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New Chemical Treatments for Fungal Diseases of Seed Potatoes

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Horticulture Australia

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Final Report
Horticulture Australia Project PT97015

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Horticulture Australia Project PT97015 – New chemical treatments for fungal diseases of seed potatoes

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Purpose of project

The purpose of this project was to evaluate chemical treatments of seed potatoes for the control of diseases passed on from the mother tuber to the daughter tubers in the potato crop. This was to provide potato growers with more options for the control of seed-borne diseases and to better inform them of the most appropriate and effective use of chemical treatments for disease management on their farms.

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1 Media Summary

This project has provided valuable information that will help seed potato growers make informed decisions about the used of seed treatments on their farms. A series of field trials were conducted over four seasons to compare the effects of fungicide treatments of seed potatoes prior to, or at the time of planting, on the carry-over of seed-borne diseases into the crop and to identify new fungicide treatments. Trials were planted in fields with a history of potato production ('old' ground; volcanic clay loam) and in fields where potatoes had not been grown previously ('new' ground; acid sandy loam). The trials showed that

- black scurf and silver scurf were the most common diseases in the crops grown in new ground, whereas black dot, black scurf and silver scurf were the most common diseases in the crops in old ground;
- infected seed potatoes contributed significantly to disease spread to the progeny in crops on new ground, but less so in old ground;
- when planting infected seed potatoes, the seed tubers were a significant source of spread of black scurf and silver scurf to the progeny, whereas soil tended to be the major source of black dot, powdery scab and common scab in the progeny tubers;
- in new ground, seed treatments with fungicides was very effective in preventing disease spread to progeny;
- the benefits of using seed treatments on seed planted in old ground were variable and unpredictable because background levels of pathogens in soil masked the treatment effects;
- two fungicides for Rhizoctonia control were consistently reliable at all trial sites, another was less effective in the acid sandy loam (new ground) than in the volcanic loam (old ground); and a fourth was ineffective in reducing seed-borne Rhizoctonia in all trials;
- two new fungicides incorporated into soil prior to planting effectively controlled soil-borne Rhizoctonia and powdery scab, respectively.

The results show that growers are advised to conduct their own comparative trials to determine which treatments are the most effective on their farms, especially if they are growing seed in old ground.

A major outcome of this project for the potato industry is that a number of disinfectant chemicals have been identified as potential replacements for formaldehyde, a harmful chemical used by seed growers as a post-harvest seed treatment.

2 Technical Summary

A series of field trials were conducted over four seasons to compare the effects of fungicide treatments of seed potatoes prior to, or at the time of planting, on the carry-over of seed-borne diseases. Trials were planted in fields with a history of potato production ('old' ground; volcanic clay loam) and in fields in which potatoes had not previously been grown ('new' ground; acid sandy loam). The trials showed that, when planting infected seed potatoes, the seed tubers were a significant source of black scurf and silver scurf in the progeny, whereas soil tended to be the major source of black dot, powdery scab and common scab in the crop. Seed treatments had the greatest impact on the carry-over of black scurf and silver scurf

Rhizoctonia canker and black scurf were the main target of four fungicide seed tuber treatments tested. The results of field trials on 'old' ground showed varying and unpredictable levels of control of the diseases with these treatments. In one trial, for example, treatment of cv. Russet Burbank seed tubers with fludioxonil (Maxim® 100 FS), pencycuron (Monceren® 250 FS) and tolclofos-methyl (Rizolex® 100 D) reduced the incidence of plants with cankers by 69% cf. controls (53% plants affected) and the incidence of tubers with black scurf by 55% cf. controls (69% tubers affected). Similar effects were not recorded with cv. Sebago. A 40% incidence of black scurf in the progeny of untreated, disease-free, minitubers, indicated the presence of soil inoculum of *R. solani*. In experiments in new ground, a very low incidence of black scurf in minituber progeny each year indicated very low levels of soil inoculum of *R. solani*. In these trials, fludioxonil and pencycuron seed treatments reduced the incidence of black scurf by 90-98% cf. controls. Tolclofos-methyl had no effect in these soils and iprodione (Rovral® Liquid Fungicide) was ineffective in all trials on the two soil types. Overall, results showed that seed treatments were more useful on potatoes grown in 'new' rather than 'old' ground. Fludioxonil treatments also caused reductions in the incidence of silver scurf in the progeny of 50-80%.

A new fungicide, azoxystrobin (Amistar®), applied as a soil treatment, reduced the incidence of progeny tubers by 76% compared with the untreated control. A second soil treatment (fluazinam; Shirlan®) reduced the incidence of powdery scab in progeny tubers by 83% of the untreated control.

Glasshouse trials did not provide conclusive data on the efficacy of chemical treatments for the control of seed-borne powdery scab. Although disease developed in the progeny tubers, disease incidence was too low and variable between replicate treatments to differentiate treatment effects. One trial showed that apparently 'clean' seed potatoes selected from a batch of 'scabby' potatoes was as infective to the progeny tubers as seed tubers with scab pustules. One of the fungicides tested, flusulfamide (Nebijin®), has recently been registered as pre-plant treatment for the control of seed-borne powdery scab in New Zealand.

Laboratory trials identified a number of disinfectant chemicals that could be used as alternative seed treatments to formaldehyde. By using powdery scab cystosori and seed tubers affected with Rhizoctonia black scurf as models, the tests showed that, for a two-minute seed dip, many of these chemicals were effective but only if used at five times the rate recommended for inorganic surfaces. The peroxygen group of chemicals was the most promising because they were effective against a range of pathogens, and were relatively safe for humans, the environment and potato sprouts.

3 Technical Report - New Chemical Treatments for Fungal Diseases of Seed Potatoes

3.1 Introduction

The trend towards washed fresh market potatoes and towards growing potatoes in new ground has highlighted the issue of skin diseases on seed potatoes. These trends have put considerable pressure on seed potato growers to improve seed quality. Furthermore, seed growers in Australia are confronted with some of the most stringent tolerances for fungal diseases on seed potato tubers in the world (98% disease free for powdery and common scab). Despite these low tolerances, growers are still concerned about the risk of disease carry-over from seed to progeny. Seed tubers can also carry contaminants on the tuber skin in the form of soil and fungal spores. Seed tuber treatments, therefore, must are an integral part of a disease management program in potatoes.

This project aimed to evaluate new chemical treatments for seed potatoes, compare different treatments for their relative efficacy at sites with different disease pressures and evaluate potential replacements for formaldehyde, which has traditionally been used by seed growers as a post-harvest seed treatment. The project also aimed to evaluate chemical treatments for the control of seed-borne powdery scab for which there are no registered fungicides at present.

3.2 Evaluating chemical seed treatments in the field

3.2.1 Introduction

A series of field trials were conducted over four seasons to compare the effects of various seed treatments on the carry-over of disease from mother tubers to daughter tubers. Trials included fungicide seed treatments (registered and unregistered), disinfectant treatments of seed and soil treatments.

The trials were conducted in two different cropping areas, namely a traditional production area with a history of potato production (‘old’ ground) and an area where crops were planted in paddocks that had not grown potatoes before (‘new’ ground). Populations of the various potato pathogens were expected to be high and low, respectively, in the two different areas.

Untreated minitubers from tissue cultured, potato plantlets grown in the glasshouse were planted in all trials as ‘disease-free’ controls to gauge background levels of soil inoculum. Soil treatments were applied in some trials to control soil-borne inoculum as a means of measuring disease caused by soil-borne inoculum. Treatments were applied just before or at the time of planting. *Rhizoctonia solani*, causing stem and stolon canker, and black scurf, were a major focus of the field trials because the disease is common and widespread and most available fungicides are targeted at this pathogen.

3.2.2 Materials and Methods

Field trial sites, site history and preparation

Old ground – Ballarat, Central Highlands Victoria

Trials were conducted over four seasons (spring 97 to autumn 2001) at sites on old ground located 20 km north east of Ballarat. Potato cropping in this area is dedicated mainly to the production of seed or processing potatoes (French fries). Trial plots were within a commercial potato crop in paddocks that were generally cropped with potatoes once every 5 years. Potatoes were always sown after a pasture phase of at least three years duration. Soil type is a red, volcanic loam to a depth of 15 to 20 cm over clay (pH of 5.2).

Seedbed preparation was as per normal commercial practice for seed and processing crops in this area. Generally, a pasture paddock was sprayed with the herbicide glyphosate and ploughed-in during late winter. Follow-up cultivation leading up to planting time in late spring included consecutive workings with an agro-plough for sub-surface cultivation, a scarifier and a rotary hoe. Crop nutrition was as per normal commercial practice for Russet Burbank crops grown for processing.

Old ground – Yeodene, South West Victoria

A trial was established to specifically evaluate the effects of seed treatments on common scab. The trial was located at a site near Yeodene, 10 kilometres south east of Colac in the 1999/2000 season. Trial plots were within a commercial potato crop in a circular 50 ha paddock irrigated with a centre-pivot irrigation system. The paddock had been cropped to potatoes the previous year (1998/1999) and five years prior to that. The paddock was in pasture during the intervening period. The 1998/99 potato crop in this field was severely affected with common scab. Soil type is a grey, sandy loam to a depth of 15 to 20 cm over clay with a pH of 5.69.

Seedbed preparation included deep ripping of the site with an agro-plough one month before sowing, broadcasting fertiliser a week later followed by a pass with rotary hoe. The site was rotary hoed again one week prior to sowing potatoes.

New ground – Colac, South West Victoria

Trials were conducted over four seasons (spring 1997to autumn 2001) at sites located 20 kilometres south east of Colac. Potato cropping in this area is dedicated mainly to the production of seed or processing potatoes (French fries and crisps). Trial plots were located immediately adjacent to, or within, a commercial potato crop in paddocks that had no previous history of potato production (‘new’ ground). These paddocks had been in pasture for approximately 40 years. The trend for potato producers in this area, especially for seed potato growers, is to lease permanent pasture paddocks from dairy farmers and to grow only one crop at each location. Most of these sites were originally considered marginal for potato production but high yielding potato crops can now be grown with the use of modern varieties, machinery, fertilisers and irrigation. Soil type is a grey, sandy loam to a depth of 15 to 20 cm over clay with a pH of 5.6.

Seed-bed preparation usually involved the ploughing-in of pasture with a single pass of a rotary hoe in early spring followed by deep ripping (30-40 cm) a few weeks prior to planting.

Cement ash lime and fertiliser were broadcast and incorporated into soil with a rotary hoe to a depth of 15 cm approximately one week prior to planting.

Experimental treatments and design, planting and crop maintenance

Seed tuber treatments included untreated controls, untreated 'disease-free' minitubers and various fungicides, disinfectant chemicals, and in some seasons, soil applied fungicides. Treatments were either sprayed or dusted onto tubers prior to planting or tubers were immersed into chemical solutions (tuber dips). Soil treatments were either applied to the soil surface and cultivated-in or applied into open furrows.

In each trial, whole seed tubers (seed generations G3-G6) (35-100 g) were taken at random from potato bins and counted into nylon mesh bags (42/bag). The number of bags depended on the total number of treatments and replicates. Labels representing seed treatment and replicate block were randomly assigned to each bag and the weight of each bag recorded. The application rate for each treatment was applied according to label recommendations and was based on the average weight of the 5 or 6 replicate tuber lots.

Details of experimental treatments for five field trials conducted in 'old' ground are presented in Table 4, Table 8, Table 12, Table 16 and Table 20. Details of treatments in the four trials in 'new' ground are presented in Table 23, Table 27, Table 31 and Table 35.

Pre-planting tuber treatments

Tuber sprays and dusts: Tubers were removed from their bag, placed in a clean, dry, 9L plastic bucket and sprayed with a fine mist of fungicide solution from a hand-held atomiser whilst the bucket was gently rotated at an angle of 45 degrees to the ground to ensure good coverage. Between 25-50 ml was applied to each tuber lot depending on the average weight of tubers. Each successive replicate was treated in turn in the same bucket. Fungicide dust treatments were gently dusted onto each tuber lot in 46 L plastic bins while the bins were slowly rotated at an angle. Clean, dry buckets or bins were used for each different treatment.

Tuber dips: Each replicate bag of tubers was immersed in chemical solutions (18 L) in 46 L plastic bins and agitated for 2 minutes after which the bags were removed and allowed to drain. Each successive replicate lot was treated in turn in the same solution.

After chemical application, tubers were re-bagged and allowed to air dry in a cool, dark area of the potato shed before planting.

Pre-planting soil treatments

Rovral® Liquid Fungicide (iprodione) was applied to seed tubers in an open furrow with a watering can at the recommended rate based on the average weight of seed tubers in the replicate plots. The rows were then raked over and hilled up by hand. The rates of application of Monceren® 250 FS (pencycuron) to soil was also based of the weight of seed tubers in each plot as per the seed spray rate. Shirlan® (fluazinam) and Amistar® (azoxystrobin) were applied on a per hectare rate. The latter three treatments were sprayed onto soil surface of each plot using a motorised knapsack sprayer and a hand-held boom fitted with four nozzles that covered the width of the two-row plot. After application, each plot was rotary hoed and hills raked up by hand.

All plots were planted by hand. Plots were 2 potato rows wide by 5 m long. Row spacing varied between 81-90 cm depending on the farm. Generally, 42 seed tubers (21/row) were planted in each plot. Tubers were either pushed into previously formed hills by hand, placed in the bottom of open furrows and hilled by hand-raking or closed and hilled up by the discs of a tractor-drawn planting machine. Replicate blocks were separated from each other by 1.5 m long borders that were planted with a red-skin variety to ensure separation of treated tubers from each successive plot at harvest. Headlands (1.5 m long) and two buffer rows on either side of each trial were also planted with the red-skin variety.

Trials were generally planted in early to late December each year and harvested in early to late May. Crop husbandry (fertiliser, weed control, irrigation and insect and foliar disease control) was as per normal commercial practice.

Plant sampling, disease assessments

A sample of 50 seed tubers was washed and assessed for the incidence and severity of skin blemishing diseases prior to planting. The severity of silver scurf, black dot, powdery scab and common scab on each individual tuber was rated on a scale of 0-4, based on the proportion of tuber surface affected. Tubers with no disease, less than 2% of tuber surface affected, 2-10% of tuber surface affected, 10-25% of tuber surface affected, or more than 25% of tuber surface affected were assigned ratings of 0, 1, 2, 3, and 4, respectively. Symptoms of black scurf were rated as no disease (0), trace (1), slight (2) moderate (3), or severe (4) depending on the relative quantity, width and thickness of sclerotia on the tuber surface. The incidence and severity of diseases on seed tubers planted in each of the field trials in old ground are presented in Table 5, Table 9, Table 13, Table 17 and Table 21. Disease levels on seed planted in trials in new ground are presented in Table 24, Table 28, Table 32 and Table 36.

To assess the possible effects of disease and treatments on plant emergence and growth, the number of plants emerged in each plot and the degree of stunting was recorded approximately 6 weeks after planting. (Emergence data is only reported where there were obvious treatment effects).

Plants were assessed for the incidence of Rhizoctonia stem canker approximately six to eight weeks after planting. Six plants (3/row) were systematically removed from each plot and examined for the presence of Rhizoctonia cankers on sprouts and stolons. Severity of stem canker was assessed on the basis of the number of lesions per stem, the severity of lesions and the number of stems affected on each plant. Categories of 0, 1, 2, 3 and 4 were assigned to plants with 0 (no stem canker lesions), less than 25% of stems affected, 25-50% of stems affected, more than 50% stems affected and all stems pruned below ground, respectively. These ratings also took into account damage to the stolon. Disease incidence was recorded as the percentage of affected plants.

After the crop had died down, the number of late-senescing plants with aerial tubers were counted in each plot and recorded as the percentage of malformed plants. These plants remain green after the rest of the crop senesced and are an indication of Rhizoctonia stem damage. Symptoms include stunting, thickened main stems, shortened nodes between leaf axils and aerial tubers in the leaf axils.

Plots were harvested with a two-row mechanical harvester. A random sub-sample of 50 tubers was taken from each plot for disease assessments. The remaining tubers were graded into different size categories (<35g, 35-110g, 110-250g, 250-350g, >350g and malformed tubers) and numbers and weight in each category recorded.

Sub-samples were stored at 4°C in the intervening period between harvest and disease assessment. Disease assessment involved washing soil from each 50-tuber sub-sample and recording the severity of disease symptoms on the tuber skin using the severity rating scales described above. These tubers were also graded into the different size categories and their number and weight recorded. Disease incidence was expressed as the proportion of tubers (%) in each replicate sub-sample with a particular disease symptom.

Experimental Design and Statistical Analysis

All trials were randomised block designs replicated 5 or 6 times. All data were analysed by analysis of variance (ANOVA, Genstat for Windows 5th Edition ™; Lawes Agricultural Trust, Rothamsted Experimental Station).

3.2.3 Results and Discussion

Tables of Results of the different field trials are listed in Table 1. Some of these results are also presented in Figures 1-12.

Table 1 Location of Tables of Results for field trials on the effects of seed treatments on disease and yield in the progeny for each location and season

Location	Year	Tables of results
Old ground		
Ballarat	1997/98	Table 6, Table 7
	1998/99	Table 10, Table 11
	1999/2000	Table 14, Table 15
	2000/2001	Table 18, Table 19
Yeodene	1999/2000	Table 22
New ground		
Colac	1997/98	Table 25,Table 26
	1998/99	Table 29, Table 30
	1999/2000	Table 33, Table 34
	2000/2001	Table 37, Table 38, Table 39

Disease on the progeny of minitubers planted in old and new ground gave an indication of soil-borne inoculum. A consistently high incidence of black dot each season indicated relatively high levels of soil-borne inoculum of *Colletotrichum coccodes* in the old ground trial sites. Black scurf (*Rhizoctonia. solani*) was the next most common disease on minituber progeny followed by silver scurf (*Helminthosporium solani*) and powdery scab (*Spongospora subterranea*). In contrast, relatively few minituber progeny had symptoms of black dot, black scurf, silver scurf and common scab (*Streptomyces scabies*). Powdery scab was not detected in new ground. These comparisons are summarised in Table 3.

Generally, the results of these trials showed that, when planting infected seed potatoes, seed tubers were a significant source of black scurf and silver scurf in the progeny, whereas soil tended to the major source of black dot, powdery scab and common scab in the crop. Although seed tubers may have contributed inoculum of the black dot, powdery scab and common scab pathogens, this inoculum did not appear to contribute to significantly to disease in the crop in that season. Because seed-borne black scurf and silver scurf contributed to disease in the crop, the impact of seed treatments was immediately obvious.

Table 2 A summary of the relative incidence of diseases in the progeny of disease-free minitubers and untreated control tubers planted in field trials in old and new ground

Disease	Old ground – Ballarat		New ground – Colac	
	Disease-free minitubers	Diseased untreated seed	Disease-free minituber	Diseased untreated control
Black dot	+++	+++	0 to trace (+)	+
Black scurf	++	+++	0 to trace	++
Silver scurf	+	++	0 to trace	++
Powdery scab	+	++	0	0
Common scab	-	-	0 to trace	+

Rhizoctonia stem canker and black scurf

Seed-borne *R. solani* (black scurf), which causes Rhizoctonia canker and black scurf in progeny, was the major target of four fungicides evaluated (tolclofos-methyl, pencycuron, fludioxonil and iprodione). Rhizoctonia diseases were evident at all sites each season as stem canker on young plants, as malformed plants after crop senescence and as black scurf (sclerotia) on the skin of progeny tubers. The incidence of malformed plants was generally very low (<20% plants affected) in trials in old ground and occurred infrequently in new ground.

Generally, the effectiveness of these seed treatments in controlling Rhizoctonia canker and black scurf in potatoes varied with fungicide, cultivar, season and location.

The effect of treatments was most noticeable in controlling black scurf in progeny tubers than in controlling the incidence of plants with stem canker. The treatments were generally more effective in controlling black scurf in potatoes planted in new ground than in old ground. This is probably related to higher levels of soil inoculum of *R. solani* in old compared with new ground which was evident as a higher incidence of minituber progeny with black scurf in old compared with new ground (Table 3). The most effective treatments reduced the incidence of progeny with black scurf by 96 to 100% in comparison with the untreated controls (Table 3). In contrast, the most effective treatments in old ground reduced the incidence of black scurf by no more than 64% in comparison with the untreated control.

In old ground, the effectiveness of seed treatments against Rhizoctonia canker and black scurf varied with the treatments, the diseases, cultivars and season. The incidence of plants with stem canker in untreated control treatments varied from 5% to 50% of plants affected and the incidence of progeny tubers with black scurf varied from 30% to 70% of tubers affected from seasons to season. Effective fungicide seed treatments reduced the incidence stem canker and black scurf by no more that about 60% compared with the untreated control treatment (Figure 2, Table 3, Table 10). Overall, seed treatments were more effective in reducing the incidence of the progeny with black scurf than in reducing the incidence of plants with stem canker.

The effect of seed treatment was not consistent between two different cultivars planted in the same trial. In the 97/98 trial at Ballarat, seed treatments reduced incidence of black scurf by 50% of the untreated controls in cv. Sebago (94% tubers affected) (Figure 1, Table 3, Table 6), although only 8% of the seed of this cultivar had visible black scurf at the time of planting. In contrast, the incidence of the progeny of cv. Russet Burbank with black scurf in the same trial was no different in the treated compared with untreated progeny, even though 60% of the seed were affected with the disease. In the 98/99 trial however, seed treatments significantly reduced the incidence of plants with stem canker and progeny with black scurf in cv Russet Burbank, but had no significant effect on either disease in cv. Sebago (Figure 2, Figure 3, Table 3, Table 10). These differences did not appear to be related to differences in inoculum on the seed piece, although little is known about inoculum thresholds for *R. solani*. These effects may be due to differences in the rates of sprout emergence, timing of tuber set, timing of tuber maturity and relative susceptibility to the pathogen between the cultivars.

