PT96010
Investigation on common scab disease of potatoes and development of control methods

H Pung and S Cross
Serve-Ag Research

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PT96010

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

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Investigation on common scab disease of potatoes and development of control methods

Final Report

Conducted on behalf of

Horticultural Research and Development Corporation

Project PT96010
(completion 30/06/00)

by

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and

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December 29, 2000

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Common scab on Potatoes (cv. Russet Burbank)

Common scab symptoms on potatoes can vary from one location to another.

Photo 1: Russet common scab lesions.

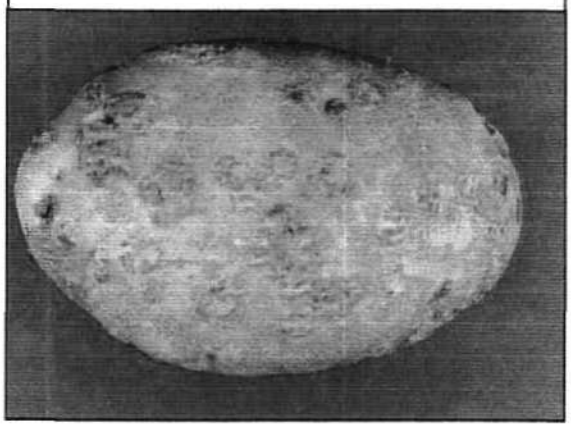


Photo 2: Irregular shaped common scab lesions.

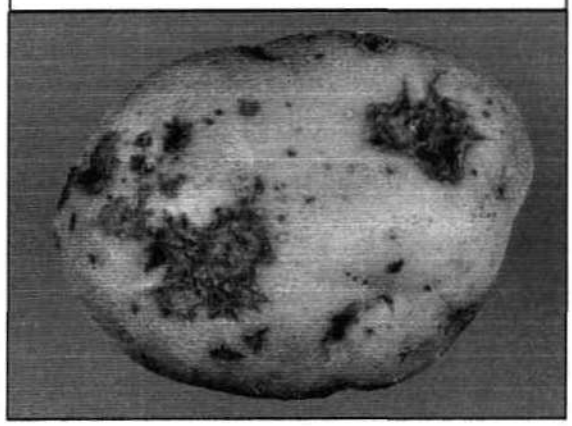


Photo 3: Circular shaped common scab lesions.

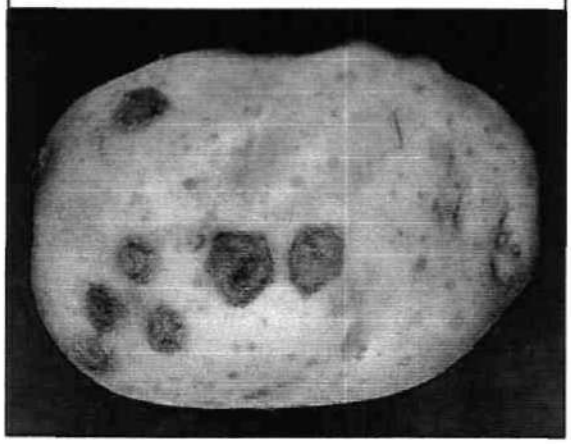


Photo 4: Deep common scab lesions.

Photo 5: Shallow and deep common scab lesions that resembled powdery scab lesions.

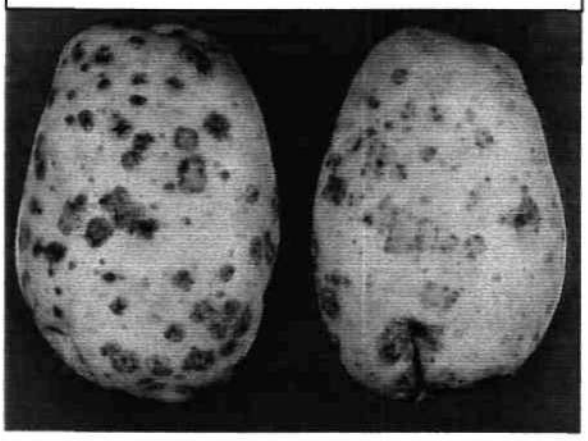
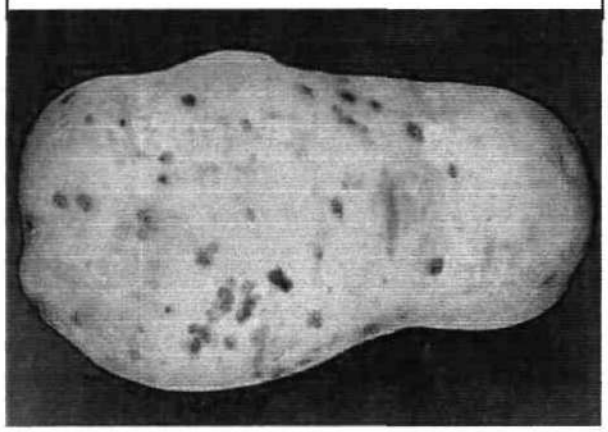


Photo 6: Powdery scab on potato (cv Russet Burbank).



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Industry Summary

Common scab (*Streptomycetes* spp.) is a serious disease of potatoes grown for processing, seed and fresh markets in Tasmania and in some major production regions in other states of Australia.

There has been uncertainty in the potato industry regarding the significance of common scab infected seed in commercial seed lines, and their potential for transmitting the disease to new tubers. This project, therefore, aimed to determine and clarify the relevance of seedborne infections, and to evaluate methods for their control. In initial studies, seed treatments with high concentrations of mancozeb were effective in reducing common scab disease caused by infected seed. Therefore, extensive studies were conducted in this project to develop a safe and cost effective seed treatment method that could be incorporated into current commercial operations for the control of seedborne infections. Field inspections were also conducted to improve our understanding of the influence of field conditions on the disease.

A survey of certified tuber seed lines of Russet Burbank has shown that the incidence of common scab disease on tuber seed potatoes can vary according to climatic conditions. In low rainfall seasons, common scab can be widespread, even on certified tuber seeds.

Trial studies have shown that the incidence of common scab on tuber seed lines alone is not directly related to the level of common scab transmitted onto new tubers. Disease severity as indicated by deep scab lesions and high surface coverage by many scab lesions appeared to be more important than scab incidence in the level of seedborne scab transmission.

Low incidence and low severity of common scab on infected certified tuber seeds, can be controlled with chemical seed treatments. Mancozeb based products have been identified as low cost products for common scab control (eg. at the time of printing, the approximate cost of Dithane® is $8/kg, and Tato dust® $5/kg, compared to $205/L for Shirlan®).

In trials conducted as part of this project, all mancozeb-based products, Penncozeb®, Dithane®, Tato dust® and Tato bark®, reduced the incidence and severity of common scab infections on new tubers. The level of common scab control achieved with mancozeb was similar to that achieved with Shirlan® and Maxim®.

The tuber seeds can be treated before or after storage, and can be dusted or sprayed. In ground where the common scab pathogen level is high and widespread, fungicide seed treatments have little or no effect on common scab.

Technical Summary

Common scab (*Streptomycetes* spp.) is a serious disease of potatoes grown for processing, seed and fresh markets in Tasmania and in some major production regions in other states of Australia. Reduced yield and quality of potatoes due to common scab results in lower returns for growers. This is a serious concern in an increasingly competitive market.

There has been uncertainty in the potato industry regarding the significance of common scab infected seed in commercial seed lines, and their potential for transmitting the disease to new tubers. This project, therefore, aimed to determine and clarify the relevance of seedborne infections, and to evaluate methods for their control.

In initial studies, seed treatments with high concentrations of mancozeb were effective in reducing common scab disease caused by infected seed, although high concentrations of mancozeb may cause phytotoxicity when applied to freshly cut seed tubers. Therefore, extensive studies were conducted in this project to develop a safe and cost effective seed treatment method that could be incorporated into current commercial operations for the control of seedborne infections. Some studies were also conducted to evaluate chemical methods to control common scab due to field or soilborne inoculum.

Field inspections were also conducted to improve understanding of the influence of field conditions on the disease.

