R-Fos 200, 4L/ha Shirlan or 2kg/ha Acrobat MZ were applied at 10-20mm tuber size, 44 (Expt 5) and 39 days (Expt 6) after planting, and again 12 days later. An additional Foli-R-Fos 200 spray was applied after a further 15 days. The plots were harvested 136 (Expt 5) and 131 days (Expt 6) after planting by hand digging a 3m long section of each of the centre two rows in each plot. Potato tubers were assessed and weighed as previously described. The harvest data in one replicate from experiment 6 was omitted from the final analysis, as severe waterlogging had occurred in those rows.

Results

In experiment 5 the incidence of Pink rot was extremely variable between plots. Although no significant difference was detected between treatments, the highest incidence (11.1%) was found in the control and the lowest incidence (1.8%) and (0.9%) was observed in the Ridomil Gold MZ treatments at 1.25 and 2.5kg/ha respectively (Table 13). Yield differences were not significantly different although the lowest yield was found in the untreated control treatment.

In experiment 6, 9.6% of tubers developed Pink rot in the untreated plots. The Foli-R-Fos 200 treatment had little effect on the incidence of Pink rot, but all other treatments significantly reduced the level of disease (Table 13). Again, Ridomil was the most effective fungicide, with 2.1% and 0.3% Pink rot in the Ridomil Gold MZ treatments at 1.25 and 2.5kg/ha respectively. This was also reflected in the yield, as the weight of healthy tubers was highest in the Ridomil treatments.

Table 13. Effect of fungicides applied to the foliage on the incidence of Pink rot and the yield of Russet Burbank and Kennebec potatoes grown in naturally infected field soil, Kalangadoo 1998/99.

Fungicide treatment rate of product ha	Healthy tuber yield		% Weight of tubers with Pink rot	
	kg plot			
	Expt 5 ^A	Expt 6 ^B	Expt 5 ^A	Expt 6 ^B
Acrobat MZ - 2kg	30.6	25.4 bcd*	3.2	5.2 bc
Shirlan - 4L	27.8	27.7 abc	4.7	3.1 cd
Ridomil Gold MZ - 1.25kg	29.7	29.6 ab	1.8	2.1 cd
Ridomil Gold MZ - 2.5kg	29.2	31.1 a	0.9	0.3 d
Foli-R-Fos 200 - 12L ^C	29.4	23.1 cd	3.1	8.3 ab
Control	24.7	22.3 d	11.1	9.6 a
LSD (P=0.05)	n.s.	4.97	n.s.	4.17

* treatment means with the same letter are not significantly different from one another

n.s. there are no significant differences between the treatments

A = foliar sprays applied 44 and 56 days after planting

B = foliar sprays applied 39 and 51 days after planting

C = A third spray applied 71 (Exp 5) and 66 (Exp 6) days after planting

Experiments 7, 8 and 9: Kalangadoo and Mount Gambier 1999-00

Materials and Methods

Experiments 7 and 8 were planted to Shepody and Russet Burbank on the 14th and 15th October 1999 respectively with a row spacing of 85cm. Experiment 9 was to Pontiac on 16th November at 80cm row spacing. Treatment plots consisted of 4 rows each 10m long with 8 replications in a randomised block design. The treatments are shown in Table 14 including application rates and time of application.

Results

All these trials were harvested and tubers examined for Pink rot. However little disease developed in all three trials (0.3%, 0.2% and 0% Pink rot in control plots) and as a result the effect of the treatments could not be assessed.

Table 14. Treatments and application times for experiments 7-9.

Treatments	Rate	Time of Application
Ridomil Gold 480 EC	1.04kg	Planting
Ridomil Gold 480 EC + Ridomil Gold MZ x 1	1.04kg + 2.5kg	Planting + 42 days
Ridomil Gold 480 EC + Ridomil Gold MZ x 2	1.04kg + 2.5kg	Planting + 42 days + 56 days
Ridomil Gold MZ x 1	2.5kg	42 days
Ridomil Gold MZ x 2	2.5kg	42 days + 56 days
Mustard Meal	1T	Planting
Mustard Meal	3T	Planting

Experiment 10: Lenswood 1999-00

Materials and Methods

Coliban tubers were planted on 13th December 1999 with a row spacing of 80cm. Eight replicates of each treatment were established in 4 rows each 5m long in a randomised block design. The treatments in this experiment were exactly the same as in experiments 7-9 however Ridomil Gold MZ was applied at 43 days after planting and again 14 days later. At 147 days after planting the tubers were harvested by hand from 2m sections of the centre two rows in each plot. The treatments are shown in Table 15.