The fungicide treatments differed in their relative effectiveness in controlling stem canker and black scurf in each trial and these differences were not consistent when comparing old and new ground. Iprodione (Rovral) treatments did not reduce the incidence of stem canker and black scurf in any trial in both old and new ground (Figure 2, Figure 3, Figure 10, Table 10, Table 29). It is possible that the rate of application was not high enough in the conditions tested. Alternatively, our method of application may not have been as effective as a commercial application to adequately mixing the fungicide into the soil profile around the seed and progeny tubers.

When comparing efficacy across trials, pencycuron and fludioxonil treatments consistently in reduced the incidence of black scurf in the progeny tubers (eg. Figure 2, Figure 3, Figure 9, Figure 10) in all trials. Tolclofos-methyl, on the other hand, was not effective every season (eg. Figure 2 and Figure 9 cf. Figure 4 and Figure 10).

There was no correlation between the efficacy the three fungicides against stem canker and against black scurf. In some trials (Ballarat 98/99. Colac 97/98) pencycuron and fludioxonil reduced the incidence of plants with stem canker and progeny tubers with black scurf (Figure 2, Figure 9). However, in another trial (Colac 98/99) neither treatment reduced the incidence of stem canker, despite having a significant effect on the incidence of progeny with black scurf (Figure 10). The results of tolclofos-methyl treatments, however, were contradictory. The treatment sometimes reduced the incidence of stem canker but had no effect on the incidence of black scurf (Figure 10).

A thiabendazole (Tecto®) treatment applied to tubers at Colac in 1997/98 had no effect on the incidence of silver scurf in the progeny (58% tubers affected), despite the fact that 46% of seed tubers were affected (Figure 9, Table 24, Table 25). However, the treatment reduced the incidence of progeny tubers with black scurf by 60% in comparison the untreated control. Another benzimidazole treatment (thiophanate methyl) has been used as a seed piece treatment for black scurf in the USA, but has proved to be unreliable in Australia against the more specific Rhizoctonia fungicides available here. The lack of control of silver scurf with thiabendazole may be due the development of fungicide resistant strains of *Helminthosporium solani* (Stewart-Wade *et al*. 2003).

Silver scurf

A seed treatment of fludioxonil (Maxim) reduced the incidence of silver scurf on progeny tubers of 50-80% compared with the untreated controls in trials in both old and new ground (Figure 6, Figure 7, Figure 9). The fungicide has recently been registered as a pre-planting treatment for silver scurf (Table 54). The fungicide thiabendazole, also registered for control of silver scurf, albeit as a post-harvest storage treatment, did not seed-borne silver scurf. A fludioxonil treatment in the same trial reduced the incidence of silver scurf by 80% (Figure 9).

Black dot

Black dot was, overall, the most common disease on the progeny tubers in trials at Ballarat over four seasons. There was no apparent effect of seed treatments on the incidence or severity of this disease in progeny tubers. A very high incidence of black dot in the progeny of minitubers planted in these trials every season indicates high soil-borne inoculum levels of *C. coccodes*. Any effects of seed treatments would be masked by disease from soil-borne inoculum. Soil treatments of pencycuron, fluazinam or azoxystrobin did not reduce the incidence of black dot in the progeny tubers in comparison with the untreated control.

Black dot occurred infrequently in trials in new ground. Where it did occur, disease incidence was too low for any effects of seed treatments to be apparent. A small number of minituber progeny planted in trials in new ground at Colac were found to have symptoms of black dot, which suggests that *C. coccodes* may be present in new ground. In the trials at Colac 1997/98, black dot was not detected in the progeny, although 44% of seed tubers were affected with the disease.

Powdery scab

Powdery scab was relatively common in old ground at Ballarat, occurring on the progeny of 'disease-free' minitubers and commercial seed. However, powdery scab there was no evidence of powdery scab on seed potato tubers or on progeny tubers in the trials in new ground.

In old ground, the incidence of powdery scab was not affected by seed treatments in any season. However, an application of fluazinam (Shirlan) to soil in the 2000/2001 trial (Figure 8, Table 19) reduced the incidence of progeny of cv Russet Burbank with powdery scab to 4% compared with 24% in the untreated control.

Common scab

Common scab occurred relatively infrequently in the trials at Ballarat and Colac and where it occurred, incidence was very low. However, this disease has become relatively common in seed and processing production areas of Victoria over the past five years and has caused devastating losses for some processing growers whose entire crop was affected with severe symptoms of common scab.

In a trial at Yeodene (1999/2000), treating seed tubers (2% tubers affected with common scab) with fungicides known to have some activity against common scab had no impact on the incidence of the disease in progeny tubers (Table 22). The incidence of the disease in the progeny of untreated minitubers and the untreated controls were 99.6% and 100% of tubers affected respectively, indicating very high disease pressure in the soil. A mancozeb soil treatment did not reduce the incidence or severity of common scab in this trial.

Fungicide vs disinfectant seed treatments

When comparing fungicide seed treatments with disinfectant treatments, hydrogen peroxide, at a relatively high rate (10% product- 3% active), did not reduce the incidence or severity of Rhizoctonia stem canker or black scurf. This chemical is highly reactive and may not be useful in its pure form. Treating seed with Peratec 5 Sanitiser (peroxyacetic acid) (1-2% product) at low rates was also relatively ineffective (Figure 4 and Figure 11). However, a 5% treatment reduced the incidence of Rhizoctonia stem canker and black scurf in the progeny by 38% and 52%, respectively, of the untreated control (Figure 12). This treatment was as effective as a pencycuron seed treatment when a surfactant (Triton X-100) was added, although it proved to be very phytotoxic and reduced sprout emergence and yield (Table 37, Table 38).

Seed treatments vs soil treatments

The effects of comparisons between seed and soil treatments and combinations of seed and soil treatments on disease incidence and severity are presented in Figure 5 and Figure 11 and in Table 19, Table 37 and Table 39. In a trial in old ground (Ballarat, 2000/2001), a soil treatment of pencycuron did not significantly reduce the incidence of plants with Rhizoctonia stem canker or progeny tubers with black scurf in comparison with the untreated control (Table 7). It is possible that the fungicide was not applied at an optimum rate in these soils. A soil treatment of azoxystrobin (Amistar) in the same trial reduced the incidence of black scurf by 70% of the untreated control but had no significant effect on the incidence of plants with stem canker. The efficacy of this fungicide against Rhizoctonia diseases has been demonstrated previously (de Boer 1994).

In new ground (Colac 2000/2001), the pencycuron soil treatment reduced the incidence of plants with stem canker and progeny tubers with black scurf by 50% and 60% respectively, compared with the untreated controls, but was not as effective as the pencycuron seed treatment (Table 13). This is perhaps a reflection of the relatively low soil inoculum. A Peratec 5 Sanitiser seed treatment, combined with the pencycuron soil treatment, reduced the incidence of progeny tubers as effectively as the pencycuron seed treatment alone. Furthermore, the combined treatment was twice as effective in reducing the incidence of progeny with black scurf as the Peratec 5 Sanitiser treatment alone.

Seed treatments and potato yield

Overall, there were few examples of increases in the number and yield of tubers associated with seed treatments. Seed treatments generally did not significantly affect total and marketable yields. There were some examples of increased numbers and yields in the 35-110g and 110-250g size categories. At Ballarat in 1997/98, fludioxonil and pencycuron seed treatments increased ($P \leq 0.05$) the number and yield of tubers in the 110-250g size category by about 20% in comparison with the untreated control in cv. Russet Burbank but not in cv. Sebago (Table 7). This may have been due to reduced damage from *R. solani* in the treated progeny as indicated by the lower incidence and severity of black scurf on tubers (Figure 1). Fludioxonil and pencycuron seed treatments increased ($P \leq 0.05$) the number and yield of Russet Burbank in the 35-110g and 110-250g categories by about 40% and 20%, respectively, at Ballarat in 1998/99, but had no significant effect the number and yield of Sebago tubers in the same trial (Table 11). These treatments reduced the incidence of black scurf on Russet Burbank but not on Sebago (Figure 2 and Figure 3).

3.2.4 Conclusions

The results of trials in old and new ground indicated that, when planting seed with disease symptoms (black dot, black scurf, silver scurf, powdery scab or common scab), seed tubers were a significant source of black scurf or silver scurf in the progeny in the subsequent crop. However, for black dot, powdery scab and common scab, soil-borne inoculum tended to the major source of disease in the progeny. That is, the impact of the inoculum of these pathogens on the seed was not immediately apparent in the first generation.

Circumstantial evidence from the trials suggests that a relatively low proportion of seed tubers with black scurf (less than 10%) can cause significant disease in the progeny.

Trials showed that three standard fungicide treatments (tolclofos-methyl, pencycuron, fludioxonil) reduced the carry-over of *R. solani* from diseased seed tubers. The effectiveness of these treatments was variable and unpredictable in old ground because of disease from soil-borne inoculum. These treatments were more effective in reducing disease incidence in new ground where disease pressure from soil-borne inoculum was low. Relative reductions in disease incidence in old and new ground were 0-60% and 90-100%, respectively.

The effects of seed treatments on the incidence of plants with stem canker were not consistent from trial to trial. In some trials there was a good correlation between the incidence of stem canker and progeny tubers with black scurf but in other trials where treatments reduced the incidence of black scurf, the incidence of plants with stem canker was unaffected by treatments.

The effectiveness of treatments also depended on cultivar. In trials where the effects of treatments on two different cultivars were compared, some treatments reduced the incidence of stem canker or black scurf in one cultivar, but not the other. In a second trial with the same cultivar the effects were reversed. This did not appear to be correlated with the initial incidence and severity of black scurf on the seed potatoes.

The fungicide iprodione was ineffective in reducing disease incidence in all trials on both old and new ground. Fludioxonil and pencycuron were the most consistent treatments, reducing disease incidence to the same degree in trials in old and new ground. The effectiveness of tolclofos-methyl varied, reducing disease incidence in some trials but not in others.

The Rhizoctonia seed treatment of fludioxonil reduced the incidence of progeny tubers with silver scurf by 50-80% of the untreated control. A thiabendazole seed treatment, normally used to control silver scurf post-harvest, reduced the incidence of Rhizoctonia black scurf in progeny tubers.

A new fungicide azoxystrobin, registered for the control of target spot in potato foliage, effectively controlled soil-borne black scurf when incorporated into soil pre-planting. Fluazinam, applied to soil pre-planting effectively control the incidence of powdery scab in Russet Burbank progeny.

Black dot was the most common disease on progeny tubers in trials in old ground. However, any effects of fungicide treatments on seed-borne black dot were masked by very high soil-borne disease pressure.

Disinfectant treatments applied to tubers pre-planting, were less reliable than standard fungicide treatments and tended to be phytotoxic.

The results of these trials indicated that there was no certainty from season to season that seed treatments provide tangible benefits in terms of disease control and improved yield and quality in old ground. Farmers are encouraged to compare all treatments on their farms over a number of seasons to determine which was the most effective for them.

Table 3 A summary of the relationships between the incidence of black scurf on seed potatoes and the incidence of progeny plants with stem canker and progeny tubers with black scurf in field trials in old and new ground

Season	Cultivar	Seed tubers	Progeny					
			Untreated control		Best fungicide treatment		Untreated minituber progeny	
		% tubers affected	% plants with stem canker	% tubers with black scurf	% tubers with black scurf	% change (untreated vs control – stem canker)	% plants with stem canker	% tubers with black scur
Old ground – Ballarat								
1997/98	Russet Burbank	8.0	-	35.2	23.6	33.0	-	32.8
	Sebago	60.0	-	94.4	34.0	64.0*	-	19.6
1998/99	Russet Burbank	80.0	52.7	69.3	25.7	63.0*	-	22.7
	Sebago	20.0	22.3	60.3	41.7	31.0	-	39.7
1999/2000	Russet Burbank	80.0	12.5	54.7	25.0	54.0*	22.7	18.0
2000/2001	Russet Burbank	12.0	6.7	34.0	17.0)	50.0	6.7	26.8
					(8.4 soil treatment		6.7	9.24 (Exton)
New ground – Colac								
1997/98	Sebago	68.0	-	19.2	0.8	96.0*	-	1.6 (Sebago)
1998/99	Denali	100.0	-	60.7	2.0	97.0*	-	2.0 (Sebago)
1999/2000	91-106-1	62.0	-	22.4	0.00	100.0*	-	0.0 (Sebago)
2000/2001	Coliban	72.0	66.7	48.5	0.8	98.0*	0.00	0.8 (Exton)
							6.7	0.8 (Russet Burbank)

* Statistically significant at P≤0.05

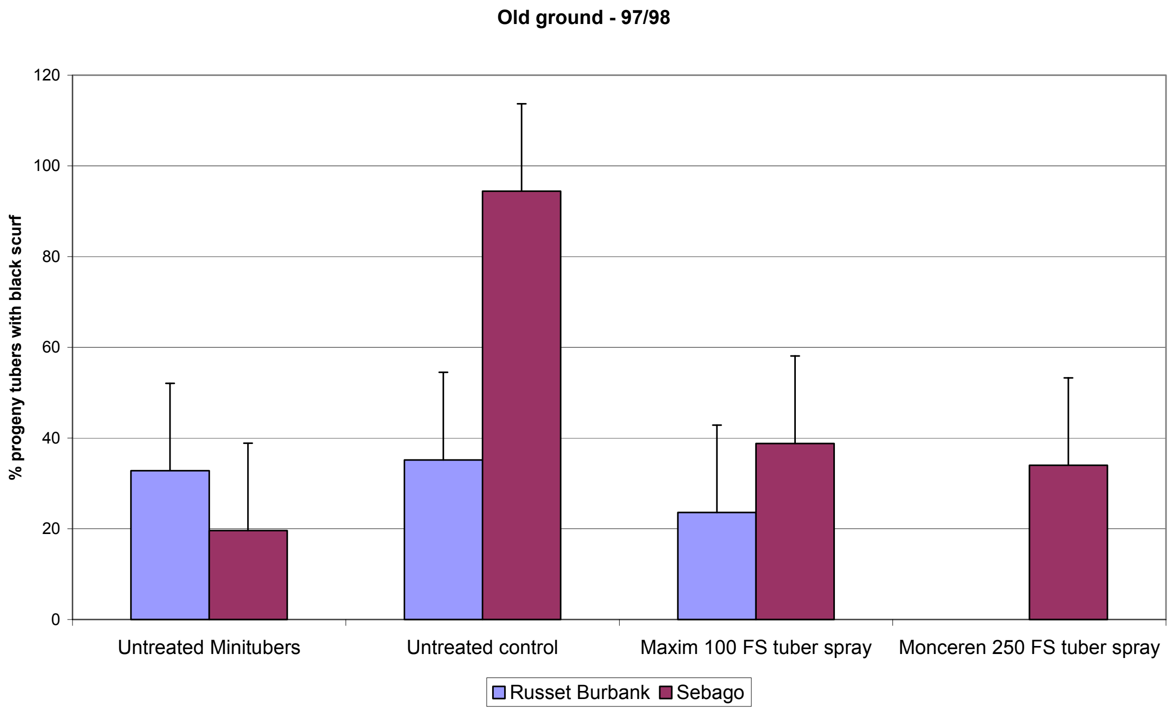

Figure 1 Effects of pre-planting fungicide treatments of seed tubers on the incidence of progeny tubers of two different cultivars with black scurf in a field trial in old ground – Ballarat, 1997/98 (Bars above the histograms represent the lsd at P=0.05)

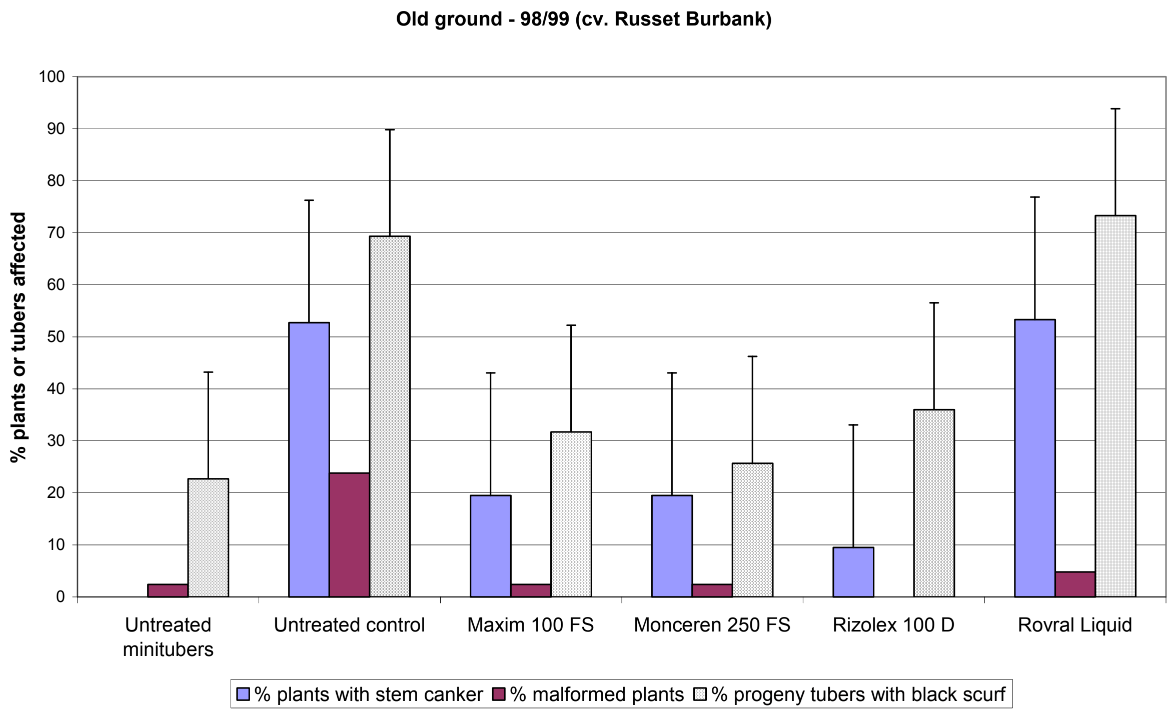

Figure 2 Effects of pre-planting fungicide treatments of seed tubers on the incidence of plants affected with Rhizoctonia canker (stem canker and malformed plants) and incidence of progeny tubers with black scurf of cv. Russet Burbank in a field trial in old ground – Ballarat, 1998/99 (Bars above the histograms represent the lsd at P=0.05)

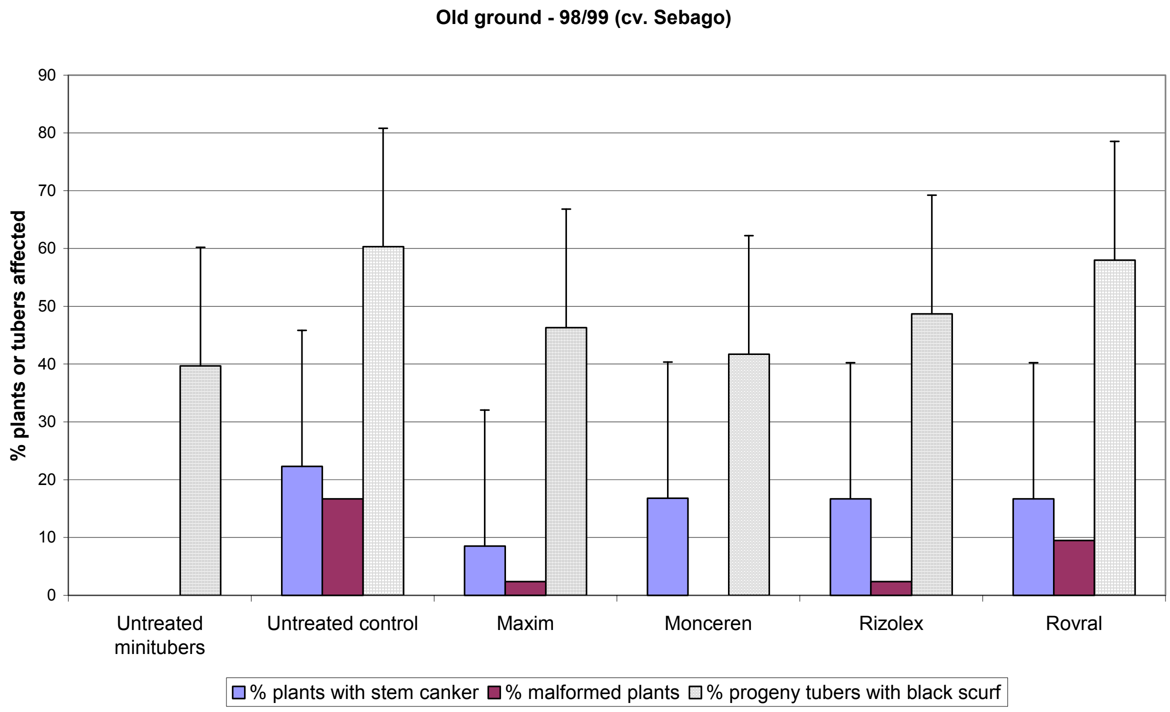

Figure 3 Effects of pre-planting fungicide treatments of seed tubers on the incidence of plants affected with Rhizoctonia canker (stem canker and malformed plants) and incidence of progeny tubers with black scurf of cv. Sebago in a field trial in old ground – Ballarat, 1998/99 (Bars above the histograms represent the lsd at P=0.05)