Seed-borne transmission of common scab disease

- The incidence of common scab disease on certified seed potatoes can vary markedly in some seasons. In 1998, 49% of Russet Burbank seed lines examined had common scab, which ranged from 2 to 15 % of tubers infected, whereas in tubers harvested in 1999, only 24% of seed lines were infected with low levels of common scab, ranging from 2 to 6 % of tubers infected.
- Trial studies have shown that the incidence of common scab on tuber seed lines alone is not directly related to the level of common scab transmitted onto new tubers. An increase in the incidence of common scab on the tuber seed lines alone, did not cause an increase in the disease incidence on new tubers.
- Disease severity as indicated by deep scab lesions and high surface coverage by many scab lesions appeared to be more important in the level of seedborne scab transmission.
- The increased severity of common scab on tuber seed potatoes increased the incidence and severity of the disease on new tubers. Laboratory tests showed that deep common scab lesions had higher pathogen levels than superficial lesions.
- Common scab may still be transmitted from seed that had no obvious common scab lesions, but which came from an infected seed line.
- The removal of soil particles from infected seed potatoes by washing only caused a slight reduction in the percentage of tubers with common scab.

Methods of seed treatments to reduce common scab from seed source

- Trials conducted in this project have indicated that fungicide seed treatments are effective for the control of seedborne common scab infections.
- All mancozeb-based products, Penncozeb, Dithane, Tato dust and Tato bark, reduced the transmission of common scab from infected seeds.
- Shirlan and Maxim seed treatments also provided significant common scab control.
- Treating infected seeds with mancozeb at 4 months prior to use, or at 24 hours prior to planting, gave good control of common scab, reducing the percentage of tubers infected from 52-86% in the untreated control, to 0-13% with mancozeb treatments. This indicates that seeds may be treated for common scab control after harvest and prior to storage.
- In ground where the common scab pathogen level is high and widespread, fungicide seed treatments have little or no effect in reducing common scab infections due to soilborne inoculum.

Factors influencing common scab development

- Common scab development appears to be strongly influenced by localised field conditions. Field trials conducted in this project have shown that infected seed lines can produce very different levels of common scab incidence in different locations. Tubers free of common scab can also be generated from infected seed tubers.
- The multitude of field variables makes it difficult to single-out any particular field factor that may be responsible for the low to no disease levels in some crops. However, field studies conducted in this project helped provide a better understanding of how field factors can interact to influence the incidence and severity of scab infections on tubers.
- Two types of scab were often found on Russet Burbank in Tasmania, with common scab being more prevalent than powdery scab. Hence, the ability to distinguish between the two types of scab is very important. High soil moisture, which is recommended during the tuber initiation period for common scab control, is conducive to severe powdery scab, and vice versa.
- Field factors, such as climatic conditions, paddock terrain, soil drainage and irrigation management, could be useful indications of the type of scab that is likely to occur. Powdery scab tends to be prevalent in poorly drained soil. Conversely, common scab tends to be prevalent in well-drained soil.
- Different types of crop rotations also appeared to affect the severity of common scab disease. Obvious differences in disease severity could be observed on tubers in different parts of the same paddock, which had different crop rotations in previous years.

Recommendations

- The use of a common scab threshold levels based only on the incidence of scab on tubers needs to be reviewed.
    - With the use of an effective seed treatment for seedborne common scab, the current scab threshold level may be increased from 4% to 10% or more.
    - Common scab severity would be a better measure than disease incidence for the disease threshold on seed lines.
    - Field trials should be conducted to determine and verify the appropriate scab threshold level on seed lines for use by the industry.
- Mancozeb seed treatment is recommended for use on seed lines that have low incidence and severity of common scab.
- Further studies are required to evaluate soilborne common scab inoculum levels and to determine appropriate control methods.
    - The potential for the use of biocides, soil fumigants, beneficial soil microorganisms, and biocontrol agents to control soilborne common scab should be evaluated.
    - Studies are required on the effects of crop management practices on common scab levels in infected soil, and the disease on subsequent potato crops.

Introduction

Background

Common scab is a serious disease of potatoes grown for processing, seed and fresh markets in Tasmania and some major production regions in Victoria. Reduced yield and quality of potatoes due to common scab results in lower returns for growers.

Steptomyces spp., which causes common scab disease, is both soil and seed-borne. In Tasmania, fluctuations in the disease incidence on tubers from season to season indicates that virulence of the pathogen could vary according to different *Streptomyces* strains, local conditions and seasonal changes.

Irrigation management has often been quoted as one effective means of controlling this disease. A large-scale field trial was conducted in Tasmania on irrigation schedules to identify watering conditions that may be conducive to disease development in the field (Wilson, HRDC final report PT205). The limited success obtained in this study, due to poor control of conditions in the field, indicated that under commercial conditions, precise irrigation scheduling for a narrow soil water regime might be difficult to achieve. Other studies in different areas have had mixed results. Lapwood et al. (1973) showed that irrigation management during the critical initial stages of growth gave good control, while Davis et al. (1976) showed that water management alone during this critical stage did not reduce disease level. In overseas studies, different *Streptomyces* strains appeared to respond differently to soil moisture (Doering-Saad et al. 1992). Local conditions appeared to be an important factor and must be taken into account in developing effective control methods. Currently, the role that various field conditions and practices have on common scab incidence and severity in Tasmania is not well understood.

There is also uncertainty in the potato industry, of the significance of tuber seed infected with common scab in commercial tuber seed lines, and their potential for transmitting the disease onto new tubers. The threshold level on common scab for seed certification in Tasmania is 4%-infected tuber seed. In Europe and America, where common scab is frequently found in crops, common scab incidence on tuber seeds is not a concern. The aim of this study, therefore, was to determine and clarify the relevance of seedborne infections.

This project's focus was on evaluating, identifying and developing chemical treatment methods, which offer the most promising control for common scab to be used by growers in the short-term. These short-term studies could be supplemented with other biocontrol studies conducted at the University of Tasmania in PhD studies by Michael Lacey in 1995-1999.

Peliminary studies conducted by Wilson (HRDC final report PT205, Wilson et al. 1999) showed that the fungicide products fluazinam and flusulfamide have the potential to control common scab. This project aimed to further evaluate the potential of these new products, as well as other low cost products such as mancozeb.

Aims

- This main objective of this project was to determine the incidence of common scab on certified tuber seed lines, to investigate the relevance of seedborne transmission of common scab, and to develop a cost effective method of treating common scab infected tuber seeds.

- The use of chemical seed treatments and chemical applications in soil for soilborne common scab was also examined in field studies.

- Field inspections were conducted to obtain a better understanding of the influence of field factors on common scab severity in commercial crops.

Target Disease

Common scab caused by *Streptomyces* spp.

Streptomyces scabies is the most common pathogen found in association with common scab on potatoes. However, common scab could also be caused by other different *Streptomyces* species, which include *S. acidiscabies, S. griseus, S. aureofaciens, S. flaveolus*, as well as others that are yet to be described or named. The *Streptomyces* strains isolated from common scab on potato in a previous HRDC project (PT205) are still being studied at the University of Tasmania.

Product Formulations

Product	Active ingredient (a.i.)	Rate of a.i.	Formulation	Fungicide Group#
Agri-Fos	phosphonic acid	400g/L	Liquid	Y
Aliette	fosetyl - al	740g/kg	Water dispersable granules	Y
Boric acid	boric acid	100%	Liquid	-*
Cement	cement	100%	Dustable powder	-*
Dithane WP	mancozeb	800g/kg	Wettable powder	Y
Fir bark	Douglas fir bark	100%	Dustable powder	-*
Fungaflor	imazalil	750g/L	Water soluble powder	C
Kocide	copper hydroxide	500g/kg	Wettable powder	Y
Manganese sulphate	Manganese sulphate	98%	Granules	-*
Maxim	fludioxonil	100g/L	Suspension concentrate	L
Nylate	hydro-chlorobromide	280g/kg	Granules	-*
Penncozeb DF	mancozeb	750g/kg	Dry flowable granules	Y
Rizolex	tolclofos-methyl	100g/kg	Dustable powder	Y
Scablok	flusulfamide	5%	Liquid	Not specified
Shirlan	fluazinam	500g/L	Suspension concentrate	Y
Tato Bark (Tato dust + Fir bark)	mancozeb	80g/kg	Dustable powder	Y
Tato Dust	mancozeb	200g/kg	Dustable powder	Y
Tecto	thiabendazole	450g/L	Suspension concentrate	A
Terraclor	quintozene	750g/kg	Wettable powder	Y

The fungicide group, used for resistance management, was developed by Avcare (Appendix i).
* Non fungicides products.

Section 1: Relevance of seedborne common scab

Trial Details

	Section 1.1	Section 1.2	Section 1.3
Aim	Common scab levels on certified seed lines	Seedborne common scab and disease transmission	Infected seed threshold and disease transmission
Seed Source	Tubers from certified seed lines	Infected certified seed lines and ware potatoes	Infected certified seed lines and ware potatoes
Trial Design	N/a	Randomised complete block	Randomised complete block
Crop/Variety	Russet Burbank	Russet Burbank	Russet Burbank
Treatments	N/a	9	10
Replicates	N/a	10	8
Season	97/98	98/99	99/00

Summary

There has been uncertainty in the potato industry regarding the significance of tuber seed infected with common scab in commercial tuber seed lines, and their potential for transmitting the disease to new tubers. The aim of these studies, therefore, was to determine and clarify the relevance of seedborne infections.