Table 15. Treatments and application times for experiment 10.

Treatments	Rate	Time of Application
Ridomil Gold 480 EC	1.04kg	Planting
Ridomil Gold 480 EC	0.52 kg	Planting
Ridomil Gold Granules	20 kg	Planting
Ridomil Gold Granules	10 kg	Planting
Ridomil Gold 480 EC + Ridomil Gold MZ x 1	1.04kg + 2.5kg	Planting + 42 days
Ridomil Gold 480 EC + Ridomil Gold MZ x 2	1.04kg + 2.5kg	Planting + 43 days + 57 days
Ridomil Gold MZ x 1	2.5kg	43 days
Ridomil Gold MZ x 2	2.5kg	43 days + 57 days
Mustard Meal	1T	Planting
Mustard Meal	3T	Planting
Shirlan	4L	Planting

Results

Pink rot developed in tubers in all plots with 6% found in the untreated plots (Table 16). Both the mustard meal treatments and the one foliar application of Ridomil Gold MZ were the least effective treatments with levels of Pink rot similar to or greater than that of the control. There was also no significant difference with the Shirlan treatment to the control. The most effective treatments were the Ridomil 480 EC (1.04kg) drench, Ridomil Gold granules (20kg) and the Ridomil 480 EC (1.04kg) drench treatment plus Ridomil Gold MZ (2.5kg) foliar application. No significant difference was detected between these treatments. The effect of these treatments was also reflected in the yield as they also produced the highest number of healthy tubers per m².

Table 16. Effect of fungicides on the development of Pink rot in Coliban potatoes planted in soil known to be infected with *P. erythroseptica*, Lenswood 1999/00.

Fungicide treatment rate of product ha	Healthy Tubers kg m ² #	% Weight of tubers with Pink rot #
Ridomil Gold Granules – 20kg ^A	3.9	2.2 c
Ridomil Gold Granules – 10kg ^A	3.7	3.2 bc
Ridomil Gold 480 EC – 1.04kg ^A	3.9	1.0 c
Ridomil Gold 480 EC – 0.52kg ^A	3.3	3.3 abc
Shirlan – 4L ^A	3.7	5.7 ab
Ridomil Gold 480 EC – 1.04kg ^A + Ridomil Gold MZ – 2.5kg ^B	3.9	2.0 c
Ridomil Gold 480 EC – 1.04kg ^A + Ridomil Gold MZ – 2.5kg ^C	3.7	3.1 abc
Ridomil Gold MZ – 2.5kg ^B	3.2	6.5 a
Ridomil Gold MZ – 2.5kg ^C	3.5	3.3 abc
Mustard Meal – 1T ^A	3.2	7.8 a
Mustard Meal – 3T ^A	3.3	6.5 a
Control	3.3	6.0 ab

*treatment means with the same letter are not significantly different from one another

data was analysed log transformation to provide normality of data and analysed by standard ANOVA. Raw data means are shown so no LSD is included

A = soil treatments applied at planting

B = foliar sprays applied 43 days after planting

C = foliar sprays applied at 43 and 56 days after planting

Experiments 11 and 12: Kalangadoo 2000-01

Materials and Methods

Ranger Russet tubers were planted on 15th November 2000 with a row spacing of 80cm. Two replicates of each treatment were established in 4 rows 10m long. In furrow treatments of Ridomil Gold 480 EC at 1.04kg/ha and 0.52kg/ha and Ridomil Gold granules at 10kg/ha and 20kg/ha. At 115 and 125 days after planting tubers were harvested by hand from the control plots to determine if there was any disease.

Results

Less than 1% of tubers in the control plots developed Pink rot and as a result treatment effects could not be determined.

Experiment 13: Lenswood 2000-01

Materials and Methods

Coliban tubers were planted on 15th December 2000 with a row spacing of 80cm. Six replicates of each treatment were established in 4 rows each 3.6m long in a randomised block design. In furrow treatments of 0.52kg and 1.04kg/ha Ridomil Gold 480 EC were applied at planting. Ridomil Gold Granules at 10kg/ha and 20kg/ha were also applied at planting. Tubers were harvested at 137 days and assessed for Pink rot.