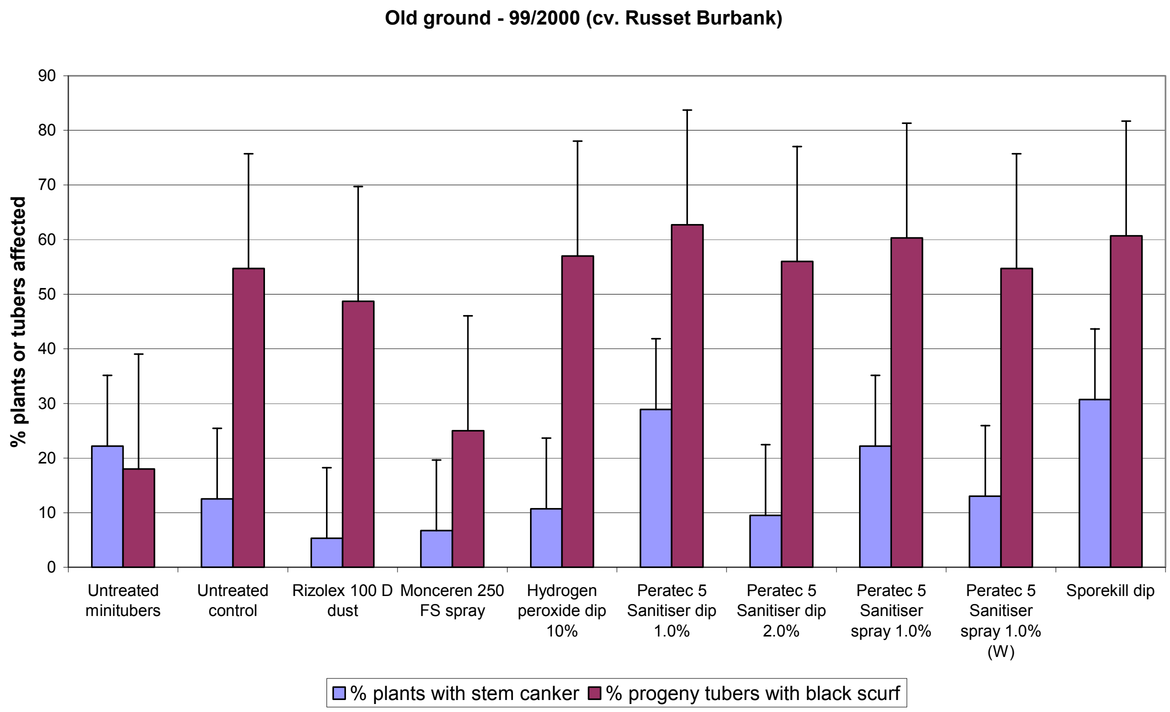

Figure 4 Effects of pre-planting fungicide and disinfectant treatments of seed tubers on the incidence of plants affected with Rhizoctonia stem canker and incidence of progeny tubers with black scurf in a field trial in old ground – Ballarat, 1999/2000 (Bars above the histograms represent the lsd at P=0.05)

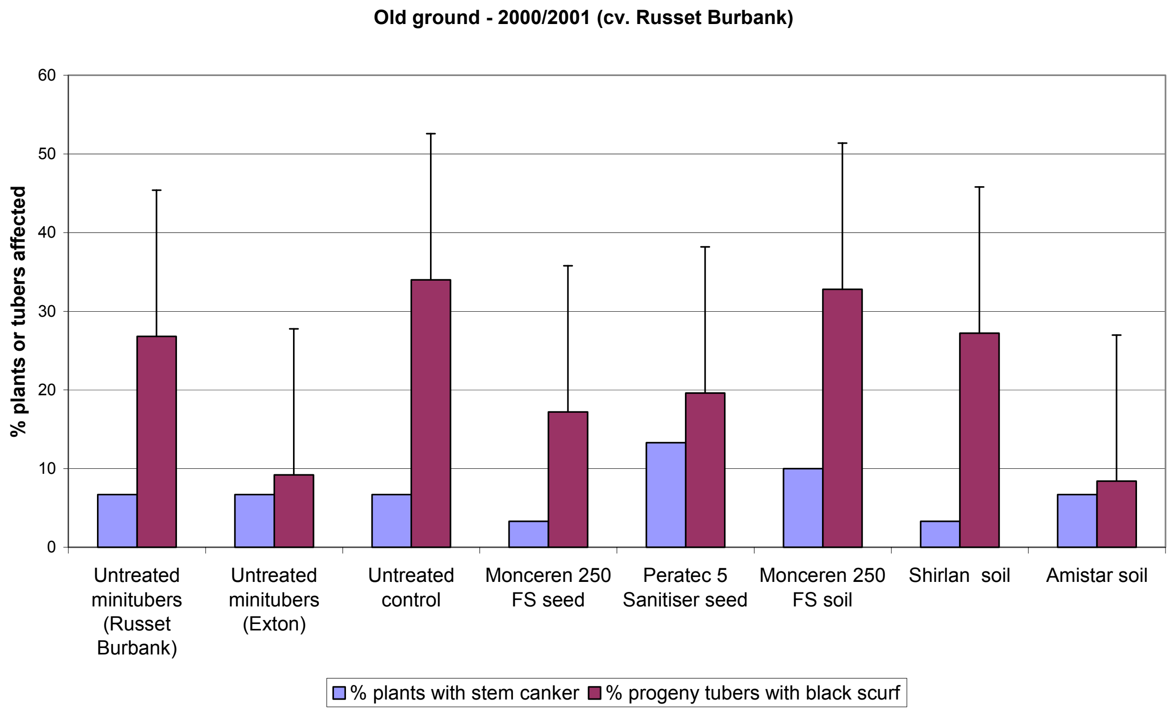

Figure 5 Effects of pre-planting fungicide and disinfectant treatments of seed tubers and fungicide treatments of soil on the incidence of plants affected with Rhizoctonia stem canker and incidence of progeny tubers with black scurf in a field trial in old ground – Ballarat, 2000/2001 (Bars above the histograms represent the lsd at P=0.05)

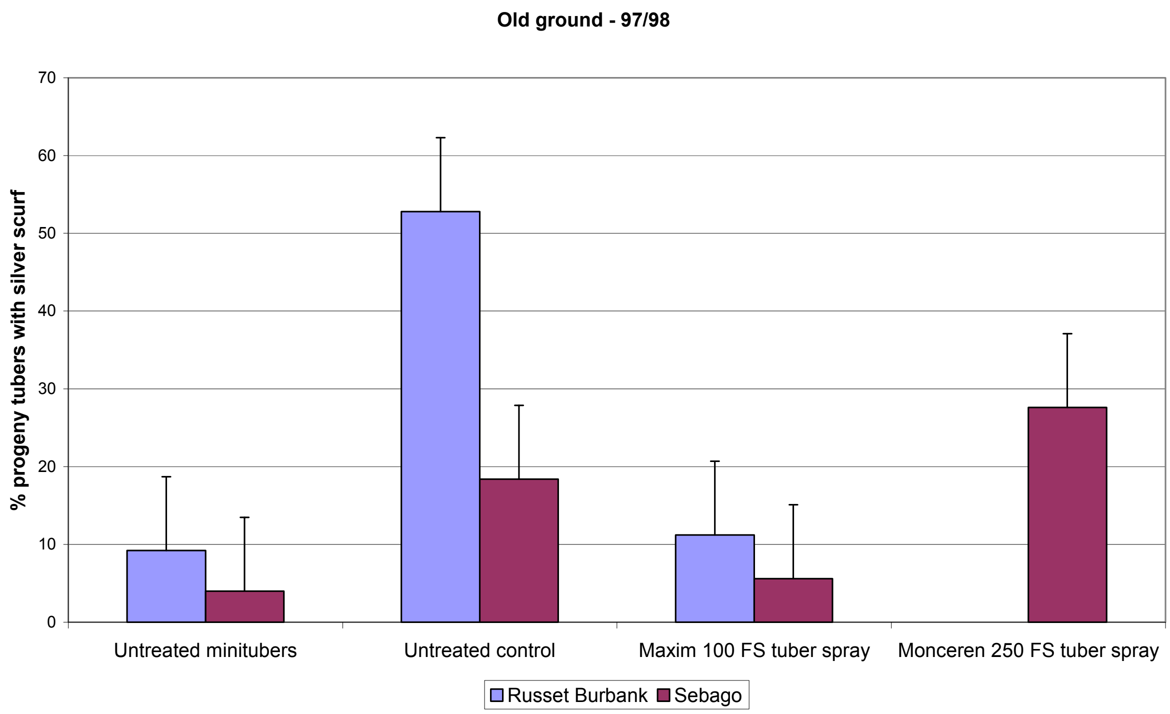

Figure 6 Effects of pre-planting fungicide treatments of seed tubers on the incidence of progeny tubers of two different cultivars with silver scurf in a field trial in old ground – Ballarat, 1997/98 (Bars above the histograms represent the lsd at P=0.05)

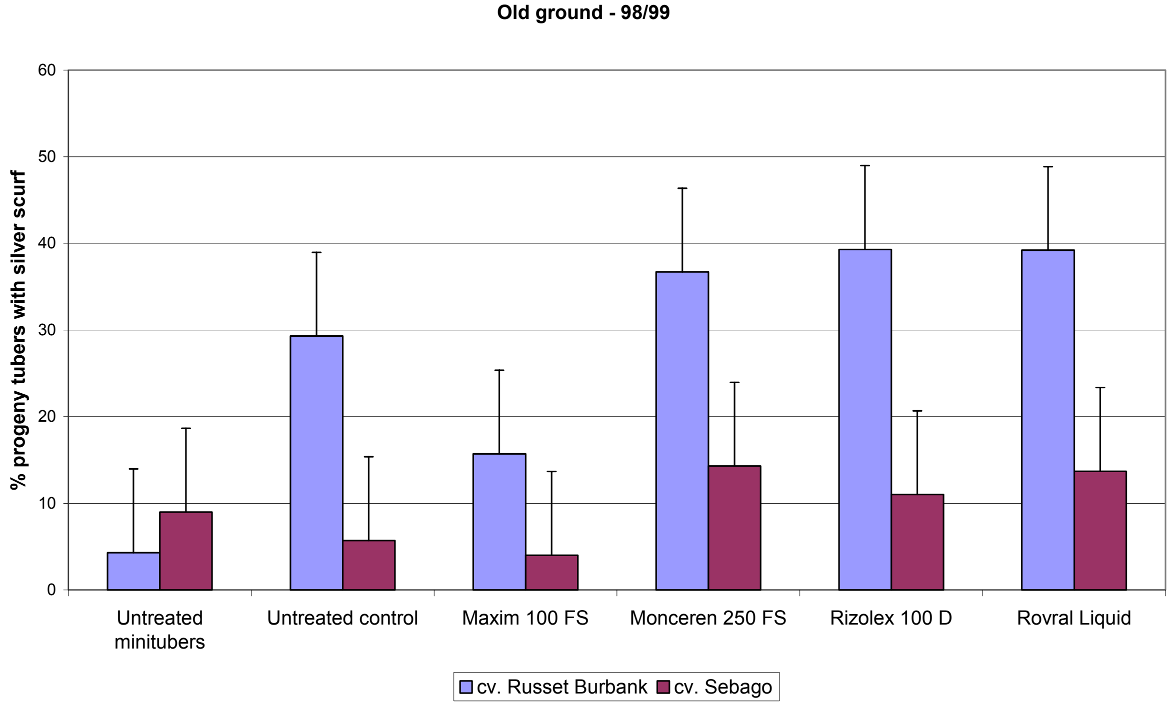

Figure 7 Effects of pre-planting fungicide treatments of seed tubers on the incidence of progeny tubers of two different cultivars with silver scurf in a field trial in old ground – Ballarat, 1998/99 (Bars above the histograms represent the lsd at P=0.05)

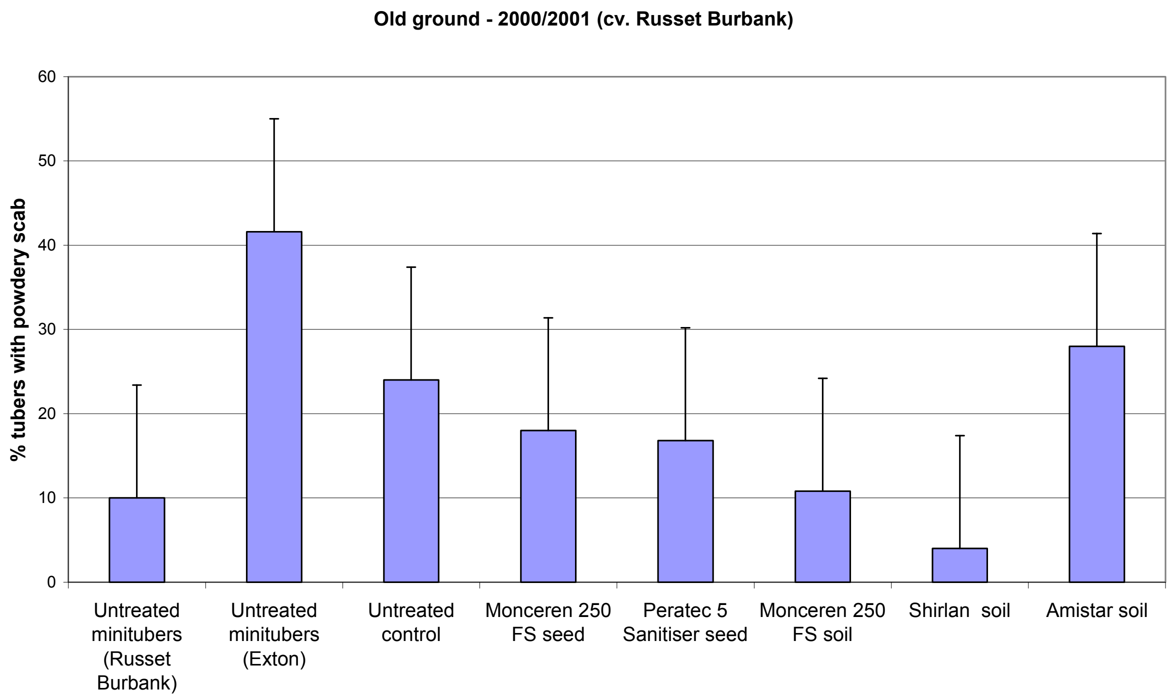

Figure 8 Effects of pre-planting fungicide and disinfectant treatments of seed tubers and fungicide treatments of soil on the incidence of progeny tubers with powdery scab in a field trial in old ground – Ballarat, 2000/2001 (Bars above the histograms represent the lsd at P=0.05)

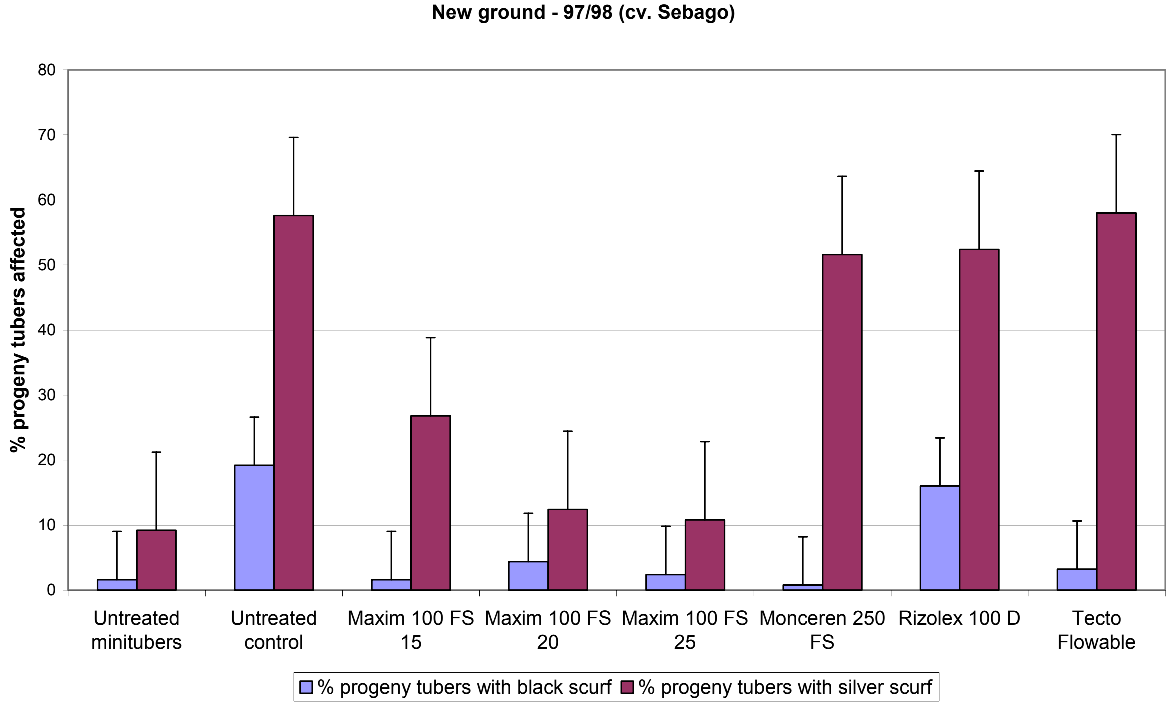

Figure 9 Effects of pre-planting fungicide treatments of seed tubers on the incidence of progeny tubers of with black scurf and silver scurf in a field trial in new ground – Colac, 1997/98 (Bars above the histograms represent the lsd at P=0.05)

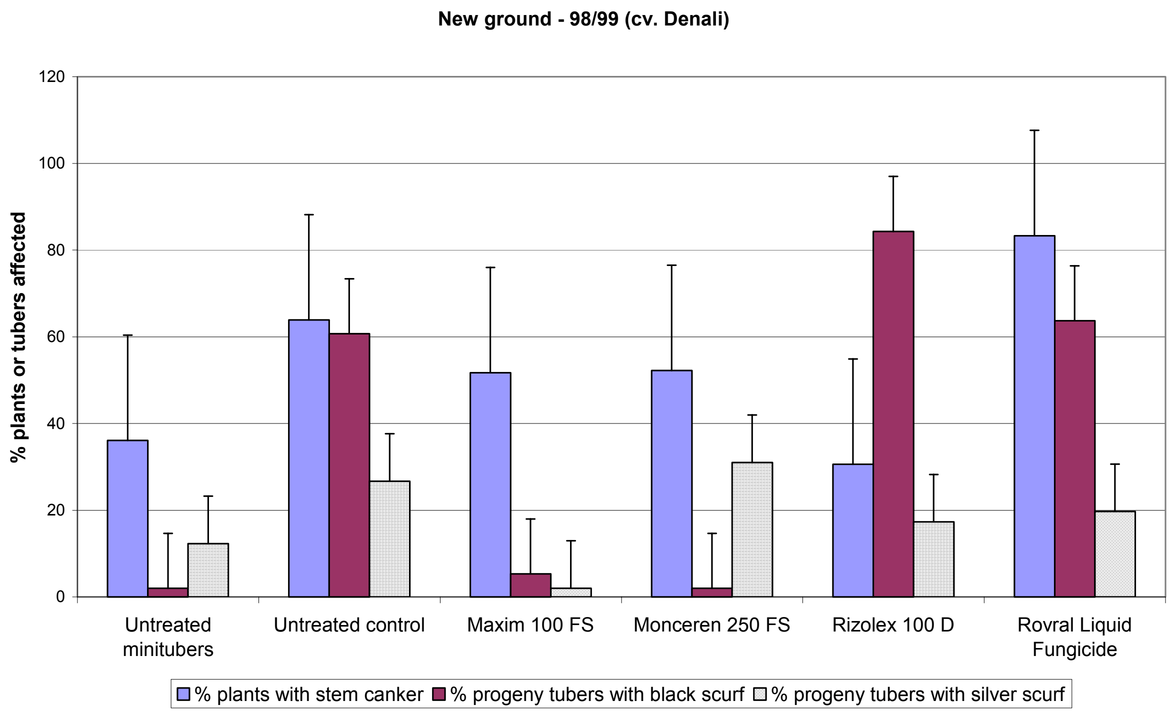

Figure 10 Effects of pre-planting fungicide treatments of seed tubers on the incidence of plants affected with Rhizoctonia stem canker and incidence of progeny tubers with black scurf and silver scurf in a field trial in new ground – Colac, 1998/1999 (Bars above the histograms represent the lsd at P=0.05)

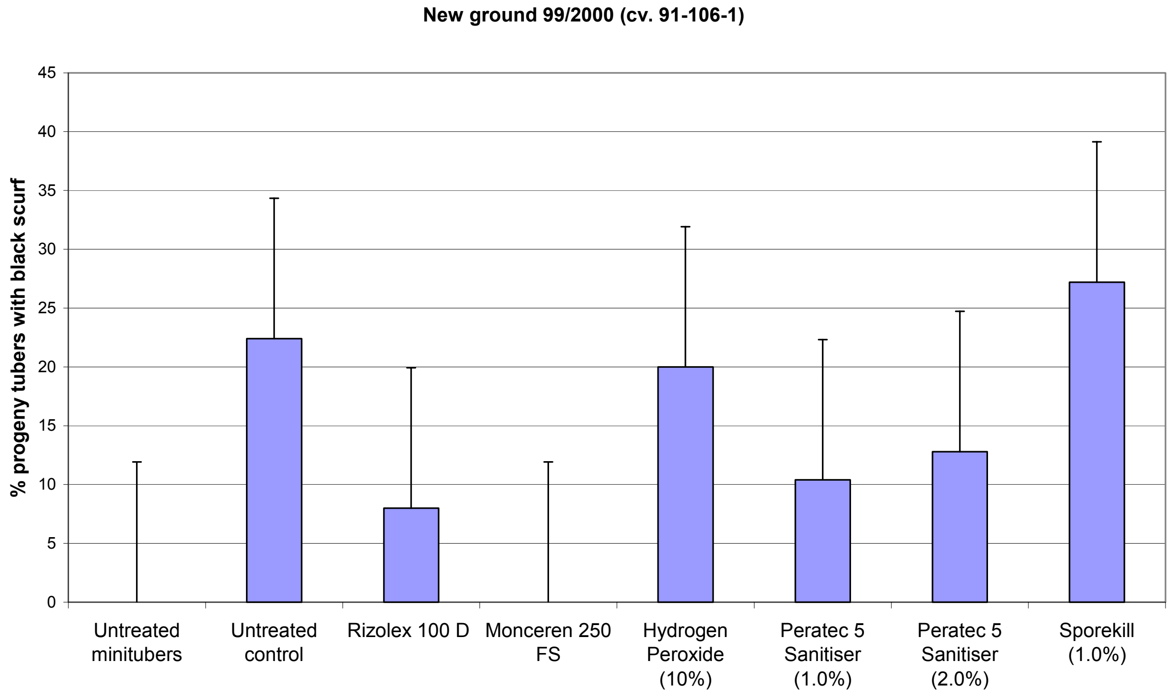

Figure 11 Effects of pre-planting fungicide and disinfectant treatments of seed tubers on the incidence of progeny tubers with black scurf in a field trial in new ground – Colac, 1999/2000 (Bars above the histograms represent the lsd at P=0.05)