The incidence of common scab disease on seed potatoes can vary markedly in some seasons. In 1998, 49% of Russet Burbank seed lines examined had common scab, which ranged from 2 to 15 % of tubers infected, whereas in tubers harvested in 1999, only 24% seed lines were infected with low levels of common scab, ranging from 2 to 6 % of infected tubers.

Trial studies have shown that the incidence of common scab on tuber seed lines alone is not directly related to the level of common scab transmitted onto new tubers. An increase in the incidence of common scab on the tuber seed lines did not cause an increase in the disease incidence on new tubers. Apart from the incidence of scab infection of the seed lines, there are other factors that may be of greater importance in influencing the level of disease transmitted onto new tubers. These include disease severity, seed origin, amount of soil attached to tubers, and strains and species of the scab causing pathogen.

The increased severity of common scab on tuber seed potatoes increased the incidence and severity of the disease on new tubers. Laboratory tests showed that deep common scab lesions had higher pathogen levels than superficial lesions. Common scab was also transmitted from seed that had no obvious common scab lesions, but which came from an infected seed line, showing that the absence of disease symptoms on tuber seeds is not a reliable indicator of their ability to transmit common scab disease onto new tubers.

1: Relevance of seedborne common scab (Cont.)

1.1: Common scab levels on certified seeds

Introduction

This study was conducted to determine the levels of common scab on certified tuber seed lines of Russet Burbank, which is the preferred variety for the processing industry.

Materials & Methods

The incidence of scab diseases, which include common scab and powdery scab, was investigated in the certified Russet Burbank tuber seed lines. A total of 57 tuber seed lines harvested in 1998 and 1999 were examined. Tuber seed lines from three cold storage facilities were selected at random, and 50 to 100 tubers from each line were washed and assessed for both common scab and powdery scab incidence. Tubers were assessed for common scab lesions and disease severity at harvest.

Results & Discussion

The percentage of tubers infected with common scab was higher in tuber seed lines produced in 1998 than in those harvested in 1999 (Table 1.1.1). The opposite applied with powdery scab disease.

Table 1.1.1: The level of scab disease in certified tuber seed lines.

Year harvested	1998	1999
Total no. tuber seed lines examined	37	25
% Tuber seed lines infected by:		
Common scab	49	24
Powdery scab	24	40
Both types of scab	14	4

The differences in the incidence of common and powdery scab diseases appeared to be related to the differences in rainfall between the two seasons. The average monthly rainfall from October to March (when most potato crops are grown in Tasmania) for 1997/98 and 1998/99 was 26mm and 67mm, respectively. Low soil moisture generally favours common scab development, and vice versa for powdery scab.

1: Relevance of seedborne common scab (Cont.)

1.2: Evaluation of the ability of common scab infected seed lines to transmit disease

Introduction

The ability of tuber seed from infected seed lines to transmit common scab disease was examined in a pot trial using pasteurised potting mix.

Materials & Methods

Infected tuber seeds (cv Russet Burbank) were evaluated in a pot trial for their ability to transmit common scab onto new tubers in pasteurised soil (Table 1.2.1). This trial was conducted in 1998/99 growing season, and consisted of two separate studies, Study 1 and Study 2, as described below.

Table 1.2.1: Treatment details

Study No.	No.	Seed line	Common scab lesions on seed tubers	Seed Origin	% Common scab incidence of tuber seeds
		Commercial seed 1			
1	1	Unwashed	Unknown	Wilmot	11
1	2	Washed scab	Yes	Wilmot	11
1	3	Washed no scab	No	Wilmot	11
		Commercial seed 2			
1	4	Unwashed	Unknown	Riana	12
1	5	Washed scab	Yes	Riana	12
1	6	Washed no scab	No	Riana	12
		Non-commercial seed 3			
2	7	No scab seed	No	Bellfield	90
2	8	Mild superficial scab seed	Yes	Bellfield	90
2	9	Severe deep scab seed	Yes	Bellfield	90

Study 1

This study was conducted to determine whether washing of tuber seeds to remove soil particles would reduce the transmission of scab onto new tubers (Table 1.2.1).

Two commercial seed lines that had relatively high levels of common scab (11% in seed line 1, and 12 % in seed line 2) were separated into three categories: unwashed seed picked at random, washed seed with no visible scab lesions and washed seed with visible scab lesions.

The potatoes were then evaluated in a pot trial for their ability to transmit common scab to new tubers in pasteurised soil.

The level of common scab on the unwashed tubers in the commercial seed lines is unknown because dirt on the surfaces may have been obscuring scab lesions.

Study 2

Tubers from a non-commercial seed lot that had a very high level of common scab infections (90 % tubers infected) were examined for their ability to transmit scab, based on the severity of the common scab infections. Tubers were separated into 3 categories: no scab, mild scab and severe scab (Table 1.2.1).

Disease assessment

Tubers from an infected crop were separated into three categories, according to the presence of common scab lesions and disease severity. The three categories of tuber seeds used were: no scab - no visible common scab lesion on the tuber; mild superficial scab - scab lesions that were only skin deep, and deep scab - lesions that were 3 to 5mm deep. Both the superficial and deep scab tuber seeds had low scab coverage of about 5%. The trial design was a randomised complete block, with 10 replicate pots. Plants were watered on alternate days, and soil moisture ranged from field capacity (after irrigation or rainfall) to close to wilting point.

Analysis

Analysis of variance was performed using StatGraphics Plus 2.0. Comparisons were made of mean values using Least Significant Difference (LSD) Test.

Results & Discussions

Study 1

Common scab infected tubers were found in most of the plants produced from the infected seed lines, including those from seed that had no common scab lesions (Table 1.2.2). The washing process appeared to cause a slight reduction in the percentage of new tubers with common scab (Table 1.2.2). It is interesting to note that the unwashed tuber seeds tended to have a higher percentage of plants with infected new tubers, compared to those that were washed and selected based on the absence or presence common scab lesions. The unwashed tuber seeds were picked at random from two seed lines with 11 and 12% scab incidence, and hence were expected to be more likely to be free of common scab lesions.

1: Relevance of seedborne common scab (Cont.)

Table 1.2.2: The ability of unwashed and washed infected seed potatoes to transmit common scab

No.	Seed Classification	Common scab lesions on seed tubers	% Plants with common scab infected tubers	% Tubers with common scab	% Tubers with deep scab
	Commercial seed 1				
1	Unwashed	Unknown	90	63 bc	41 bc
2	Washed scab	Yes	80	74 c	51 cd
3	Washed no scab	No	60	40 ab	22 ab
	Commercial seed 2				
4	Unwashed	Unknown	80	81 c	62 cd
5	Washed scab	Yes	60	83 c	73 d
6	Washed no scab	No	40	66 c	58 cd

Within the same column, means followed by the same letter are not significantly different at the 5% level according to LSD Test.

Tuber seeds with no common scab lesions from the two infected certified lines still transmitted the disease onto new tubers (Table 1.2.2). This indicates that, as for many other potato disease-causing pathogens (eg. *Erwinia carotovora* and *Rhizoctonia solani*), the absence of disease symptoms on tuber seeds is not a reliable indicator of their ability to transmit the common scab pathogen onto new tubers.

Study 2

Increased severity of common scab symptoms on tuber seed potatoes resulted in increased incidence and severity of the disease on new tubers (Table 1.2.3). Laboratory tests showed that deep common scab lesions were found to have higher pathogen levels than superficial lesions. As in Study 1, tuber seeds from the infected line, with no common scab lesions, could still transmit the disease onto new tubers (Table 1.2.3).

Table 1.2.3: The effect of scab disease severity of infected tuber seed potatoes, on disease development on new tubers

No.	Common scab symptom on tuber seeds	% Tubers with common scab	% Tubers with deep scab
	Non-commercial seed 3		
7	No scab	27 a	4 a
8	Mild superficial scab	38 ab	14 a
9	Severe deep scab	61 bc	44 bc

Within the same column, means followed by the same letter are not significantly different at the 5% level according to LSD Test.

1: Relevance of seedborne common scab (Cont.)

1.3: Seedborne threshold levels

Introduction

The threshold level for common scab incidence on certified seed lines is currently 4%. This study examined whether there is any correlation between scab incidence in tuber seed lines and disease transmission onto new tubers. The study also examined whether, with effective seedborne disease control using mancozeb seed treatment, the disease threshold level may be increased.