Results

As less than 1% of tubers in the control plots developed Pink rot treatment effects could not be determined.

Discussion

All formulations of Mefenoxam and Metalaxyl consistently controlled Pink rot in experiments where potatoes were planted in soil inoculated with *P. erythroseptica* and in naturally infected field soil.

These results are consistent with other reports on the efficacy of Metalaxyl for the control of Pink rot (Mulrooney, 1983; Johnson and Duniway, 1997; Torres *et al*, 1985 and Zink, 1995). Although no comparisons were made in the efficacy of Mefenoxam and Metalaxyl, the former is likely to be most effective when applied to the foliage and soil and leached into the root zone as the solubility of Mefenoxam in water is 26g/L compared to around 8g/L for metalaxyl (Anon, 1997). This increased solubility may enable lower rates of Mefenoxam to be used. For example, we were unable to demonstrate any significant increase in Pink rot or reduced yields when applications of Ridomil Gold MZ were reduced from 2.5 to 1.25kg/ha. Further experiments with different rates of Mefenoxam are warranted as the increased solubility of this formulation may require more frequent applications, particularly if regular irrigation leaches the Mefenoxam from the root zone of the potato, or the chemical is applied by chemigation (Zink, 1995).

Comparisons of Ridomil applied as granules at planting and Ridomil Gold as a foliar spray at tuber initiation showed no significant difference in the incidence of Pink rot in the field experiments. However, in all but one plot in one field experiment, the granular formulation controlled Pink rot completely, whereas Pink rot developed in at least 1 plot in each trial where Ridomil Gold was applied as a spray. Although we made no direct comparison of the spray application of Ridomil Gold at the 1.25kg/ha rate with the 20kg/ha granular rate of either formulation, our results suggest that 2 sprays at that rate should be just as effective as the granular application at planting. At the present costing of around AUS\$34.60/kg for Ridomil Gold MZ and \$16.50/kg for the Ridomil Gold granules, 2 sprays each at 1.25kg/ha costs around AUS\$86/ha compared to AUS\$330/ha for the granule treatment.

In the field experiments, tubers were planted in naturally infected soil and between 5% to 21% of tubers developed Pink rot symptoms. In many of these experiments the incidence of tubers infected with Pink rot may have been greater than that evident at harvest. Examination of tubers outside of the trial areas frequently showed that many tubers infected with *P.*

erythroseptica also showed symptoms of soft rot, and these tubers often rotted completely before harvest. Bacterial breakdown of tubers infected with *P. erythroseptica* has also been reported by Sturdy and Cole (1974). Nevertheless, yield increases of 6 to 17 tonnes/ha of healthy tubers were recorded in these field trials following the application of Ridomil either as a spray or granules. In these situations the treatment costs are more than justified by the economic return. However further fine tuning of spraying rates and spray timing in relation to tuber development and irrigation timing may provide further savings in treatment costs. Mancozeb was applied as a foliar spray in several experiments and at rates that were higher than that occurring in the formulations of Ridomil Gold MZ or Acrobat MZ. In these experiments the incidence of Pink rot in the Mancozeb treatments was similar to that in the control treatments which suggests that the Mancozeb component of these fungicides had little influence on the control of Pink rot.

In Australia phosphonic acid is registered for the control of *Phytophthora* related diseases of many crops and because of its systemic activity potato growers have applied foliar sprays of phosphonic acid in an attempt to control Pink rot. We evaluated different rates and spray timing of Foli-R-Fos 200 in both pot and field experiments and found highly variable results between these experiments. In all experiments the control with Foli-R-Fos 200 was not as great as that achieved with Ridomil granules. In other experiments two or three applications of Foli-R-Fos 200 at the high rate of 12L/ha had little effect on reducing the incidence of Pink rot. The reasons for the poor control of Pink rot are unclear as phosphonic acid is a very effective fungicide in controlling several root diseases caused by other species of *Phytophthora* (Wicks *et al.*, 1990). However variable control of *P. infestans* has also been reported with the phosphonate fosetyl-Al (Basham *et al.*, 1990) and this may be related to the phosphate content of the host plant. On the other hand Cooke and Little (1996) reported that foliar sprays of phosphonic acid reduced tuber infection by *P. infestans*. In any case, our variable results and the conflicting reports on the efficacy of the phosphonates on potatoes suggest that phosphonic acid should not be relied upon for the control of Pink rot.