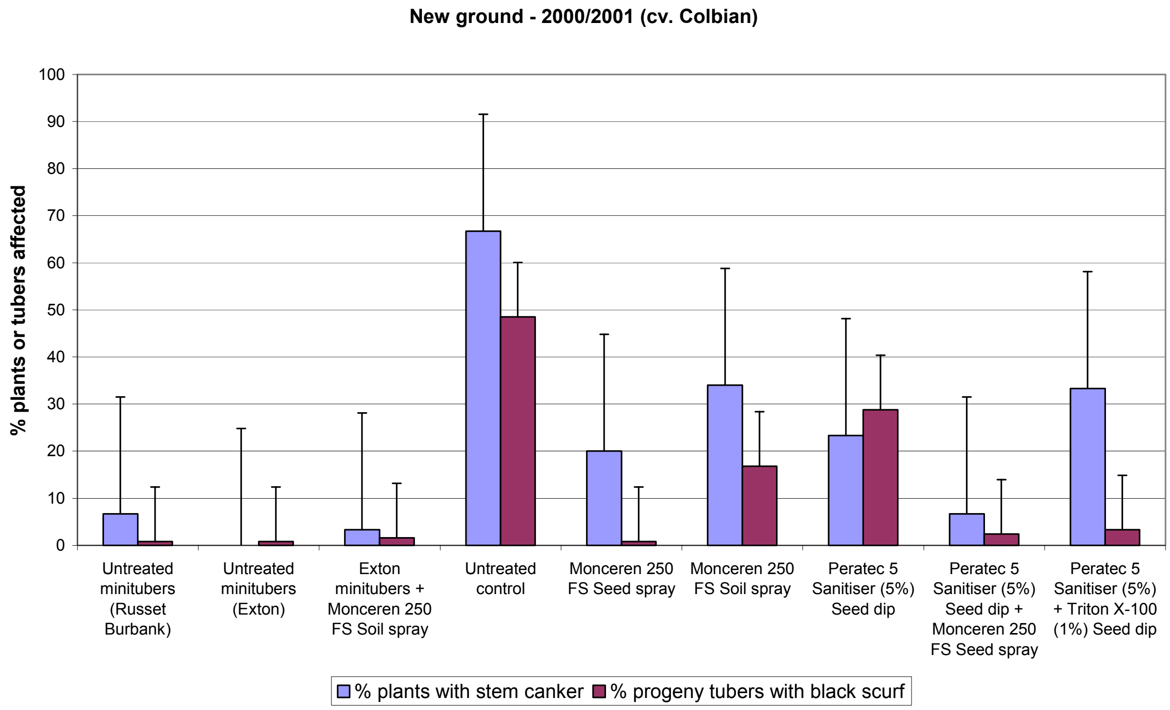

Figure 12 Effects of pre-planting fungicide and disinfectant treatments of seed tubers and fungicide treatments of soil on the incidence of plants affected with Rhizoctonia stem canker and incidence of progeny tubers with black scurf in a field trial in new ground – Colac, 2000/2001 (Bars above the histograms represent the lsd at P=0.05)

Table 4 Tuber treatments in a field trial in old ground, Ballarat, 1997/98

Treatment	Active ingredient	Application	Rate
Maxim® 100 FS Fungicide	100g/L fludioxonil	tuber spray	0.25ml/kg of seed
Monceren® 250 FS Fungicide	250g/L pencycuron	tuber spray	0.60ml/kg of seed

Table 5 Incidence and severity of diseases on seed potatoes (cvs. Russet Burbank and Sebago) planted in a field trial in old ground, Ballarat, 1997/98

Cultivar	Disease	Black scurf	Silver scurf	Black dot	Powdery scab	Common scab
Russet Burbank	% tubers affected	8.0	92.0	20.0	0.0	0.0
	Severity (0-4)[A]	0.14	2.44	0.28	0.0	0.0
Sebago	% tubers affected	60.0	44.0	0.0	2.0	0.0
	Severity (0-4)[A]	1.30	1.04	0.0	0.02	0.0

[A] Disease severity scales. Black scurf: 0, no disease; 1, a trace; 2, slight; 3, moderate; 4, severe;
Silver scurf, black dot, powdery scab and common scab severity ratings: 0, no disease; 1, <2%; 2, 2-10%; 3, 10-25%; 4, >25% tuber surface affected.

Table 6 Effects of pre-planting seed tuber treatments on diseases of progeny tubers in a field trial in old ground, Ballarat 1997/98

Cultivar	Treatment	Black Dot		Silver Scurf		Black Scurf		Powdery Scab	
		% tubers affected	Severity (0-4)[A]	% tubers affected	Severity (0-4)[A]	% tubers affected	Severity (0-4)[B]	% tubers affected	Severity (0-4)[A]
Russet Burbank	Untreated Minitubers	72.4	0.9	9.2	0.1	32.8	0.5	0.0	0.0
	Untreated control	95.2	1.6	52.8	0.7	35.2	0.5	1.6	0.02
	Maxim	94.8	1.7	11.2	0.1	23.6	0.3	1.2	0.01
Sebago	Untreated Minitubers	50.8	0.6	4.0	0.05	19.6	0.3	8.8	0.1
	Untreated control	71.2	1.0	18.4	0.2	94.4	1.8	48.4	0.6
	Maxim	80.8	1.2	5.6	0.06	38.8	0.7	50.8	0.8
	Monceren	72.8	1.1	27.6	0.4	34.0	0.5	34.0	0.5
	F-Test	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	lsd (P=0.05)	11.39	0.2617	9.50	0.1331	19.27	0.3068	17.23	0.2829

[A] Disease severity rating: 0, no disease; 1, <2%; 2, 2-10%; 3, 10-25%; 4, >25% tuber surface affected

[B] Black scurf severity rating: 0, no disease; 1, a trace; 2, slight; 3, moderate; 4, severe

Table 7 Effects of pre-planting seed tuber treatments on total and marketable yield and the number and yield of progeny tubers in different size categories in a field trial in old ground, Ballarat 1997/98

Cultivar	Treatment	Total yield	Marketable yield (35-350g)	<35g		35-110g		110-250g		250-350g		>350g	
		t/ha	t/ha	Tubers/ plot	t/ha`	Tubers/ plot	t/ha	Tubers/ plot	t/ha	Tubers/ plot	t/ha	Tubers/ plot	t/ha
Russet Burbank	Untreated Minitubers	39.8	28.1	13.8	0.39	55.2	4.50	87.0	16.95	20.4	6.62	12.4	5.75
	Untreated control	52.6	46.4	25.0	0.72	127.6	10.40	167.4	29.20	21.2	6.79	5.2	2.39
	Maxim	54.5	48.9	23.6	0.68	138.4	11.92	174.6	31.29	17.6	5.71	4.4	1.96
Sebago	Untreated Minitubers	34.5	23.4	14.6	0.40	38.8	2.81	62.8	11.97	26.2	8.57	20.2	10.08
	Untreated control	53.7	43.0	28.2	0.71	80.4	6.66	123.8	23.93	38.6	12.36	16.2	7.62
	Maxim	52.9	44.9	37.8	1.06	93.4	7.31	149.6	28.87	27.0	8.70	11.2	4.74
	Monceren	55.7	46.6	33.2	0.85	86.0	6.94	149.6	29.16	32.2	10.50	14.0	5.81
	F-Test[A]	<0.001	<0.001	0.401	0.406	<0.001	<0.001	<0.001	0.009	0.002	0.001	0.004	0.001
	lsd (P=0.05)	6.267	5.265	13.21	0.3055	25.11	1.7197	20.76	3.445	8.422	2.620	6.811	2.664

[A] Minituber data not included in the statistical analysis

Table 8 Tuber and soil treatments in a field trial in old ground, Ballarat 1998/99

Treatment	Active ingredient	Application	Rate
Maxim® 100 FS Fungicide	Fludioxonil 100g/L	tuber spray	0.25ml/kg of seed
Monceren® 250 FS Fungicide	Pencycuron 250g/L	tuber spray	0.60ml/kg of seed
Rizolex® 100 D Fungicide	Tolclofos-methyl 100g/kg	tuber dust	2g/kg of seed
Rovral® Liquid Fungicide	Iprodione 250g/L	Sprayed onto tuber in open furrow	0.8ml/kg of seed

Table 9 Incidence and severity of diseases on seed potato tubers (cvs Russet Burbank and Sebago) planted in a field trial in old ground Ballarat, 1998/99

Cultivar	Disease	Black Dot	Silver Scurf	Black Scurf	Powdery Scab	Common Scab
Russet Burbank	% tubers affected	74	92	80	6.0	0.0
	Severity (0-4)[A]	1.62	2.50	1.48	0.08	0.0
Sebago	% tubers affected	6.0	54	20	4.0	0.0
	Severity (0-4)[A]	0.06	1.08	0.48	0.04	0.0

[A] Black Scurf severity rating: 0, no disease; 1, a trace; 2, slight; 3, moderate; 4, severe.
Silver scurf, powdery scab and common scab severity ratings: 0, no disease; 1, <2%; 2, 2-10%; 3, 10-25%; 4, >25% tuber surface affected.

Table 10 Effects of pre-planting seed tuber and soil treatments on diseases of progeny tubers in a field trial in old ground, Ballarat 1998/99

Treatment	Rhizoctonia disease: Stem canker % plants affected	Rhizoctonia disease: Stem canker Severity (0-5)[A]	Rhizoctonia disease: Mal-formed plants % plants affected	Tuber diseases: Black Dot % tubers affected	Black Dot Severity (0-4)[B]	Silver Scurf % tubers affected	Silver Scurf Severity (0-4)[B]	Black Scurf % tubers affected	Black Scurf Severity (0-4)[C]	Powdery Scab % tubers affected	Powdery Scab Severity (0-4)B[A]
Russet Burbank											
Untreated minitubers	-	-	2.4	45.0	0.58	4.3	0.05	22.7	0.26	4.0	0.04
Untreated control	52.7	1.03	23.8	79.7	1.33	29.3	0.36	69.3	0.95	24.3	0.43
Maxim	19.5	0.19	2.4	92.7	1.90	15.7	0.26	31.7	0.44	17.0	0.18
Monceren	19.5	0.17	2.4	92.7	1.66	36.7	0.44	25.7	0.36	17.7	0.18
Rizolex	9.5	0.08	0.0	87.7	1.58	39.3	0.54	36.0	0.47	17.7	0.21
Rovral	53.3	1.31	4.8	88.7	1.60	39.2	0.45	73.3	1.02	16.3	0.17
Sebago											
Untreated minitubers	-	-	0.0	70.3	1.49	9.0	0.11	39.7	0.62	44.0	0.59
Untreated control	22.3	0.31	16.7	68.7	1.14	5.7	0.06	60.3	0.90	61.0	1.02
Maxim	8.5	0.14	2.4	74.7	1.49	4.0	0.04	46.3	0.71	52.0	0.74
Monceren	16.8	0.33	0.0	69.7	1.29	14.3	0.17	41.7	0.63	51.7	0.74
Rizolex	16.7	0.17	2.4	69.3	1.43	11.0	0.11	48.7	0.74	57.3	0.96
Rovral	16.7	0.28	9.5	72.3	1.40	13.7	0.15	58.0	0.99	52.0	0.96
F-test	0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
lsd (P=0.05)	23.55	0.56	0.80	13.43	0.33	9.66	0.17	20.52	0.36	13.27	0.33

[A] Stem canker severity scale: 0, no symptoms (healthy); 1, <25% stems affected; 2, 25-50% stems affected; 3, 50-75%stems affected; 4, >75% stems affected; 5, 100% stems affected (all shoots burnt/pruned off, plant nearly dead).
[B] Disease severity rating: 0, no disease; 1, <2%; 2, 2-10%; 3, 10-25%; 4, >25% tuber surface affected.
[C] Black Scurf severity rating: 0, no disease; 1, a trace; 2, slight; 3, moderate; 4, severe.

Table 11 Effects of pre-planting seed tuber and soil treatments on total and marketable yield and the number and yield of progeny tubers in different size categories in a field trial in old ground, Ballarat 1998/99

Treatment	Total yield	Marketable yield (35-350g)	<35 g		35-110 g		110-250 g		250-350 g		>350 g	
	kg/plot	kg/plot	Tubers/ plot	kg/plot	Tubers/ plot	kg/plot	Tubers/ plot	kg/plot	Tubers/ plot	kg/plot	Tubers/ plot	kg/plot
Russet Burbank												
Untreated minitubers	18.53	14.89	5.0	0.22	57.5	3.60	50.0	8.40	8.8	2.89	3.8	2.02
Untreated control	43.83	33.91	18.0	0.61	117.2	8.73	100.2	17.64	24.2	7.54	9.8	4.74
Maxim	45.38	41.54	17.3	0.58	173.0	13.27	127.0	21.96	21.8	6.31	5.2	2.58
Monceren	47.25	44.03	23.7	0.70	167.3	13.16	137.7	22.79	43.3	8.09	3.2	1.70
Rizolex	40.20	36.07	18.5	0.57	139.3	9.61	117.2	19.72	22.7	6.74	6.0	2.81
Rovral	46.17	39.45	16.5	0.64	123.5	9.90	124.7	21.61	28.2	7.95	7.0	3.53
Sebago												
Untreated minitubers	48.09	38.94	8.5	0.34	79.2	6.61	102.2	18.04	43.7	14.29	14.0	8.67
Untreated control	44.75	37.57	22.7	0.68	118.3	8.86	112.0	19.80	29.0	8.91	12.5	5.91
Maxim	45.45	40.91	19.0	0.62	132.7	9.85	118.2	22.17	27.0	8.89	7.5	3.48
Monceren	47.51	41.56	18.3	0.57	126.0	9.40	128.3	22.59	30.7	9.56	10.7	4.90
Rizolex	47.62	42.64	24.3	0.64	129.2	9.79	123.0	22.41	34.3	10.43	9.2	4.02
Rovral	50.91	43.56	18.3	0.59	120.2	9.72	124.3	22.51	35.0	11.33	12.0	6.05
F-test	<0.001	<0.001	0.006	<0.001	<0.001	<0.001	<0.001	<0.001	0.066	<0.001	<0.001	<0.001
lsd (P=0.05)	6.436	5.299	9.68	0.21	27.8	2.35	19.54	3.81	19.98	3.71	4.72	2.86

Table 12 Tuber treatments in a field trial in old ground at Ballarat, Victoria 1999/2000

Treatment	Active ingredient	Application	Rate
Rizolex® 100 D	100g/kg tolclofos-methyl	tuber dust	200g/100kg of seed
Monceren® 250 FS	250g/L pencycuron	tuber spray	60ml100kg of seed
Hydrogen Peroxide	30%w/hydrogen peroxide v	tuber dip	1.8L diluted to 18L
Peratec 5 Sanitiser® (1%)	250g/L hydrogen peroxide, 50g/L peroxyacetic acid	tuber dip	180ml diluted to 18L
Peratec 5 Sanitiser® (2%)	250g/L hydrogen peroxide, 50g/L peroxyacetic acid	tuber dip	360ml diluted to 18L
Peratec 5 Sanitiser® (1%)	250g/L hydrogen peroxide, 50g/L peroxyacetic acid	tuber spray	10ml/L
Peratec 5 Sanitiser® (1%) washed tubers	250g/L hydrogen peroxide, 50g/L peroxyacetic acid	tuber spray	10ml/L
Sporekill®	120g/L didecyldimethyl ammonium chloride	tuber dip	180ml diluted to 18L

Table 13 Incidence and severity of diseases on seed potato tubers (cv. Russet Burbank) planted in a field trial, Ballarat 1999/2000

Disease	Black Dot	Silver Scurf	Black Scurf	Powdery Scab	Common Scab
% tubers affected	74	92	80	6	0
Severity (0-4)[A]	1.62	2.50	1.48	0.08	0.0

[A] Black Scurf severity rating: 0, no disease; 1, a trace; 2, slight; 3, moderate; 4, severe.
Black dot, silver scurf, powdery and common scab severity rating: 0, no disease; 1, <2%; 2, 2-10%; 3, 10-25%; 4, >25% tuber surface affected.

Table 14 The effect of pre-planting seed tuber treatments on diseases of progeny tubers in a field trial, Ballarat 1999/2000

Treatment	Rhizoctonia disease			Tuber diseases							
	Stem Canker		Mal-formed plants	Black Dot		Silver Scurf		Black Scurf		Powdery Scab	
	% plants affected	Severity (0-5)[A]	% plants affected	% tubers affected	Severity (0-4)[B]	% tubers affected	Severity (0-4)[B]	% tubers affected	Severity (0-4)[C]	% tubers affected	Severity (0-4)[A]
Untreated minitubers	22.2	0.43	1.2	54.0	0.71	4.7	0.05	18.0	0.20	7.7	0.08
Untreated control	12.5	0.38	2.0	86.3	1.42	17.3	0.20	54.7	0.77	38.7	0.46
Rizolex	5.3	0.15	2.4	91.0	1.67	23.7	0.29	48.7	0.61	36.0	0.42
Monceren	6.7	0.20	0.8	88.3	1.53	20.0	0.25	25.0	0.40	38.7	0.44
Hydrogen peroxide (10%)	10.7	0.35	0.8	86.7	1.43	21.7	0.26	57.0	0.69	37.3	0.43
Peratec dip (1%)	28.9	1.02	2.4	93.3	1.95	15.7	0.19	62.7	1.01	36.7	0.43
Peratec dip (2%)	9.5	0.38	1.6	87.7	1.54	8.0	0.08	56.0	0.81	38.7	0.46
Peratec spray (1%)	22.2	1.03	2.0	89.0	1.54	16.3	0.17	60.3	0.92	26.3	0.29
Peratec spray (1%) (tubers washed)	13.0	0.47	1.2	87.7	1.46	19.0	0.20	54.7	0.71	34.3	0.40
Sporekill	30.7	0.87	1.2	87.7	1.45	20.3	0.23	60.7	0.92	29.3	0.34
F-test	<0.001	<0.001	0.677	0.838	0.018	0.229	0.189	0.032	0.051	0.653	0.567
lsd (P=0.05)	12.95	0.45	0.89	8.89	0.29	10.99	0.14	21.02	0.36	14.69	0.18

[A C] Stem canker severity scale: 0, no symptoms (healthy); 1, <25% stems affected; 2, 25-50% stems affected; 3, 50-75%stems affected; 4, >75% stems affected; 5, 100% stems affected (all shoots pruned off or plant moribund

[B] Disease severity rating: 0, no disease; 1, <2%; 2, 2-10%; 3, 10-25%; 4, >25% tuber surface affected.

[B] Black Scurf severity rating: 0, no disease; 1, a trace; 2, slight; 3, moderate; 4, severe.

Table 15 Effects of pre-planting seed tuber treatments on total and marketable yield and on the number and yield of progeny tubers in a field trial, Ballarat 1999/2000

Treatment	Total yield	Marketable yield (35-350g)	<35 g		35-110 g		110-250 g		250-350 g		>350 g	
	kg/plot	kg/plot	Tubers/plot	kg/plot	Tubers/plot	kg/plot	Tubers/plot	kg/plot	Tubers/plot	kg/plot	Tubers/plot	kg/plot
Untreated minitubers	22.72	15.38	6.7	0.21	40.3	3.00	44.7	7.89	15.5	4.49	14.7	6.48
Untreated control	45.06	40.89	33.7	0.80	190.2	13.97	139.7	23.30	12.7	3.62	3.7	1.54
Rizolex	44.10	40.96	40.2	0.95	207.3	15.82	140.2	21.72	11.8	3.43	3.3	1.32
Monceren	46.39	43.43	37.8	0.91	202.5	14.95	165.7	25.32	11.2	3.17	2.8	1.19
Hydrogen Peroxide (10%)	44.29	40.48	31.5	0.74	189.0	14.46	146.2	22.99	10.3	3.03	4.2	1.84
Peratec dip (1%)	44.90	39.65	40.3	1.01	174.2	13.43	140.0	22.51	12.7	3.72	4.2	1.71
Peratec dip (2%)	45.93	42.21	36.0	0.88	188.3	14.04	157.8	24.92	11.3	3.26	3.0	1.25
Peratec spray (1%)	44.76	41.45	24.7	0.57	175.0	13.40	152.5	24.15	13.7	3.91	3.0	1.29
Peratec spray (1%) washed	43.26	39.40	34.2	0.76	154.8	11.71	152.5	24.33	11.7	3.36	2.5	1.07
Sporekill	45.01	40.98	37.7	0.84	191.7	14.90	156.2	23.48	9.0	2.60	2.2	0.89
F-test[A]	0.970	0.823	0.479	0.355	0.047	0.102	0.418	0.728	0.920	0.931	0.802	0.744
lsd (P=0.05)	5.10	4.84	14.31	0.35	30.58	2.50	25.65	4.09	6.31	1.85	2.65	1.09

[A] Minituber data excluded from the statistical analysis

Table 16 Tuber treatments in a field trial in old ground, Ballarat 2000/2001

Treatment	Active ingredient	Application	Rate
Monceren® 250 FS	pencycuron 250g/L	tuber spray	60ml/100kg of seed
Monceren® 250 FS	pencycuron 250g/L	soil spray	8.3ml diluted to 7L
Peratec 5 Sanitiser® (5%)	hydrogen peroxide 250g/L, peroxyacetic acid 50g/L	tuber dip	750ml diluted to 15L
Shirlan® Fungicide	500g/L fluazinam	soil spray	27.6ml diluted to 7L
Amistar® WG Fungicide	500 g/kg azoxystrobin	soil spray	1.84g in 7L

Table 17 Incidence and severity of diseases on seed potato tubers (cv. Russet Burbank) planted in a field trial in old ground, Ballarat 2000/2001

Disease	Black Dot	Silver Scurf	Black Scurf	Powdery Scab	Common Scab
% tubers affected	44	6	12	0	0
Severity (0-4) [A]	0.72	0.10	0.18	0	0

[A] Black Scurf severity rating: 0, no disease; 1, a trace; 2, slight; 3, moderate; 4, severe.
Black dot, silver scurf, powdery and common scab severity rating: 0, no disease; 1, <2%; 2, 2-10%; 3, 10-25%; 4, >25% tuber surface affected.