Materials and Methods

This study was conducted in a pot trial (using pasteurised soil) in the 1999/2000 growing season. The common scab incidence levels to be examined were 2, 4, 6, 50 and 100%. The tuber seeds lines with 2, 4 and 6% common scab incidence were from certified seed lines. The seed lines with 50% scab came from ware potatoes that were destined for processing, while the 100% infected tuber seeds were from a process potato crop that was not harvested due to its high disease incidence and severity.

The unwashed tuber seeds were cut, and 20 tubers were taken at random from each seed line for the pot trial. Half of the cut seeds in each incidence level were treated with mancozeb, while the other half remained untreated. In the mancozeb seed treatments, the cut tuber seeds were dusted with Tato dust (20% mancozeb) at the rate of 4kg/tonne seed weight.

Only one cut seed piece (sett) from each tuber seed was used. The sett was planted to a depth of 15cm in each 2.5L pot. The trial design was randomised complete block, with 8 replicate pots. The pots were watered on alternate days, with soil moisture ranging from field capacity to close to wilting point. Fertiliser was applied fortnightly.

Table 1.3.1: Treatment details

No.	% Common scab incidence in tuber seed line	Chemical seed treatment	Application method
A1	2	None	None
A2	4		
A3	6		
A4	50		
A5	100		
B1	2	Tato dust (20% mancozeb)	Dusted onto cut setts
B2	4		
B3	6		
B4	50		
B5	100		

1: Relevance of seedborne common scab (Cont.)

Disease assessments

Common scab incidence was tabulated from the percentage of tubers with visible common scab lesions. Infected tubers were also rated for disease severity according to the presence of deep scab (lesions that were more than 3mm deep), and common scab coverage. The common scab coverage rating was based on the proportions of tuber surface covered by scab lesions as described by Falloon et al (1995).

Common scab coverage of the whole tuber surface was rated as follows:

% mild = % tubers with 1-10% surface covered by scab lesions
% moderate = % tubers with 11-30% surface covered by scab lesions
% high = % tubers with 31-60% surface covered by scab lesions

Analysis

All data sets were log transformed, and analysis of variance was performed using StatGraphics Plus 2.0. Comparisons were made of mean values using Least Significant Difference (LSD) Test. Mean values presented in the tables below are based on the means of non-transformed data.

Results & Discussion

Table 1.3.2: The effects of common scab incidence in tuber seed lines and mancozeb seed treatments, on the incidence and severity of common scab on new tubers

No.	% Common scab incidence in tuber seed line	Chemical treatment	% Tubers with common scab	Scab coverage			% Tubers with deep scab
				% Mild	% Moderate	% High	
A1	2	None	2 ab	1.7	0.0	0.0	0.0
A2	4		13 c	10.9	2.4	0.0	3.3
A3	6		5 ab	2.5	2.5	0.0	2.5
A4	50		15 cd	11.2	2.5	1.7	7.5
A5	100		89 d	25.6	34.2	29.3	53.1
B1	2	Tato dust	2 ab	1.6	0.8	0.0	1.6
B2	4		3 ab	1.9	0.7	0.0	2.6
B3	6		1 a	0.0	0.0	0.0	0.0
B4	50		3 ab	2.5	0.0	0.0	0.0
B5	100		82 d	33.4	40.4	8.2	25.1

Within the same column, means followed by the same letter are not significantly different at the 5% level according to LSD Test.

1: Relevance of seedborne common scab (Cont.)

There was no significant correlation between the different incidence of common scab on the 2, 4, 6 and 50% seed lines and the incidence of common scab on new tubers produced from them (regression analysis: p = 0.4124, R squared = 2.25%, correlation coefficient = 0.15). This showed that an increase in the percentage of infected tubers in the tuber seed lines did not cause an increase in the disease incidence on new tubers.

Tuber seeds from the seed line with 4% produced a significantly higher incidence of scab compared to those from the 2% and 6%, but were similar to those from 50%. This indicates that, apart from scab incidence of the seed lines, there are other factors that may be of greater importance in influencing the level of disease transmitted onto new tubers. These include disease severity, seed origin, amount of soil attached to tubers, and strains and species of pathogen.

Tuber seeds from the seed line with 50% scab incidence resulted in 15% tubers with common scab lesions, which were mainly superficial and low in scab coverage, with 5% or less (usually 1-3 scab lesions) (Table 1.3.2). Although the seed line used had a high disease incidence, the infected tuber seeds consisted of superficial scab lesions with low scab coverage.

Tuber seeds from the 100% scab seed line that had severe deep-pitted scab lesions and high surface coverage of about 50%, resulted in very high disease incidence, as well as greater scab coverage and deep lesions (Table 1.3.2). This indicates that disease severity may be a more important factor than disease incidence, in influencing the level of disease transmission from an infected seed line.

Apart from Treatment B5, seed treatments with Tato dust on the infected seed lines with 2, 4, 6 and 50% common scab incidence, resulted in very low to insignificant level of disease transmission onto new tubers. Infected tubers in these seed lines had superficial scab lesions with low scab coverage (usually 1-3 lesions). This indicates that seed treatments with Tato dust gave good control of seedborne scab on tuber seeds with low disease severity. This low disease severity is classified as superficial type common scab lesions and low number of scab lesions, which is typical of common scab, found in certified seed lines.

The Tato dust treatment, however, gave poor seedborne disease control in Treatment B5 (Table 1.3.2). Tuber seeds used in Treatments A5 and B5 came from a severely infected crop that was not harvested for processing, and hence is unlikely to be encountered in certified seed lines. The infected tubers had deep-pitted scab and high surface coverage (50% or more).

Section 2: Control of seedborne common scab

Trial Details

	Section 2.1	Section 2.2	Section 2.3	Section 2.4	Section 2.5
Aim	In vitro screening of potential products in a laboratory study	Examination of the effects of cement seed treatment on common scab in a pot trial	Screening of potential products in a pot trial	Evaluation of different mancozeb seed treatments in a pot trial	Field trials to refine seed treatment methods
Seed Source	Tubers from certified seed lines	Tubers from certified seed lines	Infected tubers from ware potatoes	Infected tubers with 10-20% scab coverage	See Section 2.5 for details
Trial Design	N/a	Randomised complete block	Randomised complete block	Randomised complete block	Randomised complete block
Crop/Variety	Russet Burbank	Russet Burbank	Russet Burbank	Russet Burbank	Russet Burbank
Treatments	9	10	10	18	6-7
Replicates	3	10	10	10	10
Season	96/97	97/98	97/98	98/99	99/00

2: Control of seedborne common scab (Cont.)

Summary

Studies conducted in the early 1990s by Wilson et al. (1999) showed that the fungicide products, fluazinam (Shirlan), flusulfamide (Scablok) and mancozeb (Dithane) have the potential to control common scab.

Initial studies conducted in this project showed that Tato dust (a mancozeb based product), which is a low cost product already registered for disease control in potatoes, was effective in controlling seedborne common scab. Its efficacy was consistently found to be similar to Shirlan and Scablok. Further studies were conducted to evaluate different types of mancozeb products, with particular emphasis on the development of commercial application methods.

All mancozeb-based products, Penncozeb®, Dithane®, Tato dust® and Tato bark®, reduced the incidence and severity of common scab infections on new tubers. The level of common scab control achieved with mancozeb was similar to that achieved with Shirlan® and Maxim®.

Studies conducted to evaluate different methods of mancozeb product applications, showed that tuber seeds can be treated before or after storage, and can be dusted or sprayed.

Effective common scab control was obtained with the early application of mancozeb, at four months before planting, indicating that pre-storage seed treatment is an option to growers. Spray treatments are best applied on whole tubers, as mancozeb application can cause a toxic effect on freshly cut tuber surfaces. Dust application is, therefore, more suitable for freshly cut tubers. High rates of mancozeb can sometimes cause burn on freshly cut tuber surface, however mixing mancozeb with Douglas fir bark, eg Tato bark, can negate the toxic effect of mancozeb. Tato bark, used in many trials on different batches of freshly cut tubers, showed no phytotoxic effects.

Mancozeb seed treatments significantly reduced common scab on new tubers, when compared to untreated infected tuber seeds, in two field trials conducted in soil where common scab was not a problem in previous potato crops. However, in two field trials conducted in soil where the common scab pathogen level is high and widespread, fungicide seed treatments had little or no effect in reducing common scab.

2: Control of seedborne common scab (Cont.)

2.1: Identification of products inhibitive to Streptomyces scabies

Introduction

Laboratory screening tests were conducted on new products, as well as products currently registered for use on potatoes, to identify inhibitory activity on the common scab pathogen *Streptomyces scabies*.