Other fungicides, such as Acrobat MZ and Shirlan, had a slight effect on reducing the incidence of Pink rot in both pot and fields experiments but at the rates tested they could not be considered as alternatives to Ridomil.

Dimethomorph is active against oomycete fungal pathogens (Cohen *et al.*, 1995), and in recent experiments Dimethomorph at 1 ppm or less inhibited the mycelial growth and sporulation of several isolates of *P. erythroseptica* (Charoenwet, 1998). This suggests that further evaluation of Dimethomorph is warranted, although the solubility of the present formulation may limit its use as a soil applied fungicide.

Although *P. erythroseptica* was shown to be sensitive to volatiles released from mustard meal in laboratory experiments, the use of meal applied at either 1 or 3T/ha at planting had little effect on the incidence of Pink rot at harvest. In the one field experiment the level of Pink rot in the untreated control plots was similar to that in both of the meal treatments. Even if higher rates of meal were effective in controlling Pink rot it is unlikely that the higher rates would be as cost effective as a Ridomil treatment. However further work needs to be done to evaluate non chemical and biological means of controlling Pink rot.

TECHNOLOGY TRANSFER

The results of this project have been presented to growers on 7 occasions in South Australia, Victoria and Tasmania. Numerous extension and scientific articles have also been produced.

Oral presentations

(1) June 1997 - SAFRIES Annual Growers Meeting, Penola.

T. J. Wicks: 'Pink rot – The Scourge of the South East'.

(2) March 1998 - South East Potato Growers Association, Penola.

T. J. Wicks: 'Pink rot– Research Progress'.

(3) June 1998 - South East Potato Growers Association, Penola.

C. W. Davoren: 'Pink rot Control – Research Progress'.

(4) August 1999 - South East Potato Growers Association, Penola.

E. A. Oxspring: 'Pink rot Control – Research Progress'.

(5) August 2000 - Potatoes 2000 Conference, Adelaide.

E. A. Oxspring: 'Pink rot Control – Research Progress'.

(6) August, 2000 - Potato Growers Seminar, Victoria.

E. A. Oxspring: 'Pink rot Control – Research Progress'.

(7) November, 2000 – Key note speaker for DPIWE and TIAR, Burnie, Tasmania.

E. A. Oxspring: 'Studies on Pink rot – Research Progress'.

Interviews

(1) ABC Radio – August 1999, Penola.

(2) The Advocate Newspaper, Tasmania – Articles in newspapers 22nd and 29th November 2000.

Extension articles

- Spud Speak, Spring 1998. Control of Pink rot. T. J. Wicks and C. W. Davoren.
- Potato Australia, September 1999. Pink rot Control. E. A. Oxspring.
- Potato Australia, September 2000. Pink rot Control. E. A. Oxspring.
- Growers Newsletter, Victoria, August 2000. Studies on Pink rot. E. A. Oxspring.
- Tas - Regions, Tasmania, March 2001. Studies on Pink rot. E. A. Oxspring.

Research Articles

- Wicks, T. J., Davoren, C. W. and Hall, B. (1999). Detection of *Phytophthora erythroseptica* in Field Soil. Proceedings of the First Australasian Soil Borne Disease Symposium, Queensland, p65.
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RECOMMENDATIONS

- Studies continue to evaluate methods of detecting *P. erythroseptica* in soil eg. using molecular probes
- The survival of *P. erythroseptica* in soil and the potential of weeds as hosts be investigated
- Further studies be undertaken to evaluate new fungicides as alternatives to Ridomil for control
- The potential of biocontrol agents be investigated
- Studies continue to evaluate “in furrow” application of Ridomil at planting
- Monitoring be carried out to determine if Ridomil resistant strains of *P. erythroseptica* have developed in Australia

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SARDI

Location

Waite Research Precinct
Hartley Grove
Urrbrae SA 5064

Correspondence
GPO Box 397
Adelaide SA 5001

Telephone
08-8303 9400

Facsimile
08-8303 9309

SARDI



SOUTH AUSTRALIAN
RESEARCH AND
DEVELOPMENT
INSTITUTE