Table 18 Effects of pre-planting seed tuber and soil treatments on the size and yield of progeny tubers in a field trial in old ground, Ballarat 2000/2001

Treatment	Average tuber weight (g)	Total yield	
		kg/plot	t/ha
Untreated minitubers (cv. Russet Burbank)	203.8	37.60	41.74
Untreated minitubers (cv. Exton)	226.7	44.78	49.71
Untreated control	197.8	47.26	52.46
Monceren (seed spray)	197.3	51.05	56.67
Peratec 5 Sanitiser(Seed dip)	187.5	49.54	54.99
Monceren (Soil spray)	179.6	52.09	57.82
Shirlan (Soil spray)	213.1	51.78	57.48
Amistar (Soil spray)	181.5	46.86	52.01
F-test	0.074	<0.001	-
lsd (P=0.05	31.91	5.78	-

Table 19 Effects of pre-planting seed tuber and soil treatments on diseases of progeny tubers in a field trial in old ground, Ballarat 2000/2001

Treatment	Rhizoctonia disease			Tuber diseases							
	Stem Canker		Mal-formed plants	Black Dot		Silver Scurf		Black Scurf		Powdery Scab	
	% plants affected	Severity (0-5)[C]	% plants affected	% tubers affected	Severity (0-4)[A]	% tubers affected	Severity (0-4)[A]	% tubers affected	Severity (0-4)[B]	% tubers affected	Severity (0-4)[A]
Untreated minitubers (cv. Russet Burbank)	6.7	0.10	0.5	60.4	0.92	18.4	0.22	26.8	0.39	10.0	0.10
Untreated minitubers (cv. Exton)	6.7	0.13	0.5	60.4	1.15	18.4	0.26	9.2	0.12	41.6	0.51
Untreated control	6.7	0.13	0.0	77.2	1.14	15.6	0.19	34.0	0.44	24.0	0.24
Monceren (Seed spray)	3.3	0.03	0.0	73.2	1.06	15.2	0.18	17.2	0.21	18.0	0.18
Peratec 5 Sanitiser (Seed dip)	13.3	0.13	0.0	81.2	1.21	14.0	0.15	19.6	0.24	16.8	0.17
Monceren (Soil spray)	10.0	0.23	1.0	79.6	1.11	16.0	0.17	32.8	0.43	10.8	0.12
Shirlan (Soil spray)	3.3	0.13	0.0	69.6	0.97	11.2	0.12	27.2	0.37	4.0	0.04
Amistar (Soil spray)	6.7	0.10	0.0	77.2	1.13	17.2	0.20	8.4	0.10	28.0	0.28
F-test	0.849	0.918	-	0.024	0.306	0.977	0.855	0.047	0.078	<0.001	<0.001
lsd (P=0.05)	14.00	0.27	-	14.21	0.25	14.79	0.19	18.57	0.28	13.39	0.14

[A] Disease severity rating: 0, no disease; 1, <2%; 2, 2-10%; 3, 10-25%; 4, >25% tuber surface affected.
[B] Black Scurf severity rating: 0, no disease; 1, a trace; 2, slight; 3, moderate; 4, severe.
[C] Stem canker severity scale: 0, no symptoms (healthy); 1, <25% stems affected; 2, 25-50% stems affected; 3, 50-75%stems affected; 4, >75% stems affected; 5, 100% stems affected (all shoots pruned off or plant moribund

Table 20 Tuber treatments in a field trial in old ground, Yeodene 1999/2000

Treatment	Active ingredient	Application	Rate
Boron	boron	soil spray	40L/ha (34.6ml/plot)
Hydrogen Peroxide	30%w/hydrogen peroxide v	tuber dip	500ml diluted to 5L
Mancozeb® Fungicide	800g/kg mancozeb	tuber spray	1g/kg seed
Maxim 100 FS® Fungicide	100g/L fludioxonil	tuber spray	0.25ml/kg seed
Peratec 5 Sanitiser® (1%)	250g/L hydrogen peroxide, 50g/L peroxyacetic acid	tuber dip	50ml diluted to 5L
Peratec 5 Sanitiser® (1%)	250g/L hydrogen peroxide, 50g/L peroxyacetic acid	tuber spray	10ml/L
Shirlan® Fungicide	500g/L fluazinam	tuber spray	1ml/kg seed
Tato Dust® Fungicide	200g/kg mancozeb	tuber dust	4g/kg seed
Mancozeb® Fungicide	800g/kg mancozeb	soil spray	19.65kg/ha (17g/plot)

Table 21 Incidence and severity of diseases on seed potato tubers (cv. Atlantic) planted in a field trial in old ground, Yeodene 1999/2000

Disease	Black Dot	Silver Scurf	Black Scurf	Powdery Scab	Common Scab
% tubers affected	10	78	2	0	2
Severity (0-4)[A]	0.20	2.04	0.04	0.00	0.02

[A] Black scurf severity rating: 0, no disease; 1, a trace; 2, slight; 3, moderate; 4, severe.
Black dot, silver scurf, powdery and common scab severity rating: 0, no disease; 1, <2%; 2, 2-10%; 3, 10-25%; 4, >25% tuber surface affected.

Table 22 Effects of pre-planting seed tuber and soil treatments on common scab and other diseases of progeny tubers in a field trial in old ground, Yeodene 1999/2000

Treatment	Common Scab		Black Dot		Silver Scurf		Black Scurf		Powdery Scab	
	% tubers affected	Severity (0-10)[A]	% tubers affected	Severity (0-4)[B]	% tubers affected	Severity (0-4)[A]	% tubers affected	Severity (0-4)[C]	% tubers affected	Severity (0-4)[B]
Seed treatments										
Untreated minitubers	99.6	4.69	31.6	0.48	6.4	0.06	47.2	0.82	0.00	0.000
Untreated control	100.0	4.26	54.4	1.02	20.4	0.23	46.4	0.76	0.00	0.000
Boron soil spray	98.4	3.76	61.2	0.96	26.0	0.30	65.2	1.10	0.00	0.000
Hydrogen Peroxide dip	99.2	4.35	57.2	0.89	34.4	0.40	64.0	1.08	0.40	0.004
Mancozeb spray	98.8	4.10	59.6	0.95	12.8	0.13	74.8	1.16	0.00	0.000
Maxim spray	99.6	4.11	57.2	0.98	17.6	0.19	64.8	1.04	0.40	0.004
Peratec dip	98.4	3.94	54.8	0.94	24.8	0.26	45.6	0.73	0.40	0.004
Peratec spray	99.2	3.72	65.6	1.16	20.4	0.23	93.2	1.52	0.00	0.000
Shirlan spray	99.6	3.85	63.2	1.11	24.4	0.26	36.4	0.45	0.00	0.000
Tato Dust	99.6	3.89	54.4	0.91	18.4	0.20	67.6	1.10	0.80	0.008
Soil treatments										
Untreated control	99.6	3.92	59.2	1.23	6.0	0.06	44.4	0.81	0.00	0.000
Mancozeb soil spray	99.5	4.14	46.2	0.85	10.0	0.12	29.3	0.49	0.80	0.008
F-test[D]	0.513	0.992	0.505	0.776	0.091	0.056	0.113	0.040	-	-
lsd (P=0.05)	1.70	1.50	12.11	0.34	12.84	0.15	36.84	0.58	-	-

[A] Common scab severity rating: 0, no disease; 1, 0-1%; 2, 1-5%; 3, 5-10%; 4, 10-15%; 5, 15-20%; 6, 20-33%; 7, 33-50%; 8, 50-66%; 9, 66-80%; 10, 80-100% tuber surface affected.
[B] Disease severity rating: 0, no disease; 1, <2%; 2, 2-10%; 3, 10-25%; 4, >25% tuber surface affected.
[C] Black Scurf severity rating: 0, no disease; 1, a trace; 2, slight; 3, moderate; 4, severe.
[D] Analysis of variance excluded minitubers and Mancozeb soil treatments.

Table 23 Details of seed tuber and soil treatments in a field trial in new ground, Colac 1997/98

Treatment	Active ingredient	Application	Rate
Maxim® 100 FS Fungicide	100g/L fludioxonil	tuber spray	0.15ml/kg of seed
Maxim® 100 FS Fungicide	100g/L fludioxonil	tuber spray	0.20ml/kg of seed
Maxim® 100 FS Fungicide	100g/L fludioxonil	tuber spray	0.25ml/kg of seed
Monceren® 250 FS Fungicide	250g/L pencycuron	tuber spray	0.60ml/kg of seed
Rizolex® 100 D Fungicide	100g/kg tolclofos-methyl	tuber dust	2g/kg of seed
Tecto® Flowable Fungicide	450g/L thiabendazole	tuber spray	2ml/kg of seed

Table 24 Incidence and severity of diseases on seed potato tubers (cv. Sebago) planted in a field trial, Colac 1997/98

Disease	Black scurf	Silver scurf	Black dot	Powdery scab	Common scab
% tubers affected	68.0	46.0	44.0	0.0	0.0
Severity (0-4)[A]	1.14	1.00	0.88	0.0	0.0

[A] Black scurf severity scale: 0, no disease; 1, a trace; 2, slight; 3, moderate; 4, severe. [B] Silver scurf, black dot, powdery scab and common scab severity ratings: 0, no disease; 1, <2%; 2, 2-10%; 3, 10-25%; 4, >25% tuber surface affected.

Table 25 Effects of pre-planting seed and soil treatments on diseases of progeny tubers in a field trial in new ground, Colac 1997/98

Treatment	Silver Scurf		Black Scurf	
	% tubers affected	Severity (0-4) [A]	% tubers affected	Severity (0-4) [B]
Untreated minitubers	9.2	0.112	1.6	0.016
Untreated control	57.6	0.864	19.2	0.428
Maxim 100 FS 15	26.8	0.332	1.6	0.016
Maxim 100 FS 20	12.4	0.140	4.4	0.072
Maxim 100 FS 25	10.8	0.108	2.4	0.024
Monceren 250 FS	51.6	0.728	0.8	0.008
Rizolex 100 D	52.4	0.776	16.0	0.340
Tecto Flowable	58.0	0.904	3.2	0.052
F-test	<0.001	<0.001	<0.001	<0.001
lsd (P=0.05)	12.03	0.2150	7.412	0.1797

[A] Silver Scurf severity rating: 0, no disease; 1, <2%; 2, 2-10%; 3, 10-25%; 4, >25% tuber surface affected
[B] Black Scurf severity scale: 0, no disease; 1, a trace; 2, slight; 3, moderate; 4, severe

Table 26 Effects of pre-planting seed tuber and soil treatments on total and marketable yield and the number and yield of progeny tubers in different size categories in a field trial in new ground, Colac, 1997/98

Treatment	Total yield (kg/plot)	Marketable yield (35-350g (kg/plot)	<35 g		35-110 g		110-250 g		250-350 g	
			Tubers/plot	kg/plot	Tubers/plot	kg/plot	Tubers/plot	kg/plot	tubers/plot	kg/plot
Untreated control	23.05	22.48	30.4	0.574	162.2	12.84	60.8	9.28	1.20	0.362
Untreated minitubers	16.06	15.94	7.0	0.122	38.6	3.03	60.0	10.18	8.20	2.730
Maxim A	22.70	21.78	48.8	0.922	201.0	14.61	47.8	7.00	0.60	0.176
Maxim B	22.91	21.91	45.6	0.992	194.2	14.52	51.2	7.14	0.60	0.248
Maxim C	22.27	21.32	44.4	0.946	212.4	15.24	43.2	6.03	0.20	0.054
Monceren	22.95	21.98	49.0	0.966	183.8	12.94	58.2	8.60	1.20	0.446
Rizolex	21.65	20.85	34.6	0.796	166.4	11.90	58.8	8.75	0.60	0.210
Tecto	22.71	21.99	32.4	0.724	167.2	11.86	60.8	9.87	0.80	0.254
F-test[A]	0.964	0.961	<0.001	<0.001	<0.001	<0.001	0.425	0.141	<0.001	<0.001
lsd (P=0.05)	3.301	3.267	15.44	0.325	33.46	2.326	18.63	2.963	2.024	0.7398

[A] Statistical analysis excluding minituber data

Table 27 Tuber and soil treatments in a field trial in new ground, Colac, Victoria 1998/99

Treatment	Active ingredient	Application	Rate
Maxim® 100 FS	100g/L fludioxonil	Tuber spray	25.0ml/100kg of seed
Monceren® 250 FS	250g/L pencycuron	Tuber spray	60.0ml100kg of seed
Rizolex® 100 D	100g/kg tolclofos-methyl	Tuber dust	200g/100kg of seed
Rovral® Liquid Fungicide	250g/L iprodione	Tuber spray	80ml/100kg of seed

Table 28 Incidence and severity of diseases on seed potato tubers (cv. Denali) planted in a field trial in new ground, Colac 1998/99

Disease	Black Scurf	Silver Scurf	Black Dot	Powdery scab	Common scab
% tubers affected	100	56	0.0	0.0	0.0
Severity (0-4)[A]	2.56	0.86	0.0	0.0	0.0

[A] Black scurf severity rating: 0, no disease; 1, trace; 2, slight; 3, moderate; 4, severe
Silver scurf, black dot, powdery and common scab severity ratings: 0, no disease; 1, <2%; 2, 2-10%; 3, 10-25%; 4, >25% tuber surface affected

Table 29 Effects of pre-plant seed tuber and soil treatments on the diseases on progeny tubers (cv. Denali) in a field trial in new ground, Colac 1998/99

Treatment	Rhizoctonia stem canker[D]		Tuber diseases					
			Black Dot		Silver Scurf		Black Scurf	
	% plants affected	Severity (0-5)[A]	% tubers affected	Severity (0-4)[B]	% tubers affected	Severity (0-4)B	% tubers affected[A]	Severity (0-4)[C]
Untreated minitubers	36.1	0.47	4.3	0.04	12.3	0.16	2.0	0.02
Untreated control	63.9	0.83	10.0	0.14	26.7	0.38	60.7	1.38
Maxim 100 FS	51.7	0.60	4.7	0.05	2.0	0.02	5.3	0.08
Monceren 250 FS	52.2	0.61	4.7	0.06	31.0	0.44	2.0	0.04
Rizolex 100 D	30.6	0.39	2.3	0.02	17.3	0.24	84.3	2.10
Rovral Liquid Fungicide	83.3	1.53	2.3	0.02	19.7	0.28	63.7	1.39
F-test	0.009	<0.001	0.377	0.124	<0.001	<0.001	<0.001	<0.001
lsd (P=0.05)	24.29	0.39	7.40	0.10	10.94	0.16	12.68	0.34

[A] Stem canker severity scale: 0, no symptoms (healthy); 1, <25% stems affected; 2, 25-50% stems affected; 3, 50-75%stems affected; 4, >75% stems affected; 5, 100% stems affected (all shoots pruned off or plant moribund)
[B] Black dot and silver scurf severity rating: 0, no disease; 1, <2%; 2, 2-10%; 3, 10-25%; 4, >25% tuber surface affected
[C] Black Scurf severity rating; 0, no disease; 1, a trace; 2, slight; 3, moderate; 4, severe
[D] Data on the incidence and severity of stem canker was confounded with heat damage to stems

Table 30 Effects of pre-planting seed tuber and soil treatments on total and marketable yield and on tuber size and yield of progeny tubers (cv. Denali) in a field trial in new ground, Colac 1998/99

Treatment	Total yield (kg/plot)	Marketable yield (35-350 g) (kg/plot)	<35g		35-110g		110-250g		250-350g		>350g	
			Tubers/ plot	kg/plot	Tubers/ plot	kg/plot	Tubers/ plot	kg/plot	Tubers/ plot	kg/plot	Tubers/ plot	kg/plot
Untreated minitubers	23.97	23.32	20.7	0.39	104.3	7.75	83.2	13.94	5.5	1.63	0.7	0.27
Untreated control	29.09	28.32	32.7	0.51	113.3	9.00	109.8	17.69	5.7	1.64	0.7	0.25
Maxim	29.46	28.87	29.8	0.45	145.0	11.63	100.0	15.65	5.5	1.59	0.3	0.14
Monceren	26.54	26.07	22.7	0.37	130.2	10.34	92.8	14.97	2.7	0.76	0.2	0.10
Rizolex	27.66	27.24	18.2	0.29	118.3	10.03	100.8	16.09	4.0	1.12	0.3	0.13
Rovral	28.89	27.92	23.2	0.41	113.3	9.04	105.3	16.97	6.5	1.91	1.3	0.56
F-test	0.013	0.011	0.163	0.117	0.194	0.042	0.032	0.199	0.439	0.414	0.526	0.453
lsd (P=0.05)	3.17	3.08	9.95	0.16	30.21	2.44	14.78	2.70	3.77	1.12	0.10	0.4

Table 31 Tuber and soil treatments in a field trial in new ground, Colac 1999/2000

Treatment	Active ingredient	Application	Rate
Rizolex® 100 D	100g/kg tolclofos-methyl	tuber dust	200g/100kg of seed
Monceren® 250 FS	250g/L pencycuron	tuber spray	60.0ml100kg of seed
Hydrogen Peroxide	30%w/v hydrogen peroxide	tuber dip	1.8L diluted to 18L
Peratec 5 Sanitiser® (1.0%)	250g/L hydrogen peroxide, 50g/L peroxyacetic acid	tuber dip	180ml diluted to 18L
Peratec 5 Sanitiser® (2.0%)	250g/L hydrogen peroxide, 50g/L peroxyacetic acid	tuber dip	360ml diluted to 18L
Sporekill® (1.0%)	120g/L didecyldimethyl ammonium chloride	tuber dip	180ml diluted to 18L

Table 32 Incidence and severity of diseases on seed potato tubers (cv. 91-106-1) planted in a field trial in new ground, Colac 1999/2000

Disease	Black Scurf	Silver Scurf	Black Dot	Powdery scab	Common scab
% tubers affected	62	62	12	0.0	0.0
Severity (0-4)[A]	1.50	1.08	0.18	0.0	0.0

[A] Black scurf severity rating: 0, no disease; 1, trace; 2, slight; 3, moderate; 4, severe
Severity rating on other diseases: 0, no disease; 1, <2%; 2, 2-10%; 3, 10-25%; 4, >25% tuber surface affected

Table 33 Effects of pre-planting seed tuber treatments on the diseases of progeny tubers (cv. 91-106-1) in a field trial in new ground, Colac 1999/2000

Treatment	Black Scurf	
	% tubers affected	Severity (0-4)[A]
Untreated minitubers	0.00	0.00
Untreated control	22.4	0.34
Rizolex 100 D	8.0	0.14
Monceren 250 FS	0.00	0.00
Hydrogen Peroxide (10%)	20.0	0.32
Peratec 5 Sanitiser (1.0%)	10.4	0.18
Peratec 5 Sanitiser (2.0%)	12.8	0.27
Sporekill (1.0%)	27.2	0.45
F-test[B]	<0.001	0.002
lsd (P=0.05)	11.93	0.22

[A] Black Scurf severity rating; 0, no disease; 1, a trace; 2, slight; 3, moderate; 4, severe
[B] Minituber data excluded from the statistical analysis.

Table 34 Effects of pre-planting seed tubers treatments on total and marketable yield and on the tuber number and yield of progeny tubers in different size categories in a field trial in new ground, Colac 1999/2000

Treatment	Total yield	Marketable yield (35-350g)	<35g		35-110g		110-250g		250-350g		>350g	
	(kg/plot)	(kg/plot)	Tubers/ plot	kg/plot	Tubers/ plot	kg/plot	Tubers/ plot	kg/plot	Tubers/ plot	kg/plot	Tubers/ plot	kg/plot
Untreated minitubers	34.91	32.56	32.0	0.63	124.0	8.43	107.6	17.59	24.2	6.54	4.4	1.72
Untreated control	42.84	40.59	46.2	1.16	195.8	13.61	137.6	21.69	18.0	5.28	2.6	1.09
Rizolex 100 D	39.65	37.94	51.4	1.14	188.4	13.46	128.6	20.12	14.2	4.36	1.4	0.57
Monceren 250 FS	40.27	38.61	37.4	0.99	192.6	12.82	138.0	22.73	10.8	3.07	1.4	0.67
Hydrogen Peroxide (10%)	41.13	38.58	60.4	1.23	184.6	12.58	140.4	21.95	14.8	4.04	3.2	1.32
Peratec (1%)	40.72	38.47	46.4	1.06	155.8	10.89	140.4	22.93	16.8	4.66	3.0	1.19
Peratec (2%)	45.14	43.07	30.4	0.64	180.8	12.84	146.0	24.00	21.6	6.23	3.6	1.43
Sporekill (1%)	39.48	37.28	32.6	0.71	174.8	12.16	132.0	20.99	14.6	4.13	3.6	1.49
F-test[A]	0.672	0.679	0.110	0.529	0.378	0.135	0.789	0.652	0.073	0.100	0.269	0.284
lsd (P=0.05)	6.97	6.45	22.50	0.62	38.52	2.34	25.33	4.36	8.05	2.50	3.03	1.25

[A] Minituber data excluded from the statistical analysis.