Materials & Methods

Eight fungicide/antimicrobial products were screened for inhibitory activity on the common scab pathogen, *Streptomyces scabies* (strain 3). Chemical products of specified concentrations were mixed with *Streptomyces* inoculum at 1:1 ratio just prior to spreading over yeast-malt extract agar medium on a petri dish (Table 2.1.1). The eight products tested were Boric acid, Fungaflor, Flusulfamide, Penncozeb, Nylate, Ridomil, Shirlan and Tecto. Sterile water was used for the control treatment. Except for Flusulfamide at 10 and 100ppm, the chemicals were tested at 100 and 1000ppm. Each treatment was repeated 4 times. Inoculated plates were placed in an incubator and maintained at 22°C for 7 days, and assessment was made on growth of the *Streptomyces* pathogen.

The following rating was used in the assessment:

0 = no inhibition (normal growth, surface of agar medium completely covered)
1 = moderate inhibition (single colonies on surface of agar medium)
2 = complete inhibition (no growth found on agar medium)

Results & Discussion

Nylate, Shirlan and Flusulfamide completely inhibit growth of *S. scabies* at 100ppm. Fungaflor and Penncozeb completely inhibit the pathogen at 1000ppm but not at 100ppm. Boric acid, Ridomil and Tecto showed no inhibitory activity on growth of the pathogen.

Table 2.1.1: Inhibitory activity of various products on *Streptomyces scabies*

No.	Product	Active ingredient (a.i.)	a.i. concentration		
			10ppm	100ppm	1000ppm
1	Boric acid	Boric acid	-	0	0
2	Fungaflor	Imazalil	-	0	2
3	Penncozeb	Mancozeb	-	1.25	2
4	Scablock	Flusulphamide	0	2	-
5	Nylate	Hydro-chlorobromide	-	2	2
6	Ridomil	Metalaxyl	-	0	0
7	Shirlan	Fluazinam	-	2	2
8	Tecto	Tebuconazole	-	0	0
9	Untreated control	N/a	0	0	0

2: Control of seedborne common scab (Cont.)

2.2: Effects of cement treatments on common scab

Introduction

Cement is commonly used as a drying medium of cut potato seed in Tasmania. Cement is a highly alkaline product, and hypothetically has the potential to raise the soil pH immediately around the treated tuber seed. High soil pH is known to be favourable to the common scab pathogen, *S. scabies*. The effects of cement dusting on common scab infection from seedborne and soil inoculum is not known. This study was, therefore, conducted in a pot trial to investigate the effects of cement seed treatment of tuber seeds planted in soil with various levels of soilborne inoculum.

Materials & Methods

This study was conducted in a pot trial in the 1997/98 growing season. Certified tuber seeds with no scab lesion were used.

Each pot was initially filled with 2L pasteurized soil mix, then a potato sett was placed on the surface and covered with 8.5L soil mix to a depth of 15cm. Where appropriate, the different levels of *S. scabies* (cultured in vermiculite, sand, sucrose and yeast extract mixture) were mixed with the 8.5L topsoil.

Freshly cut potato setts were either untreated or cement coated. Cement treated setts were prepared by placing cut seed pieces in a large plastic bag, and mixed thoroughly with cement (4g/kg seed) until well coated. The pH of cement was also measured in a mixture of cement and water (1:5 ratio).

After plant emergence, Nitrophoska Blue fertiliser (12.5% nitrogen, 5.2% phosphorus, 14.1% potassium, 1.2% magnesium, 5% calcium plus trace elements) was applied at 2 week intervals. The pots were maintained in an open environment, and watering was applied to free draining capacity when required.

Disease assessment

Common scab incidence was tabulated from the number of tubers with common scab lesions. The infected tubers were also rated for disease severity, superficial or deep scab lesions, and according to common scab coverage (includes both superficial and deep scab), as follows:

0 = no scab - no scab lesion on tuber
1 = mild scab - less than 10% coverage
2 = moderate scab - between 10 to 20% coverage
3 = severe scab - greater than 20%

The common scab coverage rating was based on the proportions of tuber surface covered by scab lesions as described by Falloon et al (1995).

Analysis

Analysis of variance was performed using StatGraphics Plus 2.0. The percentage of tubers with deep scab was square root transformed to normalise the data set before analysis. Comparisons were made of mean values using the Least Significant Difference Test. All mean values presented in tables below are means of non-transformed data.

2: Control of seedborne common scab (Cont.)

Results & Discussions

Table 2.2.1: The effects of cement seed treatments, in soil with various levels of soilborne inoculum, on common scab incidence and severity

No.	Seed treatment	Scab inoculum level	% Tubers with common scab *	% Tubers with deep scab
1	None	0	21 a	4 a
2		1g	46 b	12 ab
3		5g	66 c	30 b
4		50g	95 e	63 c
5		100g	96 e	73 c
6	Dusted with 4g/kg cement	0	23 a	10 ab
7		1g	43 b	24 ab
8		5g	72 cd	38 b
9		50g	92 e	31 b
10		100g	89 de	69 c

Within the same column, means followed by the same letter are not significantly different at the 5% level according to LSD Test.

A delay of about 2 weeks in plant emergence was observed with cement treated setts. At the end of the trial, however, there was no obvious difference between the plant sizes. The pH of cement was 14.

Seed treatments with cement had little or no effect in reducing common scab incidence or severity in this trial. There was no significant difference in either the percentage of infected tubers or deep scab ($p>0.05$) on new tubers produced from tuber seeds dusted with cement, compared to those not dusted with cement (Table 2.2.1).

The percentage of tubers with common scab and deep scab increased with increasing levels of scab inoculum in soil (Table 2.2.1). Almost all the infected tubers had low or mild scab coverage of 10% or less (Table 2.2.2).

2: Control of seedborne common scab (Cont.)

Table 2.2.2: The effects of cement seed treatments, in soil with various levels of soilborne inoculum, on the percentage of tubers within different scab coverage ratings

Treatment No.	Seed treatment	Scab inoculum level	Common scab coverage		
			% Mild	% Moderate	% High
1	None	0	21	0	0
2		1g	46	0	0
3		5g	64	2	0
4		50g	93	2	0
5		100g	89	7	0
6	Dusted with 4g/kg cement	0	23	0	0
7		1g	43	0	0
8		5g	72	0	0
9		50g	88	4	0
10		100g	82	7	0

2: Control of seedborne common scab (Cont.)

2.3: Evaluation of chemical seed treatments for seedborne common scab control

Introduction

This study was conducted to evaluate the efficacy of seed treatments using products that were shown to be inhibitive to *S. scabies* (Section 2.1) for the control of seedborne common scab disease.

Materials & Methods

This study was conducted as a pot trial in the 1997/98 growing season. Infected tubers were obtained from a commercial crop with a high incidence of common scab. Disease symptoms on the infected tubers ranged from superficial scab to deep scab, with about 10 to 20% coverage.

The infected tubers were treated either before or after cutting into setts (Table 2.3.1) as follows:

- **Before cutting** - whole tubers were sprayed lightly with water to wet the surface, then either coated with a dry chemical product in a plastic bag or sprayed with a chemical suspension until all surfaces were covered. The treated tubers were then placed on a tray, air-dried, and stored in a shed for 3 days before cutting and planting.

- **After cutting** - whole tubers were cut into 50g setts, then treated as described above with either a dry chemical product or a chemical suspension until all surfaces were covered. Alternatively, cut setts were dipped into an appropriate chemical for a set time. The treated tubers were then placed on a tray, air-dried, and planted into pots on the same day.

The cut tuber setts were then planted into pots and maintained as described in Section 2.2.

Table 2.3.1: Treatment details

No.	Treatment	Product	Product Rate	Application method
1	Boric acid	Boric acid	3%	30min dip after cutting
2	Shirlan before	Shirlan	40ml/L	spray before cutting
3	Shirlan after	Shirlan	40ml/L	spray after cutting
4	Scablok after	Scablok	40ml/L	5min dip after cutting
5	Scablok before	Scablok	40ml/L	spray before cutting
6	Penncozeb before	Penncozeb	4g/kg	dust before cutting
7	Nylate before	Nylate	4g/kg	dust before cutting
8	Fungaflor before	Fungaflor	20g/L	spray before cutting
9	Kocide after	Kocide	1.5/kg	dust after cutting
10	Untreated control	Control	n/a	n/a

2: Control of seedborne common scab (Cont.)

Disease assessment

Common scab incidence was tabulated from the number of tubers with common scab lesions, and the infected tubers were also rated for disease severity according to common scab coverage, as described in Section 2.2.

Analysis

All data sets were tested for normality before analysis and, where appropriate, log transformations were applied to normalise the data. Analysis of variance was performed using StatGraphics Plus 2.0. Comparisons were made of mean values using Duncan's Multiple Range Test.

Results & Discussion

The tuber seeds used in this trial had new shoots (3-5mm long), when the chemical treatments were applied. Fungaflor was phytotoxic, delaying plant emergence from the treated seed (Table 2.3.2). All other chemical treatments showed no phytotoxic effect.

Penncozeb and Shirlan treated seed produced the highest percentage of tubers without scab, followed by Kocide. Fungaflor and boric acid treatments did not significantly reduce the percentage of common scab infected tubers (Table 2.3.2).

Tubers from the Penncozeb, Shirlan and Kocide treatments had low scab coverage indices (less than 10%). The scab coverage index of the Nylate treatment was also relatively low at 14%.

Table 2.3.2: The effects of chemical treatments of infected seed, on plant emergence and common scab control on new tubers

No.	Treatment	% Plant emergence at 27 DAP	% Plant emergence at 56 DAP*	% Tubers with common scab	% Scab coverage severity index
1	nil	95 b	100	59.0 b	38.9 f
2	Fungaflor before	40 a	100	72.3 a	46.0 ef
3	Boric acid	95 b	100	58.5 b	32.5 de
4	Scablok before	100 b	100	40.3 c	26.2 d
5	Scablok after	100 b	100	32.5 c	16.0 c
6	Nylate before	95 b	100	27.6 cd	14.3 bc
7	Kocide before	90 b	100	15.8 de	6.4 ab
8	Shirlan before	100 b	100	7.8 ef	3.2 a
9	Shirlan after	100 b	100	8.0 ef	5.0 ab
10	Penncozeb before	100 b	100	0.6 f	0.2 a

DAP = days after planting

Within the same column, means followed by the same letter are not significantly different at the 5% level according to Duncan's Multiple Range Test.

* Not significantly different according to analysis of variance.

2: Control of seedborne common scab (Cont.)

2.4: Evaluation of mancozeb treatments

Introduction

This trial was conducted to evaluate different types of mancozeb products and application methods to control common scab transmission from infected tuber seeds in a pot trial. Two new products, Shirlan and Maxim, were also examined in the study for common scab control.

Tubers from 3 different locations, Deloraine, West Pine and Bellfield, were used in this study, to determine the efficacy of mancozeb seed treatments on infected seeds that showed different types of common scab symptoms. The symptoms varied from circular scab lesions from Deloraine, to russet scab lesions from West Pine and irregular scab lesions from Bellfield. Tubers from Bellfield came from a previous season's common scab control field trial.

Materials and Methods

All tuber seeds used in this trial had common scab lesions. Tuber seeds were cut and planted within 24 hours after cutting. The cut setts were planted into pots and maintained as described in Section 2.2.

Tuber seed treatments

The methods of tuber seed treatments were as described in Table 2.4.1. Except for Treatment 11, the tuber seeds were treated without wetting the surface prior to treatments. In Treatment 11, the cut tuber seeds were sprayed with a fine mist of water in order to wet the tuber skins.

In the early Penncozeb treatments, whole tuber seeds were treated and stored in a cold store for the appropriate time. All tubers for the trial were taken out of cold store two weeks before cutting and planting. In the treatments where the products were to be applied after cutting, the cut tubers were treated within 6 hours after cutting.

The mancozeb products examined in this study were Penncozeb (75% mancozeb, dry flowable granules), Tato dust (20% mancozeb, dust powder), Tato bark (8% mancozeb in a mixture of Tato dust and Douglas fir bark), and Dithane (80% mancozeb, wettable powder). In the spray applications, Penncozeb was applied at a rate of 200g product per litre water.

In the dust application, products were dusted onto tuber seeds by mixing in a plastic bag. All the tubers treated with the dust application method were well coated with the appropriate product.

In the spray application, a suspension of the appropriate product was prepared and sprayed using a one-litre hand sprayer until run-off and the setts were completely covered. The sprayed setts were air-dried overnight before planting.

Disease assessment

Disease assessment was conducted as described in Section 2.2.

Analysis

Analysis of variance was performed using StatGraphics Plus 2.0. Comparisons were made of mean values using Least Significant Difference Test (LSD).

2: Control of seedborne common scab (Cont.)

Table 2.4.1: Treatment details

No.	Treatments	Active Ingredient	Tuber seed origin	Product Rate	Application method
1	Penncozeb 4mth	75% mancozeb	Deloraine	4g/kg seed	**Dusted** until well coated; whole tubers treated within **4 months before cutting** & sowing
2	Penncozeb 6hr	75% mancozeb		4g/kg seed	**Dusted** until well coated; cut tubers treated within **6 hours before cutting** & sowing
3	Untreated	N/a		N/a	N/a
4	Penncozeb 4mth	75% mancozeb	West Pine	4g/kg seed	**Dusted** until well coated; whole tubers treated within **4 months before cutting** & sowing
5	Penncozeb 6hr	75% mancozeb		4g/kg seed	**Dusted** until well coated; cut tubers treated within **6 hours before cutting** & sowing
6	Untreated	N/a		N/a	N/a
7	Penncozeb 4mth sprayed – complete cover	75% mancozeb	Bellfield	200g/L	**Sprayed** until run-off for **complete cover**, whole tubers treated **4 months before cutting** & sowing
8	Penncozeb 4mth sprayed – partial cover	75% mancozeb		200g/L	**Sprayed** for **50% cover** by droplets, whole tubers treated **4 months before cutting** & sowing
9	Penncozeb 4mth	75% mancozeb		4g/kg seed	**Dusted** until well coated; whole tubers treated within **4 months before cutting** & sowing
10	Penncozeb 2mth	75% mancozeb		4g/kg seed	**Dusted** until well coated; whole tubers treated within **2 months before cutting** & sowing

2: Control of seedborne common scab (Cont.)

Table 2.4.1: Treatment details (cont.)

No.	Treatments	Active ingredient	Tuber seed origin	Product Rate	Application method
11	Penncozeb 6hr wet coat*	75% mancozeb	Bellfield (cont.)	4g/kg seed	**Dusted** until well coated; sprayed water onto cut tubers to wet the tuber skin before dusting to treat them within **6 hours after cutting**
12	Penncozeb 6hr	75% mancozeb		4g/kg seed	**Dusted** until well coated; cut tubers treated within **6 hours after cutting**
13	Tato dust	20 % mancozeb		4g/kg seed	
14	Tato bark	8% mancozeb		2g/kg seed	
15	Dithane WP	80% mancozeb		4g/kg seed	
16	Shirlan	50% fluazinam		40ml/L	**Sprayed** until run-off for **complete cover**; cut tubers treated **6 hours after cutting**
17	Maxim	10% fludioxinol		13ml/L	
18	Untreated control			na	na

* In Treatment 11, the cut tuber seeds were sprayed with a fine mist of water to wet in order to wet the tuber skins.

Results & Discussion

Cut tuber seeds dusted with mancozeb products and Tato bark had a good, even coating. Cut tuber seeds, dusted with Penncozeb after wetting by a mist of water spray, in Treatment 11 resembled tubers that had been completely coated by Penncozeb spray in Treatment 7.

Tubers from the 3 different locations showed a variation in common scab symptoms; circular scab lesions from Deloraine, russet scab lesions from West Pine, and irregular scab lesions from Bellfield. Different species or strains of pathogenic *Streptomyces* have been shown to cause different types of common scab symptoms (Healy & Lambert 1991, Doering-Saad et al 1992).

Penncozeb dusted onto infected tuber seeds caused a reduction in the number of plants with infected tubers (Table 2.4.2). As a result, the common scab incidence on new tubers was significantly lower from Penncozeb treated tuber seeds than from untreated tuber seeds. This showed that Penncozeb was effective in controlling scab caused by pathogens from different sources and with different common scab symptoms.

Early treatments (at 4 months) on seed from Deloraine and West Pine, appeared to cause a greater reduction in scab incidence compared to later treatments (at 24 hours prior to planting).

2: Control of seedborne common scab (Cont.)

Table 2.4.2: The effects of mancozeb (Penncozeb DF 750g/kg) application timing on infected seed from different locations, in a pot trial

No.	Treatments	Tuber seed origin	No. plants with infected tubers (from a total of 10 plants)	% Tubers with common scab	% Tubers with deep scab
1	Penncozeb 4mth	Deloraine	1	2 a	0
2	Penncozeb 24hr		3	12 ab	5
3	Untreated		10	86 d	73
4	Penncozeb 4mth	West Pine	0	0 a	0
5	Penncozeb 24hr		2	9 ab	4
6	Untreated		9	52 c	41
9	Penncozeb 4mth	Bellfield	2	9 ab	2
12	Penncozeb 24hr		2	4 a	1
18	Untreated		9	61 c	45

Within the same column, means followed by the same letter are not significantly different at the 5% level according to LSD Test.