Table 35 Tuber and soil treatments in a field trial in new ground (8 years pasture), Colac 2000/2001

Treatment	Active ingredient	Application	Rate
Monceren® 250 FS	250g/L pencycuron	soil spray	120.0ml/100kg of seed
Monceren® 250 FS	250g/L pencycuron	Tuber spray	60.0ml/100kg of seed
Peratec 5 Sanitiser®	250g/L hydrogen peroxide, 50g/L peroxyacetic acid	Tuber dip	750ml diluted to 15L
Triton X-100®	non-ionic surfactant	Tuber dip	150ml diluted to 15L

Table 36 Incidence and severity of diseases on seed potato tubers (cv. Coliban) planted in a field trial in new ground, Colac 2000/2001

Disease	Black Scurf[A]	Silver Scurf[B]	Black Dot[B]	Powdery scab[B]	Common scab[B]
% tubers affected	72	92	2	0.0	0.0
Severity (0-4)[A]	1.20	2.72	0.02	0.0	0.0

[A] Black scurf severity rating: 0, no disease; 1, trace; 2, slight; 3, moderate; 4, severe
[B] Severity rating: 0, no disease; 1, <2%; 2, 2-10%; 3, 10-25%; 4, >25% tuber surface affected

Table 37 Effects of pre-planting seed tuber treatments on plant emergence, growth (stunting) and Rhizoctonia stem canker a field trial in new ground, Colac 2000/2001

Treatment	Emergence	Stunting		No. stems/ plant	Rhizoctonia stem Canker	
	(Max. 42)	% plants affected	Severity (0-3)[A]		% plants affected	Severity (0-5)[B]
Untreated Russet Burbank minitubers	42.0	0.00	0.00	2.8	6.7	0.07
Untreated Exton minitubers	42.0	13.8	0.15	1.2	0.0	0.00
Exton minitubers +Monceren 250 FS soil spray	41.6	3.4	0.05	1.3	3.3	0.03
Untreated control	41.6	3.4	0.05	7.1	66.7	1.50
Monceren 250 FS Seed spray	39.6	5.5	0.08	6.6	20.0	0.23
Monceren 250 FS Soil spray	41.4	4.4	0.07	6.8	34.0	0.54
Peratec 5 Sanitiser (5%) Seed dip	40.2	6.5	0.10	5.0	23.3	0.60
Peratec 5 Sanitiser (5%) Seed dip + Monceren 250 FS Seed spray	37.4	11.8	0.20	4.7	6.7	0.17
Peratec 5 Sanitiser (5%) + Triton X-100 (1%) Seed dip	6.4	40.8	0.61	0.6	33.3	0.67
F-test	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
lsd.(P=0.05)	2.67	15.28	0.21	1.09	24.81	0.52

[A] Stunting severity scale: 0, none; 1, slight; 2, moderate; 3, severe stunting
[B] Stem canker severity scale: 0, no symptoms; 1, a trace; 2, low; 3, moderate; 4, heavy; 5, severe

Table 38 Effects of pre-planting seed treatments on tuber yield of potatoes in a field trial in new ground, Colac 2000/2001

Treatment	Total yield (kg/plot)	Total yield (t/ha)
Untreated Russet Burbank Minitubers	12.76	15.69
Untreated Exton Minitubers	12.91	15.88
Exton Minitubers + Monceren 250 FS Soil spray	12.79	15.73
Untreated control (Russet Burbank)	25.92	31.88
Monceren 250 FS Seed spray	15.68	19.29
Monceren 250 FS Soil spray	24.89	30.61
Peratec 5 Sanitiser (5%) Seed dip	24.52	30.16
Peratec 5 Sanitiser (5%) Seed dip + Monceren 250 FS Seed spray	23.94	29.45
Peratec 5 Sanitiser (5%) + Triton X-100 (1%) Seed dip	3.49	4.29
F-test	<0.001	-
lsd.(P=0.05)	7.40	-

Table 39 Effects of pre-planting seed treatments of seed potatoes on the diseases on progeny plants and tubers (cv. Coliban) in a field trial in new ground, Colac 2000/2001

Treatment	Black Dot		Silver Scurf		Black Scurf		Common Scab	
	% tubers affected	Severity (0-4)[A]	% tubers affected	Severity (0-4)[A]	% tubers affected	Severity (0-4)[B]	% tubers affected	Severity (0-4)[A]
Untreated Russet Burbank Minitubers	1.2	0.01	9.2	0.10	0.8	0.01	0.0	0.00
Untreated Exton Minitubers	2.8	0.04	12.8	0.13	0.8	0.01	1.2	0.01
Exton Minitubers + Monceren 250 FS Soil spray	2.4	0.02	16.8	0.22	1.6	0.02	0.0	0.00
Untreated control (cv. Coliban)	2.4	0.03	41.2	0.49	48.5	1.07	0.8	0.01
Monceren 250 FS Seed spray	0.8	0.01	33.6	0.40	0.8	0.01	0.4	0.00
Monceren 250 FS Soil spray	2.0	0.03	42.8	0.50	16.8	0.32	0.8	0.01
Peratec 5 Sanitiser (5%) Seed dip	2.0	0.04	44.0	0.59	28.8	0.55	0.0	0.00
Peratec 5 Sanitiser (5%) Seed dip + Monceren 250 FS Seed spray	3.2	0.04	36.4	0.46	2.4	0.02	0.8	0.01
Peratec 5 Sanitiser (5%) + Triton X-100 (1%) Seed dip	0.0	0.00	26.4	0.31	3.3	0.03	2.5	0.03
F-test	0.512	0.402	<0.001	<0.001	<0.001	<0.001	0.664	0.675
lsd (P=0.05)	3.05	0.04	15.83	0.22	11.57	0.25	2.69	0.03

[A] Disease severity rating: 0, no disease; 1, <2%; 2, 2-10%; 3, 10-25%; 4, >25% tuber surface affected
[B] Black scurf severity rating; 0, no disease; 1, trace; 2, slight; 3, moderate; 4, severe

3.3 Evaluating chemical seed treatments for the control of seed-borne powdery scab, common scab and other seed-borne diseases of potato tubers – glasshouse trials

Introduction

There are currently no registered seed tuber treatments for the management of powdery scab in Australia. Farmers use formaldehyde in the absence of other suitable treatments. Common scab has also become a significant problem for seed growers over the past five or more years. Trials were conducted in the glasshouse to evaluate fungicide and disinfectant chemical treatments for the control of seed-borne powdery and common scab.

Materials and Methods

Three glasshouse experiments were conducted, two to evaluate treatments against seed-borne powdery scab and a third to evaluate treatments against seed-borne common scab. In experiment 1, whole seed tubers of cv. Sebago (35-85 g), from a lot affected with symptoms of powdery scab, were sorted into a ‘clean’ category with no apparent symptoms of powdery scab, and ‘scabby’ category with 1-5% of their surface covered with scab pustules. In experiment 2 (August 1999), whole seed tubers of cv. 93-35-9 with symptoms of powdery scab were selected and in experiment 3 (February 2000) tubers of cv. Desiree with common scab were selected. The incidence and severity of disease on seed tubers for experiments 2 and 3 are presented in Table 42 and Table 44, respectively.

Batches of 7 (experiment 1) or 10 (experiments 2 and 3) replicate tubers (experimental unit - one tuber) were left untreated, washed in water, sprayed with, or immersed in solutions of fungicides and disinfectant chemical solutions. Dip treatments involved immersing each batch of tubers for 2 minutes in 2L of solution. The sprayed treatments involved spraying solutions (10 ml) onto tubers in a rotating bucket to ensure even coverage. Details of the experimental treatments used in experiments 1, 2 and 3 are presented in Table 40, Table 43 and Table 45, respectively.

After treatment, tubers were allowed to dry under ambient conditions (about one hour) and planted into 25 cm diameter black plastic pots (one tuber/pot) filled with a pasteurised (60°C for 1 hr), sand-based-potting media (Pro Pine Seed Raising Mix™; 6 parts medium sand, 2 parts peat moss and 1 part brown coal). Pots were arranged on glasshouse benches in row-column design to take into account drying effects from glasshouse fans. In experiments 1 and 2, pots were watered to saturation with chilled water (8°C) three times a day for two months over the critical tuber setting period to ensure conditions favourable to the development of powdery scab. Pots were placed on saucers to ensure maximum periods of soil saturation over this period. Thereafter, pots were watered once per day with water at ambient temperature. In experiment 3, pots were irrigated lightly with water at ambient temperature to ensure conditions favourable for common scab. Plants in all experiments were fertilised with slow release granules and with liquid fertiliser as required.

In each experiment, the tops of plants were removed when tubers had reached maximum size, and tubers harvested approximately one month later. Harvested tubers were washed to remove soil and organic debris and the severity of powdery scab and other disease symptoms rated according to the severity of tuber surface covered with a particular symptom (see footnotes in Table 41, Table 43 and Table 45). Disease incidence was recorded as the proportion of tubers with a particular disease symptom.

Data were analysed using REML Variance Component Analysis for a row/column design or Regression Analysis using a Generalised Linear Model for binomial data (Genstat for Windows 5th Edition™; Lawes Agricultural Trust, Rothamsted Experimental Station).

Results

In experiment 1, the incidence of progeny tubers with powdery scab was relatively low and highly variable between replicate pots as indicated by the large differences in disease incidence in the different control treatments. The disease developed in the progeny of both the 'clean' and 'scabby' seed lots (Table 41). Although regression analysis showed some statistical differences between treatments, there were no clear patterns demonstrating differences between untreated controls and treatments. Powdery scab was not found on any tubers from in the progeny of 'clean' seed treated with Formalin and Shirlan and 'scabby' seed treated with Peratec 5 Sanitiser and Shirlan.

In experiment 2, a relatively high incidence of progeny tubers developed powdery scab (Table 43). Generally, seed treatments did not reduce the incidence and severity of scab in the progeny compared with the untreated controls. The relatively uniform incidence of powdery scab across all treatments suggests that the pots were contaminated with powdery scab during the course of the experiment.

The incidence of common scab in progeny tubers of experiment 3 was relatively low and highly variable between replicate pots (Table 45). Disease incidence varied ($P=0.015$) with treatments. The incidence of common scab was higher ($P \leq 0.05$) in the washed untreated control than in the unwashed control. Overall, the disease incidence in the progeny of treated seed did not differ significantly ($P>0.05$) to disease incidence in the than in the progeny of the unwashed untreated control seed. The severity of common scab also did not differ significantly when comparing progeny of the unwashed control and treated seed.

A relatively high incidence of black scurf developed in the progeny in all three experiments (Table 41, Table 43, Table 45). However, although the average incidence of affected tubers was high, only a small number of replicate pots were affected with the disease and disease incidence in each of these was relatively high. Generally, there were no significant treatment effects on black scurf incidence or severity. Progeny in experiment 2 also had silver scurf (Table 43). In the incidence and severity was not affected by seed tuber treatments.

Discussion

Glasshouse pot trials did not provide conclusive data on the efficacy of seed tuber treatments for the control of seed-borne powdery scab and common scab despite carry-over of disease from mother to daughter tubers. Disease incidence and severity in the progeny was generally very low and highly variable between replicate pots. As a result there were few, if any statistical differences between treatments. This shows that the severity of disease on seed tubers in experiments like these will have to be very high in order to develop significant disease levels in the progeny.

Table 40 Experiment 1 - Fungicide treatments for the control of seed-borne powdery scab in a glasshouse trial

Product	Active ingredient	Method of application[A]	Rate of application
Formalin®	36% w/v formaldehyde	Tuber dip	1.4% product (0.5% active)
Oxine®	52.6g/L available Cl as 20g/L $Cl0_2$	Tuber dip	0.5% product
Peratec 5 Sanitiser®	250g/L H_20_2 50g/L peroxyacetic acid	Tuber dip	0.5% product
Phytoclean®	100g/L benzalkonium chloride	Tuber dip	1% product
Shirlan® Fungicide	500g/L fluazinam	Tuber spray	100 ml/100kg
Nebijin® Fungicide	50g/L flusulfamide	Tuber spray	50 ml/100kg
Maxim® 100FS Fungicide	100g/L fludioxonil	Tuber spray	25 ml/100kg
Mancozeb® Fungicide	800g/kg mancozeb	Tuber spray	100 g/100kg

[A] Tuber dip: batches of tubers immersed in chemical solutions for 2 minutes

Table 41 Experiment 1 - Effects of pre-plant treatments of seed potatoes (cv. Sebago) with fungicides and disinfectants on the incidence and severity of powdery scab and black scurf on progeny tubers

Treatment	Powdery scab		Black scurf	
	% tubers affected	Severity (0-4)[A]	% tubers affected	Severity (0-4)[B]
'Clean' seed tubers				
Untreated	3.57	0.04	83.9	0.92
Washed untreated	14.29	0.14	28.6	0.62
Formalin dip	0.00	0.00	28.6	0.55
Shirlan® tuber spray	0.00	0.00	28.6	0.71
'Scabby' seed tubers				
Untreated	17.38	0.17	39.3	0.84
Washed untreated	2.38	0.02	42.9	0.92
Formalin dip	3.57	0.04	28.6	0.66
Oxine® dip	8.10	0.11	57.1	1.42
Peratec 5 Sanitiser® dip	0.00	0.00	66.7	1.53
Phytoclean® dip	5.24	0.05	71.4	1.63
Shirlan® tuber spray	0.00	0.00	14.3	0.39
Nebijin® tuber spray	8.57	0.09	25.0	0.50
Maxim® tuber spray	4.71	0.05	14.3	0.29
Mancozeb® tuber spray	2.86	0.03	42.9	0.96

[A] Black dot, silver scurf and powdery scab disease severity scale: 0, no disease; 1, <2%; 2, 2-10%; 3, 10-25%; 4, >25% tuber surface affected.
[B] Black Scurf severity scale: 0, no disease; 1, a trace; 2, slight; 3, moderate; 4, severe.

Table 42 Experiment 2: Incidence and severity of diseases on seed tubers (cv. 93-35-9) prior to treatment and planting

(50 tuber sample washed and inspected)

Disease	Powdery Scab	Black Dot	Silver Scurf	Black Scurf	Common Scab
% tuber affected	94.0	90.0	86.0	38.0	0.0
Severity (0-4)[A]	1.58	1.94	1.30	0.54	0.0

[A] Black Scurf severity scale: 0, no disease; 1, a trace; 2, slight; 3, moderate; 4, severe.
Black dot, silver scurf, powdery and common scab disease severity scale: 0, no disease; 1, <2%; 2, 2-10%; 3, 10-25%; 4, >25% tuber surface affected.

Table 43 Experiment 2 - Effects of pre-plant treatments of seed potatoes (cv. 93-35-9) with fungicides and disinfectants on the incidence and severity of powdery scab, silver scurf and black scurf on progeny tubers

Treatment	Rate of product	Powdery scab		Silver scurf		Black scurf	
		% tubers affected	Severity (0-4)[A]	% tubers affected	Severity (0-4)[B]	% tubers affected	Severity (0-4)[C]
Untreated	-	61.4	1.37	16.8	0.32	31.4	0.55
Untreated/washed	-	47.4	1.14	28.1	0.56	33.1	0.79
Formalin dip	1.4%	51.7	1.60	26.3	0.61	9.4	0.12
Shirlan® spray	100 ml/100kg	62.9	1.42	4.7	0.05	35.0	0.55
Mancozeb® spray	100 g/100 kg	68.5	2.20	26.5	0.48	20.2	0.37
Peratec 5 Sanitiser®	0.5%	71.4	2.05	25.4	0.47	26.9	0.67
W–Peratex 5 Sanitiser®[D]	0.5%	56.0	1.30	20.4	0.47	23.5	0.38
W–Peratex 5 Sanitiser®[D]	1.0%	63.4	1.41	17.3	0.34	47.1	0.97
Hydrogen peroxide	10%	61.2	1.72	17.8	0.38	63.2	1.12
W-Hydrogen peroxide[D]	10% product	42.3	1.01	14.0	0.25	25.5	0.52
F-test		0.053	n.s.	n.s.	n.s.	n.s.	n.s.
lsd (P=0.05)		18.37					

[A] Powdery scab severity rating: 0, no symptoms; 1, 0-1%; 2, 1-5%; 3, 5-10%; 4, 10-15%; 5, 15-20%; 6, 20-33%; 7, 33-50%; 8, 50-66%; 9, 66-80%; 10, 80-100% tuber surface affected
[B] Silver scurf severity rating: 0, no disease; 1, <2%; 2, 2-10%; 3, 10-25%; 4, >25% tuber surface affected
[C] Black Scurf severity rating: 0, no disease; 1, a trace; 2, slight; 3, moderate; 4, severe
[D] Seed tubers washed before treatment

Table 44. Experiment 3: Incidence and severity of diseases on seed tubers (cv. Desiree) prior to treatment and planting

(25 tuber sample washed and inspected)

Disease	Common Scab	Black Dot	Silver Scurf	Black Scurf	Powdery Scab
% tuber affected	96.0	100.00	100.0	16.0	0.0
Severity (0-4)[A]	1.84	3.12	2.04	0.24	0.0

[A] Black Scurf severity scale: 0, no disease; 1, a trace; 2, slight; 3, moderate; 4, severe.
Black dot, silver scurf, powdery and common scab disease severity scale: 0, no disease; 1, <2%; 2, 2-10%; 3, 10-25%; 4, >25% tuber surface affected.

Table 45. Experiment 3 - Effects of pre-plant treatments of seed potatoes (cv. Desiree) with fungicides and disinfectants on the incidence and severity of common scab and black scurf in progeny tubers

Treatment	Rate of product	Common scab		Black scurf	
		% tubers affected	Severity (0-4)[A]	% tubers affected	Severity (0-4)[B]
Untreated	-	12.5	0.26	39.1	1.05
Washed untreated	-	28.9	0.39	35.1	0.77
Tato dust® dust	400 g/100kg	11.6	0.18	30.0	0.73
Mancozeb® spray	100 g/100kg	24.2	0.50	13.3	0.28
Shirlan® spray	100 ml/100kg	7.5	0.11	6.0	0.11
Hydrogen peroxide dip	10%	11.8	0.20	40.0	0.94
Hydrogen peroxide dip	20%	10.3	0.16	10.0	0.19
Peratec 5 Sanitiser® dip	1.0%	21.1	0.34	27.9	0.54
Peratec 5 Sanitiser® dip	2.0%	4.7	0.08	20.0	0.49
Sporekill® dip	1.0%	8.5	0.18	40.0	0.91
F-probability		0.015	0.104	0.602	0.483
lsd (P=0.05)		14.10	0.289	40.52	0.955

[A] Common scab disease severity scale: 0, no disease; 1, <2%; 2, 2-10%; 3, 10-25%; 4, >25% tuber surface affected
[B] Black Scurf severity scale: 0, no disease; 1, a trace; 2, slight; 3, moderate; 4, severe.

3.4 Evaluating disinfectant treatments for seed potatoes as potential replacements for formaldehyde

Introduction

The disinfectant chemical formaldehyde was traditionally used for the post-harvest treatment of seed potato tubers to control of a number of seed-borne diseases. Formaldehyde treatments were registered with the Department of Agriculture under the Pesticides Act 1958 (No. 6257) for the period 1973-1976 (Anon 1976) (Table 46). Seed growers today still use this chemical, even though it is not registered for this purpose with the National Registration Authority or the various State registration authorities. It is used as a pre-storage dip treatment for seed potatoes to control seed-borne powdery and common scab because there are no suitable registered seed treatments for either disease at present.

Table 46 Formaldehyde dip treatments for seed potatoes in the 1970's using Formalin™(40% formaldehyde)

Target	Concentration of product	% product
General	250ml/100L	0.25
Common scab	Immerse tubers in 2L Formalin/500L water for 1.5 to 2 hrs	0.40
Seed piece decay	Immerse tubers in 1L Formalin/500L for 5 minutes	0.20
Rhizoctonia black scurf	Immerse tubers in 1L Formalin/500L for 15 minutes (mixed with organic mercury)	0.20

Formaldehyde has many industrial uses, apart from its use as a disinfectant in agriculture and is also used as a powerful fixing (embalming) agent in medical diagnostics. A recent review by the National Cancer Institute in the United States of America raised concerns that the chemical is probable human carcinogen under conditions of high or prolonged exposure (Anon 1999). Its use in the potato seed industry should be discouraged. The challenge is to find suitable alternatives.

A series of experiments were conducted to evaluate disinfectant chemical treatments for use on potatoes as potential replacements for formaldehyde by using tubers with natural infections of *Rhizoctonia solani* (*Rs*) sclerotia (black scurf) and *Colletotrichum coccodes* (*Cc*) micro-sclerotia (black dot). Although not usually the intended targets of disinfectant treatments, these pathogens nevertheless served as useful 'models' for testing disinfectant treatments. The pathogens are visible on the tuber skin, can be easily treated by immersing tubers in disinfectant solutions and can easily be cultured after treatment.

Another series of experiments evaluated the effects of disinfectant treatments on the viability of cystosori ('sporeballs') of the powdery scab pathogen *S. subterranea*. Because this pathogen cannot be cultured on agar, a tomato plant bioassay was developed to determine the effect of chemicals on the sporeballs.

3.4.1 Evaluating the efficacy of disinfectants by treating seed tubers

Materials and Methods

Efficacy

Whole, commercial seed potato tubers (cvs. 91-106-1, Coliban) with symptoms of black scurf (*Rhizoctonia solani*) (*Rs)* were immersed in disinfectant solutions or distilled water for 2 minutes, removed and allowed to dry for one hour. Four 3.5 mm diameter skin cores, taken from areas of skin covered with 3-4 mm diameter sclerotia of *Rs*, were excised from each tuber, rinsed in sterile-distilled-water, cut in half and each segment plated onto potato dextrose agar amended with 25 µg/ml tetracycline hydrochloride. The radial growth of *Rs* from each sclerotial segment was measured (two diameters at right angles to each other) and recorded after 24, 48 or 72 hours incubation at 21°C. Tubers of cv. Russet Burbank with symptoms of black dot (micro-sclerotia of *Colletotrichum coccodes*) were similarly treated and the radial growth of the fungus (*Cc*) recorded after 69 and 93 hours incubation.

Disinfectants were used at both 'standard' and 5 times standard label recommended concentrations for disinfection of non-organic surfaces. Combinations of disinfectants and a surfactant were also tested.