Table 2.4.3: The effects of different Penncozeb application methods on the control of seedborne common scab

No.	Treatments	Application method	No. plants with infected tubers	% Scab Incidence	% Tubers with deep scab
7	Penncozeb 4mth	Sprayed - complete cover	0	0 a	0
8	Penncozeb 4mth	Sprayed - partial cover	5	10 ab	5
9	Penncozeb 4mth	Dusted	2	9 ab	2
10	Penncozeb 2mth	Dusted	0	0 a	0
11	Penncozeb 12hr wet	Dusted after water spray to wet tuber skin	6	21 b	16
12	Penncozeb 12hr	Dusted	2	4 a	1
18	Untreated control	N/a	9	61 c	45

Within the same column, means followed by the same letter are not significantly different at the 5% level according to LSD Test.

2: Control of seedborne common scab (Cont.)

Infected tuber seeds from Deloraine produced a significantly higher percentage of tubers with common scab compared to those from West Pine and Bellfield. This indicates that the level of common scab transmitted from infected seeds is influenced by their origin. The differences in disease transmission could be related to either the different species or strains of *Streptomyces* pathogens, as well as the spore levels carried on those infected tuber seeds. Studies conducted elsewhere have shown that the pathogenicity of common scab pathogens is dependent on all these factors (Healy & Lambert 1991, Doering-Saad et al 1992, Keinath & Loria 1991).

Complete surface coverage of tuber seed by a high spray volume application of mancozeb (Treatment 7) appeared to improve seedborne scab control compared to the partially covered tuber seed (Treatment 8) (Table 2.4.3). In contrast, however, the wetting of seed surfaces before dusting infected seed seemed to increase common scab incidence and severity. No explanation could be given for this phenomenon.

Table 2.4.4: The effects of different chemical products on seedborne common scab control

No.	Treatment	Active ingredient	Product Rate/tonne	No. plants with infected tubers	% Tubers with common scab	% Tubers with deep scab
12	Penncozeb DF	75% mancozeb	2.0 kg	2	4 a	1
15	Dithane WP	80% mancozeb	2.0 kg	4	5 a	4
13	Tato dust	20% mancozeb	4.0 kg	4	8 ab	6
14	Tato bark	8% mancozeb	2.0 kg	5	12 ab	10
16	Shirlan	50% fluazinam	200 ml/5L	3	5 a	3
17	Maxim	10% fludioxinol	65 ml/5L	5	9 ab	2
18	Untreated control			9	61 c	45

Within the same column, means followed by the same letter are not significantly different at the 5% level according to LSD Test.

All treatments reduced the incidence and severity of common scab infections in new tubers when compared to the untreated control (Table 2.4.4). Although increased concentrations of mancozeb appeared to increase seedborne scab control, there was no significant difference between the different mancozeb rate.

As Shirlan and Maxim are also known to be effective against other seedborne diseases (eg. Maxim also controls *Rhizoctonia* disease), the use of these products should be considered when other seedborne diseases are also a concern.

2: Control of seedborne common scab (Cont.)

2.5: Field trials to refine seed treatment methods

Trial details

	Trial 1	Trial 2	Trial 3	Trial 4
Location	Sassafras	Thirlstane	West Pine	Deloraine
Paddock History	Common scab not a major problem	Common scab not a major problem	Major common scab problem in previous potato crop	Major common scab problem in previous potato crop
Seed Source	4% infected certified seed line	50% infected tuber seeds from a previous field trial	4% infected certified seed line	50% infected tuber seeds from a previous field trial
Treatment Methods	Seed treatments - 24 hours before planting	Seed treatments - 2 months or 24 hours before planting	Seed treatments - 2 months or 24 hours before planting	Seed treatments - 24 hours before planting
Trial Design	Randomised complete block	Randomised complete block	Randomised complete block	Randomised complete block
Variety	Russet Burbank	Russet Burbank	Russet Burbank	Russet Burbank
Soil Type	Ferrosol	Ferrosol	Ferrosol	Ferrosol
Treatments	6	7	7	6
Replicates	10 (5 plants per replicate)	10 (5 plants per replicate)	10 (5 plants per replicate)	10 (5 plants per replicate)
Plot Size	1 row x 12m	1 row x 12m	1 row x 12m	1 row x 12m
Plant Spacing	35cm	35cm	35cm	35cm
Row Spacing	80cm	80cm	80cm	80cm
Planting Season	99/00	99/00	99/00	99/00

Introduction

Four field trials were conducted to establish the effectiveness of mancozeb seed treatments in controlling seedborne common scab, under field conditions, on plants maintained in the same manner as commercial crops.

Materials and Methods

All the trials were conducted within commercial Russet Burbank crops, and apart from the different seed treatments, plants in the trial areas were managed in the same manner as the surrounding commercial crops.

2: Control of seedborne common scab (Cont.)

Trials 1 and 2 were conducted in fields where common scab was not observed in previous potato crops. Trials 3 and 4 were conducted in fields where previous potato crops had high common scab incidence and severity.

There were 10 replicate plots for each treatment. Based on previous field trials conducted, a combination of small plot size and a large number of replicate plots were recommended to account for variability in the field.

Tuber seed treatments

The methods of tuber seed treatments are described in Tables 2.5.1 - 2.5.4. The tuber seeds were treated without wetting the surface prior to treatments.

In the early Penncozeb treatments, whole tuber seeds were treated and stored in a cold store for 6 weeks. All tubers for the trial were taken out of cold store and left at ambient room temperature two weeks before cutting and planting. In the treatments where the products were to be applied after cutting, the cut tubers were treated within 6 hours of cutting.

The mancozeb products examined in this study were Penncozeb DF (75% mancozeb, dry flowable granules), Tato dust (20% mancozeb, dust powder), Tato bark (8% mancozeb in a mixture of Tato dust and Douglas fir bark), and Dithane WP (80% mancozeb, wettable powder). In the spray applications, Penncozeb was applied at a rate of 200g product per litre water.

Tuber seeds came from a certified seed line that had 4% common scab infected tubers (Trials 1 and 3), and from an infected crop from a previous field trial at Forth, with an average of 50% infected tubers (Trials 2 and 4). Almost all infected tubers from both seed sources consisted of mainly superficial scab with low common scab coverage. Cut setts used in the trials were picked at random, with and without common scab lesions. Tuber seeds picked from the 50% infected tubers had a 50% chance of having common scab lesions on them.

In the dust application, products were dusted onto tuber seeds by mixing in a plastic bag. All the tubers treated with the dust application method were well coated with the product.

In the spray application, 8% mancozeb spray mixture was obtained by mixing Penncozeb DF with water (10.67g product/L water).

Disease assessment

At harvest, all tubers from treatment plots were collected, washed, and checked for presence of common scab lesions. The infected tubers were then classified as either superficial scab or deep scab: superficial scab (lesions 1 to 3mm deep) and deep scab (lesions greater than 3mm deep). The percentage of tubers with common scab, superficial scab and deep scab were then tabulated.

Analysis

All data sets were log transformed to normalise the raw data, before conducting analysis of variance using StatGraphics Plus 2.0. Comparisons were made of mean values using Least Significant Difference (LSD) Test. Mean data presented in the results are based on means of non-transformed data.

2: Control of seedborne common scab (Cont.)

Results & Discussions

Trials 1 and 2

In both trials, infected tuber seeds of low common scab severity were treated and planted in ground where soilborne common scab was not a major problem based on previous history.

It is interesting to note that the percentage of tubers with common scab were similar between Trial 1 and Trial 2, 13% and 12% infected tubers, respectively. Trial 1 used tuber seeds from a certified seed line that had 4% common scab infected tubers, while Trial 2 used tuber seeds that came from a previous field trial that had 50% infected tubers. This confirmed earlier findings in a pot trial (Section 1.3), that the level of common scab transmitted by the tuber seeds was not related to the disease incidence on the tuber seeds. A high incidence of common scab infected seed does not necessarily increase the disease incidence on new tubers. Tuber seeds used in both trials had low scab coverage and superficial scab lesions.

Powdery scab was also present in Trial 1, but with low incidence (ranging from 2 to 4% tubers with powdery scab) as well as low disease severity (small superficial lesions with less than 5% coverage) (Table 2.5.1). Powdery scab in Trial 2 was insignificant (0 - 1.8% infected tubers) (Table 2.5.2). There were no differences in powdery scab incidence between the different mancozeb treatments and the untreated control in both trials ($p>0.5$). In contrast to common scab, powdery scab is favoured by high soil moisture during the tuber initiation period. The incidence of powdery scab in the two trials suggested that the soil in Trial 1 was probably wetter than in Trial 2.