Phytotoxicity

Sprouted seed tubers (cvs. Coliban and Sebago minitubers and Coliban commercial seed) were also treated with disinfectants, with or without a surfactant (Triton X-100® - non-ionic surfactant), as previously described and planted into a pasteurised sand/peat medium in 7.5 or 15cm diameter plastic pots and grown-on in a glasshouse. The proportion of plants emerged, number of stems/plant and plant-height were recorded after 41 days to determine any phytotoxic effects of disinfectant treatments. The commercial seed was physiologically old (12 months) and sprouts were removed before treatment.

Results and Discussion

The formaldehyde treatment was relatively toxic to sclerotia of *Rs* but not to those of *Cc*. A two minute immersion of tubers with black scurf in a formaldehyde solution either killed the *Rs* sclerotia of the size tested or severely reduced their viability (Table 47, Table 49, Figure 13). However, this treatment had no significant effect on the viability of micro-sclerotia of *Cc* (Table 48, Figure 14). Several other disinfectant treatments significantly ($P \leq 0.05$) reduced the viability of *Rs* sclerotia. However, only the Biogram treatments, the high rates of Peratec 5 Sanitiser and Phytoclean were as effective as the formaldehyde treatment. The hydrogen peroxide and the Oxine treatments were relatively ineffective. *Rs* sclerotia plated out seven days after treatment generally tended to produce smaller colonies than those plated out soon after treatment (Table 49).

The highest rate of Biogram significantly ($P \leq 0.05$) reduced the viability of *Cc* sclerotia (33% reduction in growth of *Cc*) (Table 49). The micro-sclerotia are partially embedded in the potato periderm giving them some protection from disinfectant chemicals. The *Rs* sclerotia, on the other hand, sit on the skin surface and are, therefore, more exposed the chemicals.

Adding Triton X-100 (1%) to a 1% solution of Peratec 5 Sanitiser enhanced the efficacy of the treatment as shown by the reduction in the radial growth of *Rs* (Table 49). The combined treatment of the disinfectant and surfactant, both at 1%, was as effective as 5% solution of

Peratec 5 Sanitiser without surfactant. The Triton treatment on its own, however, reduced viability of sclerotia intermediate to the 1% and 5% disinfectant. The use of surfactants as disease control agents needs to be explored further.

A number of disinfectant treatments proved to be phytotoxic to sprouted, physiologically old seed (Table 50, Table 51). The Formalin treatments and the highest rates of sodium hypochlorite, Biogram and Phytoclean were the most phytotoxic to commercial seed tubers (cv. Coliban), significantly affecting the number of sprouts emerged and plant growth. Minitubers of cv. Sebago were less affected, although the high rates of Biogram and Phytoclean killed all sprouts on these tubers (Table 50). In a second experiment, the combination of a low rate of Peratec 5 Sanitiser plus Triton X-100 was phytotoxic, reducing the number of sprouts and the growth of desprouted physiologically old cv. Coliban seed (Table 51), whereas the disinfectant chemical on its own was not phytotoxic. This effect was not apparent on cv. Coliban minitubers that had not been desprouted.

This study indicates that disinfectant treatments can potentially be used to manage pathogens on seed potatoes at the post-harvest stage. There are a number of chemicals from the different chemical groups, particularly the peroxygens, phenolic detergents and quaternary ammoniums, which could replace formaldehyde. However, efficacy, cost, human and environmental safety and phytotoxicity will determine which is most appropriate for the potato shed. None of the disinfectant treatments tested here are registered for this purpose and more research is needed to demonstrate efficacy and safety to potatoes, the environment and user.

Surfactants can be used to enhance the effects of disinfectants. The manufacturer of Peratec 5 Sanitiser has released a formulation of this of peroxyacetic acid/hydrogen peroxide that includes a surfactant (Perfoam 2®).

Table 47 Effects of disinfectant treatments of whole seed tubers affected with black scurf on the viability of *Rhizoctonia solani* sclerotia, as measured by the radial growth of the fungi on PDA

(Seed tubers immersed for 2 minutes in disinfectant solution or distilled water)

Product	Treatment (% of product)	Radial growth (colony diameter in mm) Experiment 1 (cv. 91-106-1)		Experiment 2 (cv Coliban G4)	
		24 hrs	72 hrs	48 hrs	72 hrs
Distilled water	-	4.95	15.4	9.45	23.22
Formalin	1.4%	0.00	0.00	0.00	0.37
Hydrogen peroxide	10.0%	5.50	19.4	-	-
Peratec 5 Sanitiser®	1.0%	0.63	3.60	5.04	19.88
Bleach	8.0%	1.63	4.2	14.97	23.39
Oxine®	0.5%	-	-	24.75	36.89
Biogram®	1.5%	-	-	0.25	3.30
Phytoclean®	1.0%	-	-	11.66	23.15
Sporekill®	1.0%	0.85	2.2	-	-
F-test		0.167	0.142	<0.001	<0.001
lsd (P=0.05)		2.46	17.01	2.75	3.81

Table 48 Effects of disinfectant treatments of whole seed tubers affected with black scurf or black dot on the viability of *Rhizoctonia solani* sclerotia and *Colletotrichum coccodes* microsclerotia as measured by the radial growth of the fungi on PDA

(Seed tubers immersed for 2 minutes in disinfectant solution or distilled water)

Product	Treatment (% of product)	Radial growth (colony diameter in mm) *R. solani* (cv. Coliban G4) Day 1[A]		Day 7[A]		*C. coccodes* (cv. Russet Burbank)	
		48 hrs	72 hrs	48 hrs	72 hrs	69 hrs	93 hrs
Water	-	31.76	49.23	25.02	42.68	11.49	16.64
Formalin	1.4%	0.06	0.22	0.50	1.77	12.81	18.96
Bleach	8.0%	16.55	29.54	8.05	16.11	12.44	18.38
Bleach	40.0%	7.93	20.33	0.32	1.64	13.97	19.73
Oxine	0.5%	26.67	45.50	24.02	42.08	12.69	19.12
Oxine	2.5%	23.67	48.36	18.69	33.75	12.83	18.29
Biogram	1.5%	0.21	2.31	0.00	0.52	9.76	14.02
Biogram	7.5%	0.00	0.00	0.00	0.00	7.66	14.02
Peratec 5 Sanitiser	1.0%	21.07	37.36	15.43	27.20	13.29	19.11
Peratec 5 Sanitiser	5.0%	1.09	2.41	0.96	1.52	13.79	20.23
Phytoclean	1.0%	8.49	24.63	17.11	34.07	12.48	17.89
Phytoclean	5.0%	4.20	15.61	6.20	14.26	15.83	21.86
F test		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
lsd (P=0.05)		3.67	5.95	4.63	3.90	1.89	2.76

[A] Sclerotia plated onto agar immediately after treatment or 7 days after treatment

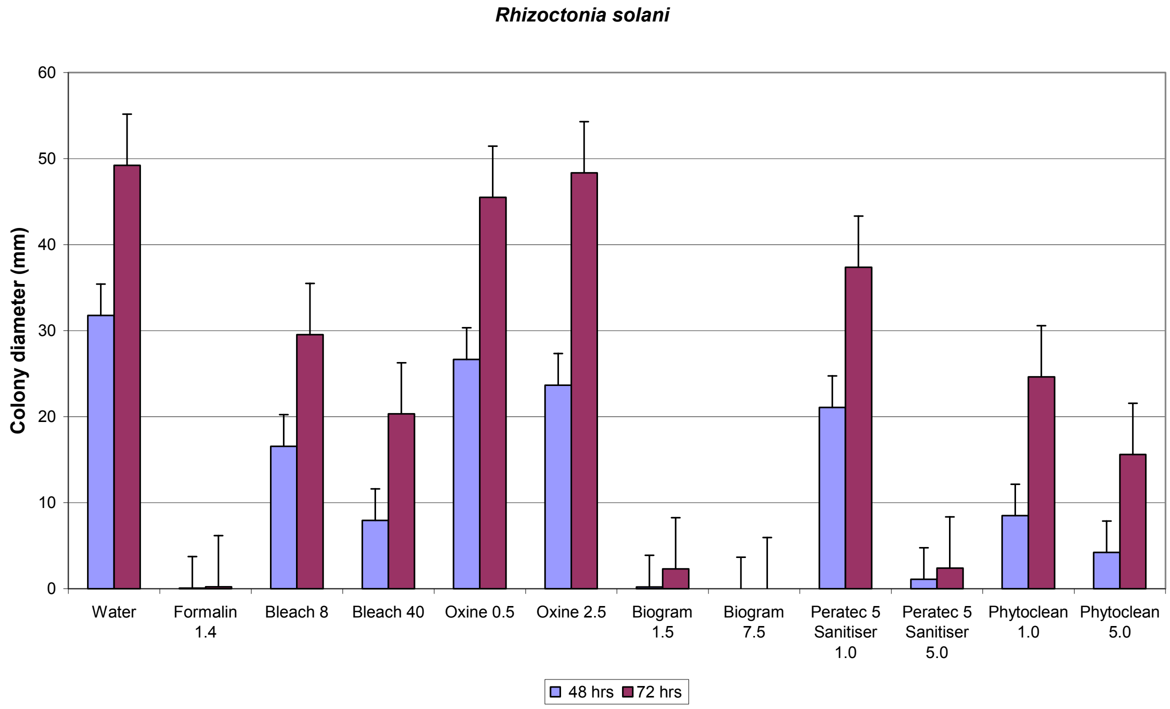

Figure 13 Effects of disinfectant treatments of seed tubers with black scurf on the viability of sclerotia of as measured by the radial growth of *Rhizoctonia solani* on PDA (48 hr & 72 hrs after plating) (Bars above the histograms represent the lsd at P=0.05)

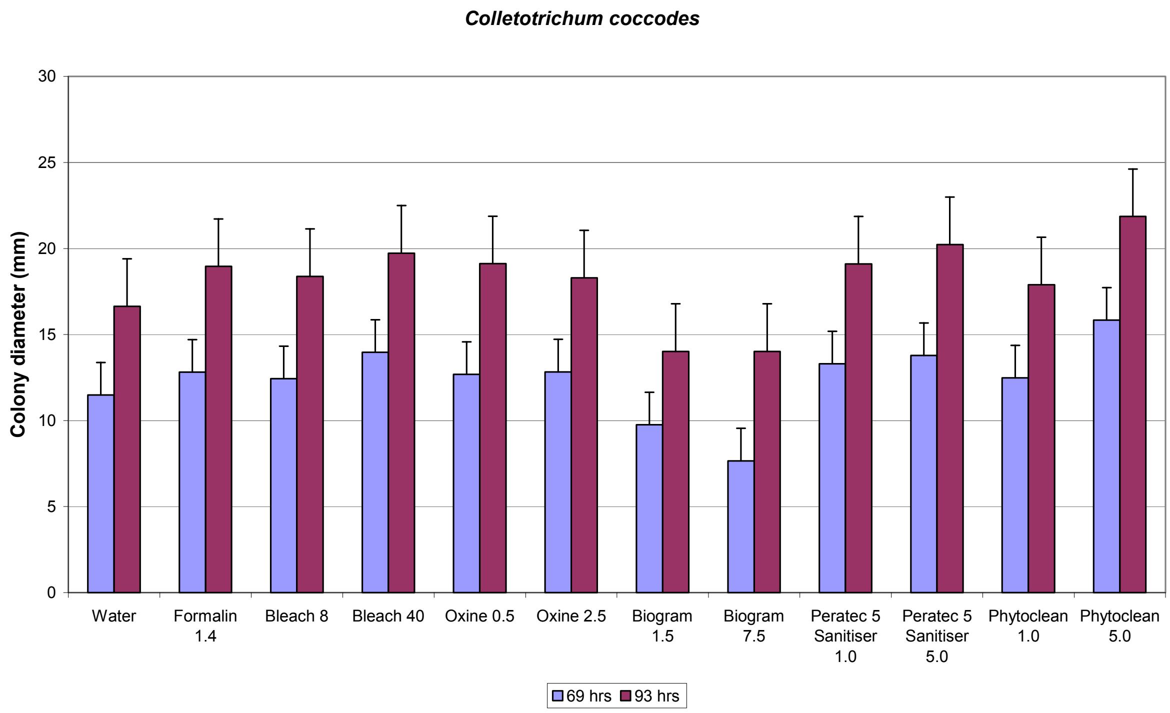

Figure 14 Effects of disinfectant treatments of seed tubers with black dot on the viability micro-sclerotia as measured by the radial growth of *Colletotrichum coccodes* on PDA (69 hrs & 93 hrs after plating) (Bars above the histograms represent the lsd at P=0.05)

Table 49 Effects of disinfectant treatments, with and without a surfactant, of whole seed tubers (cv. Coliban) with black scurf on the viability of sclerotia as measured by radial growth of *Rhizoctonia solani* on PDA

(Seed tubers immersed for 2 minutes in disinfectant solution or distilled water)

Product	Treatment (% of product)	Radial growth (colony diameter in mm) 45 hrs	69 hrs
Distilled water	-	27.0	45.1
Peratec 5 Sanitiser®	1.0%	18.6	38.4
Peratec 5 Sanitiser®	5.0%	0.5	2.0
Triton X-100®	1.0%	4.1	9.5
Peratec 5 Sanitiser® & Triton X-100®	1.0%, 1.0%	8.5	27.2
Peratec 5 Sanitiser® & Triton X-100®	5.0%, 1.0%	0.0	0.6
Triton x-100® followed by Peratec 5 Sanitiser®	1.0%, 1.0%	10.7	33.2
Triton X-100® followed by Peratec 5 Sanitiser®	1.0%, 5.0%	0.1	2.4
F test		<0.001	<0.001
lsd (P=0.05)		4.04	6.7

Table 50 Effects of disinfectant treatments of whole seed tubers on sprout emergence and growth

(Seed tubers immersed for 2 minutes in disinfectant solution or distilled water; sprouts not removed from cv. Sebago minitubers prior to treatment but were removed from cv. Coliban tubers)

Product	Treatment (% of product)	Plants emerged (%)		No. stems/plant		Height of plant (cm)	
		Sebago minitubers	Coliban G4	Sebago minitubers	Coliban G4	Sebago minitubers	Coliban G4
Untreated	-	83.3	100	2.00	5.3	45.0	35.5
Distilled water	-	100.0	100	2.00	4.0	54.0	40.5
Formalin	1.0%	83.3	50	2.33	0.8	47.5	31.7
Formalin	5.0%	83.3	17	2.00	0.3	47.5	27.5
Bleach	8.0%	66.7	67	1.00	2.3	45.0	38.0
Bleach	40.0%	50.0	33	0.50	0.3	32.5	26.0
Oxine®	0.125%	100.0	83	2.33	4.2	52.5	40.6
Oxine®	0.625%	66.7	83	1.17	2.7	40.8	36.6
Biogram®	1.0%	50.0	50	0.67	1.5	25.8	24.0
Biogram®	5.0%	0	0	0.00	0.0	0.0	0.0
Peratec 5 Sanitiser®	1.0%	83.3	67	1.50	1.7	52.5	41.5
Peratec 5 Sanitiser®	5.0%	100.0	50	2.17	1.0	52.0	28.7
Phytoclean®	1.0%	50.0	83	0.67	2.5	32.8	38.4
Phytoclean®	5.0%	0	0	0.00	0	0.0	0
F test		-	-	<0.001	<0.001	0.011	0.009
lsd (P=0.05)		-	-	1.12	1.89	33.02	14.4

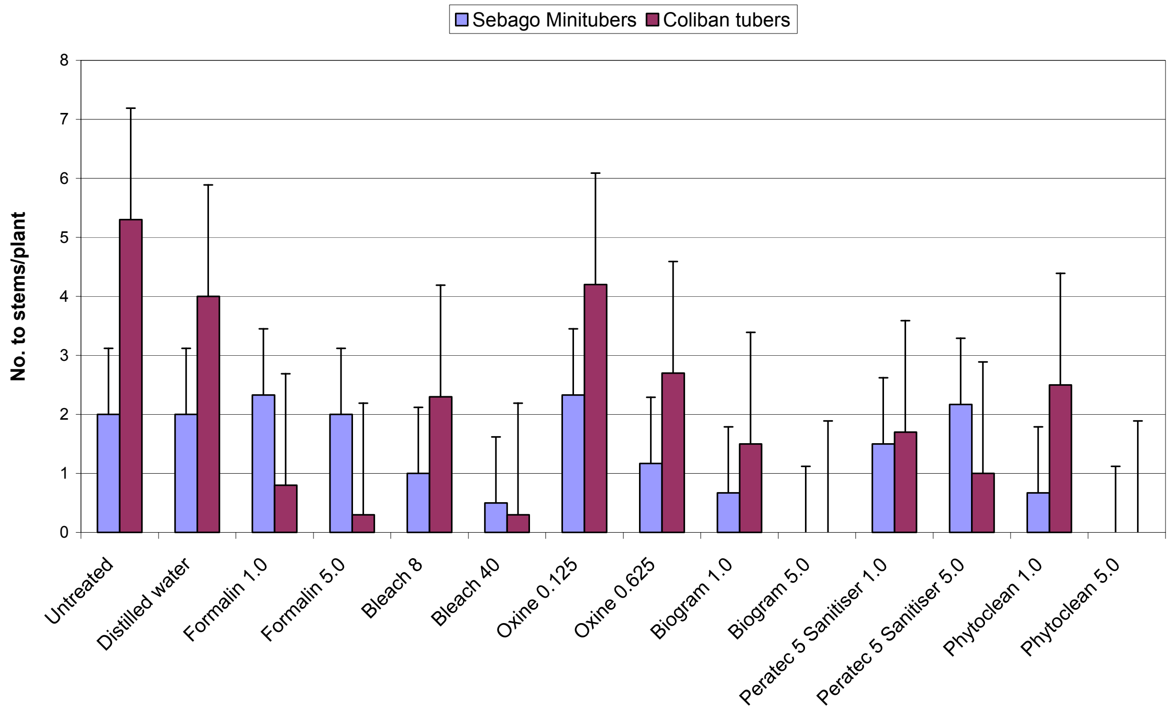

Figure 15 Effects of disinfectant treatments of seed tubers on the number of stems/plant (Sprouts were removed from Coliban tubers but were left intact on Sebago minitubers prior to treatment) (Bars above the histograms represent the lsd at P=0.05)

Table 51 Effects of disinfectant treatments, with and without a surfactant, of whole seed tubers (cv. Coliban minitubers, Coliban commercial seed tubers) on sprout emergence and growth

(Seed tubers immersed for 2 minutes in disinfectant solution or distilled water. Sprouts were removed from cv. Coliban commercial seed tubers prior to treatment)

Product & treatment (% of product)	**Plants emerged (%)**		**No. of stems/plant**		**Height of plants (cm)**	
	Coliban mini – tubers	**Coliban tubers**	**Coliban mini – tubers**	**Coliban tubers**	**Coliban mini – tubers**	**Coliban tubers**
Distilled water	100	66.7	2.0	2.3	32.7	35.0
Peratec 5 Sanitiser® 1%	100	83.3	1.5	3.8	32.5	41.6
Peratec 5 Sanitiser® 5%	100	33.3	1.7	0.7	35.5	36.5
Peratec 5 Sanitiser® 1% + Triton X-100® 1%	100	33.3	2.0	1.0	33.7	30.5
Peratec 5 Sanitiser® 5% + Triton X-100® 1%	50	0.0	1.2	0.0	31.0	0.00
Triton X-100® 1%	100	16.7	1.5	0.5	36.5	30.0
F-test	-	-	-	0.005	-	0.531
lsd (P=0.05)	-	-	-	1.97	-	25.53

3.4.2 The efficacy of disinfectant treatments against sporeballs of the *S. subterranea*, the cause of powdery scab

Materials and Methods

A preparation of 200 mg of powdered cystosori (sporeballs) of *S. subterranea*, prepared by wet sieving macerated powdery scab pustules from diseased tubers (smallest sieve size was 38 µm), were exposed for 2 minutes to solutions of different disinfectant chemicals. The reaction was inactivated by adding sodium thiosulphate and Tween® 20 to the spore suspension and by further dilution. The viability of cystosori in the suspension was determined by a tomato seedling bioassay adapted from a method described by Merz [1989]. Two different experiments were conducted (Experiments 1 & 2). Results were analysed by Analysis of Variance (Genstat for Windows 5th Edition™; Lawes Agricultural Trust, Rothamsted Experimental Station).

Results and Discussion

Experiment 1. All treatments at standard concentrations reduced ($P \leq 0.05$) the viability of cystosori by 41-54% compared with the untreated control (Table 52, Figure 16). Increasing the concentration of disinfectants solution by a factor of five resulted in a 60-80% reduction in the relative abundance of zoosporangia. However, there was no treatment that completely eliminated cystosori.

Experiment 2. All treatments of 1% product, significantly reduced ($P \leq 0.05$) the viability of cystosori, with the exception of Formalin and sodium hypochlorite, compared with the untreated control (Table 53, Figure 17). The viability of cystosori treated with 5% product was very low or undetectable.

These results show that there are several potential alternative treatments to Formalin for the treatment of seed tubers contaminated with *S. subterranea*. Relatively high concentrations are required at a 2 minute exposure time to kill the majority of spores in cystosori.

3.4.3 Conclusions

A series of *in-vitro* experiments showed that there are several potential chemical disinfectants that could replace formaldehyde as a seed tuber treatment. Our experience here indicates that disinfectants are best used at the post-harvest, pre-storage stage of seed handling rather than as pre-plant treatments (see Section 3.2). As pre-plant treatments, disinfectants were not as reliable as fungicide treatments and showed some evidence of phytotoxicity.

The chemicals from the peroxygen group are worth further investigation. They are relatively safe to use on potato tubers, are not affected greatly by organic matter and soil and break down into relatively harmless by-products. This group has consistently performed well in other trials on in projects relating to hygiene in potatoes and vegetables (RF de Boer, RJ Holmes, unpublished). However, before any such substances can be recommended for use on potatoes, they must be registered under the requirement of the National Registration Authority. This means that the necessary efficacy and safety data must be generated.

Table 52 Effect of disinfectant treatments on the viability of cystosori of *S. subterranea* as determined by a tomato seedling bioassay (Cystosori exposed to disinfectant chemicals for 2 minutes at 1 and 5 times recommended labels rates for surface disinfection)

Treatment (% of product)	Active ingredient	Disease index (0-4)[A] 1x	5x
Control – water + inactivater	-	3.89	-
Formalin® (0.5%)	36% formaldehyde	2.33	-
Oxine® (0.5%, 2.5%)	2% available chlorine dioxide	2.44	1.78
Kendocide® (1.25%, 6.25%)	423 g/L dichlorophen Na	2.17	0.50
Biogram® (1.5%, 7.5%)	2.5% w/v clorofene (Na salt)	2.00	0.44
	16.5% w/v ortho-phenylphenol (Na salt)		
Peratec 5 Sanitiser® (1%, 5%)	250 g/L H_20_2	1.83	0.39
	50 g/L peroxy acetic acid		
Virkon®S (1%, 5%)	Potassium monopersulphate	2.08	0.84
Phytoclean® (2%, 10%)	100 g/kg benzalkonium chloride	2.00	0.56
Sporekill® (1%, 5%)	120 g/L didecyldimethylammonium chloride	1.89	0.61
lsd (P=0.05)		0.342	

[A] Disease index: 0, no zoosporangia detected in the root hairs and cortical cells of the tomato root system; 1, occasional zoosporangia found; 2, several roots with zoosporangia; 3, zoosporangia regularly present, moderate infection; 4, zoosporangia regularly present, heavy infection.

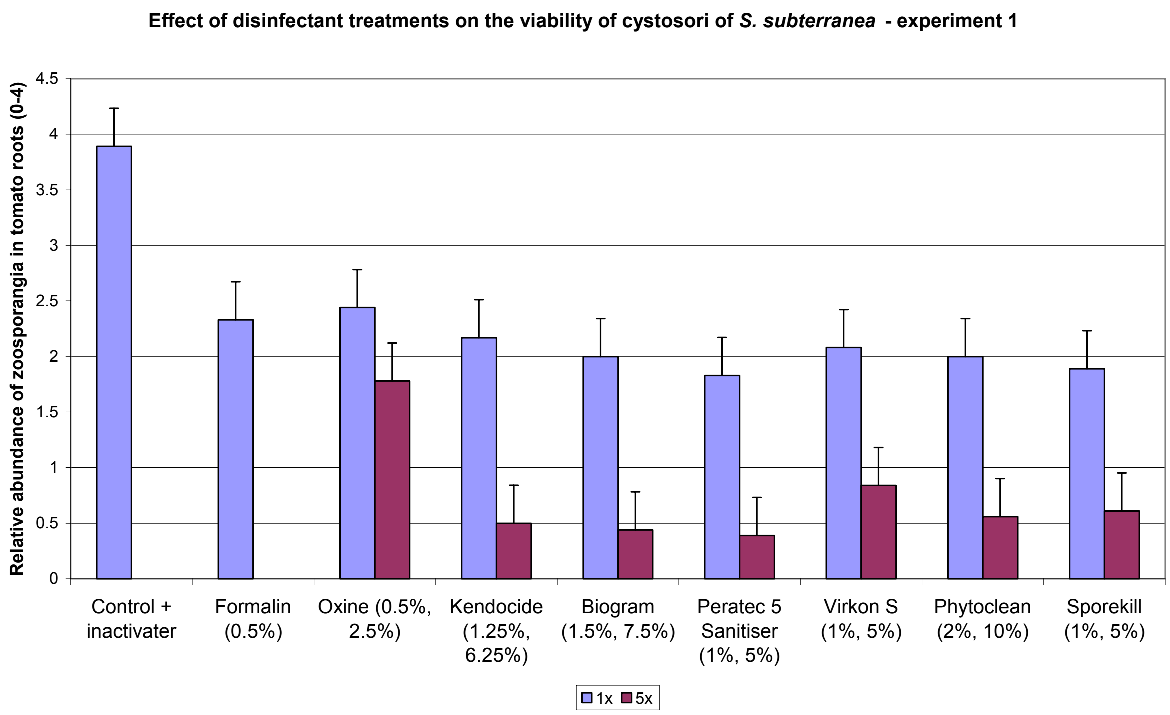

Figure 16 Effect of disinfectant treatments on the viability of cystosori of *S. subterranea* as determined by a tomato seedling bioassay (Cystosori exposed to disinfectant chemicals for 2 minutes at 1 and 5 times recommended labels rates for surface disinfection) (Bars above the histograms represent the lsd at P=0.05)

Table 53 Effect of disinfectant treatments on the viability of cystosori of *S. subterranea* as determined by a tomato seedling bioassay (Cystosori exposed to disinfectant chemicals for 2 minutes at 1% and 5% of product)

Product	Active ingredient	Disease index (0-4)[A] 1%	5%
Control	-	2.67	-
Formalin®	36% formaldehyde	2.50	-
Sodium Hypochlorite solution	10.5-15% available chlorine	2.39	0.33
Kendocide®	423 g/L dichlorophen Na	1.56	0.00[B]
Biogram®	2.5% w/v clorofene (Na salt) 16.5% w/v ortho-phenylphenol (Na salt)	1.72	0.00[B]
Peratec 5 Sanitiser®	250 g/L H_20_2 50 g/L peroxy acetic acid	1.28	0.00[B]
Perfoam 2®	5% w/w peracetic acid/hydrogen peroxide	1.17	0.00[B]
Virkon®S	Potassium monopersulphate	1.61	0.06
Phytoclean®	100 g/kg benzalkonium chloride	2.11	0.11
lsd (P=0.05)		0.31	

[A] Disease index: 0, no zoosporangia detected in the root hairs and cortical cells of the tomato root system; 1, occasional zoosporangia found; 2, several roots with zoosporangia; 3, zoosporangia regularly present, moderate infection; 4, zoosporangia regularly present, heavy infection
[B] Not included in the statistical analysis

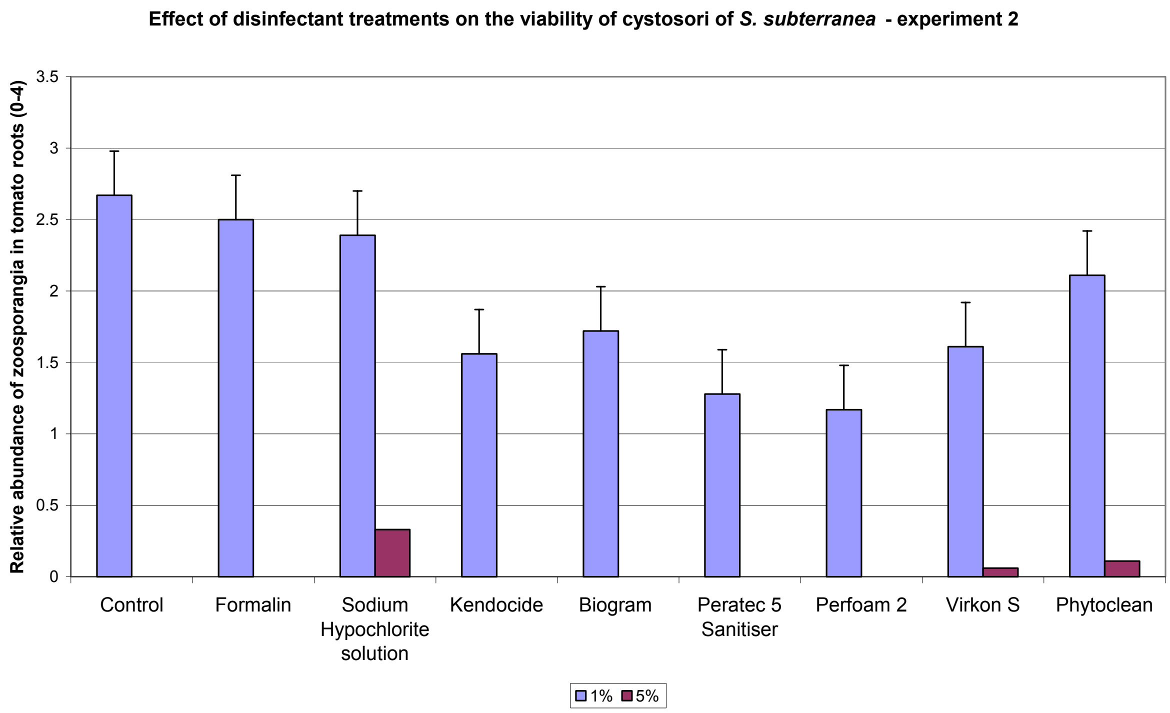

Figure 17 Effect of disinfectant treatments on the viability of cystosori of *S. subterranea* as determined by a tomato seedling bioassay (Cystosori exposed to disinfectant chemicals for 2 minutes at 1% and 5% of product) (Bars above the histograms represent the lsd at P=0.05)

3.5 Chemical seed treatments for fungal diseases of seed potatoes – an overview

Australian potato growers now have available to them seven registered fungicide treatments for seed potatoes (Table 54). Three of these treatments were only made available in the past decade. They include post-harvest treatments for storage rots and pre-plant treatments for seed-piece breakdown and seed-borne Rhizoctonia black scurf.

The arsenal of fungicides for seed potatoes currently lacks treatments that are active against powdery scab and common scab. This is one of the main reasons for the continued use of formaldehyde in the potato industry. A fluazinam (Shirlan®) treatment was registered in New Zealand for seed-borne powdery scab. It has since been withdrawn because of it proved to be phytotoxic to potato sprouts. An alternative, flusulfamide (Nebijin®) has been registered in that country for the same purpose. This fungicide is also active against common scab. However, there is no agent for this product in Australia.

In contrast to Australian growers, potato farmers in the United Kingdom have a total of 13 fungicide treatments to use in the potato store or at planting time. These treatments include mixtures of active ingredients that help reduce the risk of fungicide resistance in populations of potato pathogens. Many treatments are formulated for ultra low volume application, which means more efficient application of fungicides and reduced problems with spray drift and excessive run-off in the potato shed. Agrochemical companies have until recently ignored the issue of application and mixtures in Australia. The potato industry should be encouraged to engage the agrochemical industry to improve the availability of treatments and methods of application.

Table 54 Fungicides used as seed tuber treatments to protect seed pieces, plants and/or progeny tubers in Australia

Product	Active ingredients g/kg or g/L	Treat-ment	Timing	Target	Diseases not controlled
Tecto Flowable SC®	500 g/L thiabendazole	Spray	In store	Dry rot (*Fusarium* spp.) Gangrene (*Phoma exigua*) Silver scurf (*Helminthosporium solani*)	Black dot
Fungaflor 750 WSP®	750g/L imazalil	Spray	In store	Dry rot (*Fusarium* spp.) Gangrene (*Phoma exigua*) Silver scurf (*Helminthosporium solani*)	Black dot
Potato Dust Fungicide®	200g/kg mancozeb	Dust	Prior to planting	Seed piece breakdown (*Fusarium* spp.)	Black dot
Rizolex® 100 D	100g/kg tolclofos-methyl	Dust	Prior to or at planting	Black scurf (*Rhizoctonia solani*)	Silver scurf, black dot, powdery scab, common scab
Rovral® Liquid	250g/L iprodione	Spray	At planting	Black scurf (*Rhizoctonia solani*)	Silver scurf, black dot, powdery scab, common scab
Monceren® 250 FS	250g/L pencycuron	Spray	Prior to or at planting	Black scurf (*Rhizoctonia solani*)	Silver scurf, black dot, powdery scab, common scab
Maxim® 100 FS	100g/L fludioxonil	Spray	Prior to or at planting	Black scurf (*Rhizoctonia solani*) Silver scurf (*Helminthosporium solani*)	?[A]

[A] May be active against black dot, powdery scab, common scab and Fusarium spp.

3.6 Study Tour – Potato Association of America Conference and key potato research institutions on Prince Edward Is, Canada, England, Scotland and The Netherlands

Itinerary

August 4-8 1997 *Charlottetown, Prince Edward Island, Canada*: 81st Annual Meeting of the Potato Association of America; Fox Island Elite Seed Farm; Charlottetown Research Centre, Agriculture Canada.

August 11-15 1997 England/Scotland: Institute for Arable Crops Research, Rothamsted; Scottish Crops Research Institute, Invergowrie; Scottish Agricultural College, Aberdeen; Seed Potato Growers.

August 18-26 1997 The Netherlands: Wageningen Agricultural University, Wageningen (Phytopathology, Agronomy); Hilbrands Laboratory for Soil-borne Pests and Diseases (HLB), Assen; Research Station for Arable Farming and Field Production of Vegetables (PAGV), Lelystad; Dutch General Inspection Service for Agricultural Seeds and Seed Potatoes (NAK), Emmeloord; Netherlands Organisation for Agricultural Research (DLO), Research Institute for Plant Protection (IPO-DLO), Wageningen; Potato Breeders/Seed Potato producers - ZPC, Leuwaarden, HETTEMA, Emmeloord, AGRICO, Emmeloord.

The 81st meeting of the Potato Association of America was attended by over 500 delegates from North America as well as Europe and one from Australia (R. de Boer). Although the majority of delegates were involved with research and extension, significant numbers of representatives from various industry sectors, including farmers, attended. The Meeting provided an excellent opportunity to learn of the latest developments in R&D in potato production on the American continent and to establish important contacts with key researchers.

Late Blight (Irish Blight) caused by *Phytophthora infestans*, which is probably the single most important potato disease world wide, dominated the conference. Strains of the A2 mating type, hitherto restricted to Mexico, and new strains of the A1 mating type, are spreading rapidly through North American and Europe. These strains are extremely aggressive, attacking not only leaves and petioles but also stems and tubers. They are resistant to metalaxyl and cause significant economic losses in potato growing areas that previously only had a minor late blight problem. Heavy fungicide spray programs (every 5-7 days) are needed to minimise spread and damage in crops. If introduced into Australia these new strains can potentially cause significant losses to the Australian potato industry.

The three major Institutes visited in the UK were linked through collaborative research and were the major focus for pest and disease management in potatoes in that country. Very useful contacts were established at all three institutions. Research programs were focused on reducing disease in seed potatoes, determining sources of disease on early generations of seed, hygiene in farm sheds and stores, evaluating disinfectant treatments for use in hygiene programs, chemical and non-chemical control of diseases of seed, integrated management of seed, potato diseases, breeding and screening for disease resistance and the development of biochemical techniques for detecting soil-borne pathogens. Much of this research is directly relevant to current research programs in Australia. These Institutes also had a good record of extension of their results to the industry providing some valuable lessons for Australian researchers.

As in the UK, many valuable contacts were established in the Netherlands. There was a strong emphasis on both fundamental and applied research into the management of soil-borne diseases, particularly the potato cyst nematode, *Rhizoctonia* and *Verticillium*. Because of the intense agricultural production and rotations in that country, research projects covered several crops affected by different pathogens, for example, *Rhizoctonia solani*. Research on the effects of rotation on soil-borne diseases was well developed. The Dutch appear to have very effectively managed the potato cyst nematode in starch potato production areas through integrated management practices. Some new and novel approaches were being developed and evaluated for disease control.

Prince Edward Is, Great Britain and the Netherlands are the three major exporters of potatoes, especially seed potatoes, in the world. Informations on Certification systems obtained in these countries provide an interesting comparison with our own systems. Seed potato farmers showed a high level of skill and discipline, probably because of short growing seasons, very high virus pressure and the emphasis on round seed potato production. Potato production, distribution and marketing were highly organised through large cooperatives and other organisations, in contrast to Australian farmers who take a very individualised approach. Many of these organisations developed their own potato varieties. Farming operations and farmers in these countries have much in common with those in Australia. In view of our potential to export potatoes and potato products, Australian growers from all sectors should be strongly encouraged to visit these countries to help them recognise their own abilities, potential and deficiencies in a world market.

4 Technology Transfer

Communication with growers, industry and the scientific community

Seminars/Workshops

Aspects of chemical control of diseases of seed potatoes were presented at the following conferences and farmers workshops.

- Field Day - Bullarook, Victoria, 29 March 1996
- Grower Seminar - Thorpdale, Victoria, 18 February 1997
- ViCSPA Annual General Meeting, 17 September 1997 - 'Lessons from overseas'
- Victorian Certified Seed Potato Growers Committee Meeting. October 1997.
- Field Day - Strathalbyn South Australia, 5 March 1997
- Field Day - Demonstration Farm, Bullarook, 18 March 1997
- Information Evening - Ballarat, Victoria, 27 October 1997 (Seed and Processing growers) - Lessons from overseas
- Field Walk - Demonstration Farm, Bullarook, 19 December 1997
- Seminar Day, IHD Knoxfield. Potato production and disease problems in the Netherlands, Scotland and on Prince Edward Is., Canada. 4 March 1998
- Field Day - Demonstration Farm, Bullarook, Victoria 20 March 1998
- ViCSPA/IHD Consultative Committee, IHD Knoxfield 5 May 1998 - Seed health and disease control - new opportunities.
- Victorian Potato Crisping Research Group BBQ Tea & Information Night, 16 April 1998.
- Biofumigation Workshop - Demonstration Farm, Bullarook, 14 September 1998
- Seed Potato Industry Workshop - Colac, 16-17 September 1998
- National Potato Field Day - Institute for Horticultural Development Toolangi, 18 February 1999
- Series of Grower Meetings - Tasmania, 18-19 June 1999
- Series of Grower Information Sessions, - Perth, Bunbury, Manjimup, Albany, Western Australia, October 1999
- Series of half-day workshops held for Victorian Seed Growers – Thorpdale, Ballarat, Gellibrand, Portland, 9, 10, 16 and 17 November 1999
- Potatoes 2000 - Linking Research to Practice. Australian Potato Research, Development and Technology Transfer, Adelaide, 31 July – 3 August 2000
- Seed Potato Growers Discussion group (Thorpdale and South Gippsland seed growers), Trafalgar 9th August 2000.
- Potato Growers Seminar - CHIPS Demonstration Farm, Bullarook, 10 August 2000
- Potato Growers Seminar - CHIPS Demonstration Farm, Bullarook, 22 August 2001
- Potato Growers Seminar - CHIPS Demonstration Farm, Bullarook, 27 August 2002
- Grower workshops, Colac, Portland and Ballarat, Victoria, 2-3 September 2002
- Grower workshops Devonport and Scottsdale, Tasmania, 7-8 October 2002
- ViCSPA Certification Workshop - Toolangi, 17 January 2002

Publications from this project include conference papers, abstracts and posters, as well as articles in industry journals and the popular press.

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5 Recommendations

This report provides a detailed comparison of the efficacy of four pre-plant seed treatments for seed-borne *Rhizoctonia solani* under in fields with high and low disease pressure. The results of our investigations raise issues of the relative importance of seed verses soil inoculum. Seed potatoes are, of course, an important means of spreading disease into a crop or into 'clean' ground. The biology of each potato pathogen, however, also dictates whether controlling it on the seed piece has an immediate impact on disease levels in the subsequent crop. These concepts are difficult for growers to grasp. In light of the research conducted on disease management in seed potatoes thus far, it is timely to develop an extension program on disease management in seed potatoes better inform growers of these issues and encourage a more effective and efficient use of seed treatments and management strategies.

There is now a considerable body of information seed potato diseases and their management. However, much our knowledge is fragmented, relating to different parts of the production system. It will be beneficial to evaluate 'best practice' for the management of disease on seed potatoes in old and new ground over at least three field generations. Such trials will help determine what tangible benefits are gained from seed disease management practices.

There is an urgent need to educate the potato industry on seed health quality in relation to the management of disease in a potato crop. The industry is currently focused on the need to 'premium quality seed' for all growers, irrespective of the health status of their fields. This attitude has resulted in unrealistic demands on seed health quality overall. There is no doubt that, where potatoes are planted into new ground, seed must be of the highest quality and should be sourced from seed growers who can meet those demands (eg. free of contamination by powdery scab).

Australia has some of the most stringent tolerances for fungal diseases of the seed potatoes in the world. The development of these standards was based on historical precedents and the needs of the industry at the time. However, experience now tells us that some of these standards have no scientific basis. There is a need for research to clearly determine the relative contributions of seed and soil-borne inoculum in disease development under different scenarios of high and low soil-borne disease pressure. It may be timely to review certification standards with regard to the different needs of various sectors of the potato industry. The potato industry is faced with the dilemma of demands for 'zero tolerance' of diseases on seed where potatoes are planted in new ground and standards that may be unrealistically high for seed potatoes planted into soil with a history of potato production.

Some seed growers wash seed tubers to remove soil. Although this practice can increase of the risk of bacterial storage unless tubers are dried, it may have some merit for disease management on seed. A project on hygiene in the potato shed (PT98018) has shown that soil and dust are sources of contamination of potato tubers with pathogens. In light of the very stringent tolerances for fungal diseases on seed potatoes (98% disease free), soil and shed dust on tubers may account for higher levels of inoculum for some pathogens in a consignment of graded seed potatoes than the small proportion of tubers with disease symptoms.

A soil treatment of azoxystrobin (Amistar®) significantly reduced the incidence and severity of black scurf in progeny tubers. This was also reported in a previous Horticulture Australia project in 1994 (PT105). This fungicide is currently registered for the control of target spot

(*Alternaria solani*) in potato crops and should be developed for the control of soil-borne *R. solani*.

This project demonstrated the potential of a soil application of the fungicide fluazinam to control soil-borne powdery scab. Although Crop Care Australia has gathered efficacy data on this fungicide (Shirlan®), it has never been registered for the control of powdery scab. This product is also active against the common scab pathogen and may warrant further development as a soil treatment.

There are no registered fungicide treatments for seed-borne powdery scab in Australia at present. A flusulfamide (Nebijin®) treatment has been registered in New Zealand as a seed tuber treatment for powdery scab and is also registered in South Africa for the same purpose. There is no supplier for this Japanese-owned fungicide in Australia. The supplier, who developed the fungicide treatment in New Zealand has shown some interested in developing the fungicide for the Australian market.

There is increasing pressure to produce food crops under zero pesticide tolerance regimes. There has been some work in overseas countries, demonstrating the efficacy of simple inorganic salts, for example, against seed-borne diseases such as silver scurf. The industry may be confronted soon with the need to evaluate alternative seed treatments.

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