Table 2.5.1: The effects of mancozeb seed treatments on tubers planted in ground where common scab was not a problem in previous crop, on seedborne common scab in Trial 1

No.	Treatment *	Product	Application method	% Tubers with common scab **	% Tubers with deep scab #	% Tubers with powdery scab #
1	80% Mancozeb	Penncozeb DF	Dust	1 a	0	4
2	20% Mancozeb	Tato dust	Dust	2 ab	1	4
3	8% Mancozeb	Dithane WP	Dust	4 b	1	3
4	8% Mancozeb	Penncozeb	Spray	1 a	0	4
5	Fir bark only	Douglas Fir bark	Dust	12 c	4	2
6	Untreated	N/a	N/a	13 c	3	3

* All seed treatments were applied within 6hr after cutting and planted within 24 hours.
** Means followed by the same letter are not significantly different at the 5% level according to LSD Test.
# Not significantly different at the 5% level according to analysis of variance.

In Trial 1, all the mancozeb seed treatments resulted in a significant reduction in the percentage of tubers infected by common scab (Table 2.5.1). There was no difference between the different mancozeb seed treatments used. The mancozeb treatments also resulted in very few to no tubers with deep scab lesions.

2: Control of seedborne common scab (Cont.)

In Trial 2, only the mancozeb seed treatments (Treatments 2, 4 and 6) resulted in a significant reduction in the percentage of tubers infected by common scab compared to the untreated control (Table 2.5.2). Although not significant, the Tato dust application in Treatment 4 in Trial 2 appeared to have a lower common scab incidence compared to the untreated control.

The mancozeb seed treatments appeared to work better in Trial 1 than in Trial 2, causing a greater reduction in the percentage of tubers with common scab. It is possible that field factors such as higher soil moisture in Trial 1 at the tuber initiation period may also influence the level of disease control. Therefore, other field factors that may influence disease incidence and severity should also be taken into account, even when considering the use of chemical treatments.

Table 2.5.2: The effects of mancozeb seed treatments on tubers planted in ground where common scab was not a problem in previous crop, on seedborne common scab in Trial 2

No.	Treatments	Product	Application		% Tubers with common scab *	% Tubers with deep scab #
			Method	Timing		
1	0.15% Mancozeb	Penncozeb DF	Spray	Before storage[1]	8 bc	1
2	20% Mancozeb	Tato dust	Dust		5 ab	1
3	0.15% Mancozeb	Penncozeb DF	Spray	After storage[2]	11 c	2
4	8% Mancozeb	Penncozeb DF	Spray		4 a	1
5	20% Mancozeb	Tato dust	Dust		7 bc	1
6	80% Mancozeb	Dithane WP	Dust		6 ab	1
7	Untreated control	N/a	N/a		12 c	2

[1] Whole tubers treated and kept in cold store for 6 weeks before use.
[2] Tubers treated within 6 hours of cutting & 24 hours prior to planting.
* Means followed by the same letter are not significantly different at the 5% level according to LSD Test.
# Not significantly different at the 5% level according to analysis of variance.

Spray application of 8% mancozeb was effective for seedborne common scab control in Trial 1 (Table 2.5.1), but caused phytotoxic effect with the blackening of the cut tuber surface of treated tuber seed. Penncozeb applied by spraying at very low concentration (0.15% mancozeb) showed no such toxic effect, but did not control seedborne common scab in Trial 2 (Table 2.5.2). This low concentration was used for foliar spray for early blight disease control on potatoes. In a pot trial conducted earlier (Section 2.4), spray application of 20% mancozeb onto whole tubers also had no adverse effects. Therefore, spray application of high rates of mancozeb is probably more suitable for whole tuber seed treatments rather than cut tuber seeds. However, high concentrations of mancozeb spray may be difficult to handle – it must be mixed thoroughly for an even suspension and spray nozzles of the hand sprayer used, often get blocked.

The percentage of tubers with deep common scab lesions was low in both trials (0-3% in Trial 1, 1-2% in Trial 2).

2: Control of seedborne common scab (Cont.)

Trials 3 and 4

In Trials 3 and 4, infected tuber seeds of low common scab severity were treated and planted in ground where soilborne common scab was a major problem based on previous history.

In Trial 3, spray application at 0.15% mancozeb caused a significant reduction in the percentage of tubers with common scab compared to the untreated control (Table 2.5.3). This is surprising, as in Trial 2, 0.15% spray applications did not cause a significant reduction in the common scab incidence compared to the untreated control (Table 2.5.2). Powdery scab was insignificant in Trials 3 and 4, ranging from 0 to 0.5%.

Table 2.5.3: The effects of mancozeb seed treatments on tubers planted in ground where common scab was a major problem in previous crop, on seedborne common scab in Trial 3

No.	Treatments	Product	Application		% Tubers with common scab *	% Tubers with deep scab #
			Method	Timing		
1	0.15% Mancozeb	Penncozeb DF	Spray	Before storage[1]	76 a	0
2	20% Mancozeb	Tato dust	Dust		85 ab	1
3	0.15% Mancozeb	Penncozeb DF	Spray	After storage[2]	76 a	0
4	8% Mancozeb	Penncozeb DF	Spray		90 b	1
5	20% Mancozeb	Tato dust	Dust		87 b	1
6	80% Mancozeb	Dithane WP	Dust		85 ab	1
7	Untreated control	N/a	N/a		87 b	0

[1] Whole tubers treated and kept in cold store for 6 weeks before use.
[2] Tubers treated within 6hr after cutting & 24hr prior to planting.
* Means followed by the same letter are not significantly different at the 5% level according to LSD Test.
# Not significantly different at the 5% level according to analysis of variance.

In Trial 4, all the mancozeb seed treatments had no significant reduction in the percentage of tubers with common scab compared to the untreated control (Table 2.5.4).

Table 2.5.4: The effects of mancozeb seed treatments on tubers planted in ground where common scab was a major problem in previous crop, on seedborne common scab control in Trial 4.

No.	Treatment	Product	Application method	% Tubers with common scab #	% Tubers with deep scab #
1	80% Mancozeb	Penncozeb DF	Dust	62	34
2	20% Mancozeb	Tato dust	Dust	63	31
3	8% Mancozeb	Dithane WP	Dust	63	32
4	8% Mancozeb	Penncozeb	Spray	65	33
5	Cement only	Cement	Dust	66	31
6	Untreated	N/a	N/a	61	32

Not significantly different at the 5% level according to analysis of variance.

The common scab symptoms found in Trial 3 were russet scab, and almost all infected tubers had superficial scab lesions (% tubers with deep scab ranged from 0 to 1%). In Trial 4, however, the common scab lesions were circular and slightly raised. A high proportion of the infected tubers in Trial 4 had deep scab lesions, ranging from 31 to 34%.

Common scab incidence in Trials 3 and 4 was high, even with the mancozeb seed treatments (76-90% in Trial 3, 61-66% in Trial 2) (Tables 2.5.3 & 2.5.4). This showed that the mancozeb seed treatments have little or no effect in reducing common scab in infected ground. The seed treatment methods were only effective for seedborne scab control, as shown in Trials 1 and 2. Other methods of disease control should be considered when planting potatoes in severely infected ground.

Section 3: Control of both seedborne and soilborne common scab

Summary

In ground where the common scab pathogen level was high and widespread, all the chemical seed treatments, soil treatments or combinations of both, had little or no effect in reducing common scab.

A combined Shirlan seed and Nylate soil treatments have no effect on scab incidence, but did reduced scab severity by reducing the percentage of tubers with deep scab. Nylate is a biocide and is used in post-harvest treatments of fruits and vegetables. This indicate that other biocides or soil fumigants may have potential in controlling common scab and should be investigated in future studies.

3.1: Field trials conducted in 1997/98

Trial Details

	Trial 1	Trial 2
Location	Bellfield	Red Hills
Treatment Methods	Soil only treatments or combined seed and soil treatments	Seed only or soil only treatments
Trial Design	Complete randomized block	Complete randomized block
Variety	Russet Burbank	Russet Burbank
Soil Type	Heavy clay loam	Ferrosol
Replicates	5	4
Plot Size	1 row x 6m	2 rows x 8m
Plant Spacing	25cm (50 setts per plot)	32cm (50 setts per plot)
Row Spacing	80cm	80cm
Planting season	97/98	97/98

Introduction

Two field trials were conducted to evaluate the efficacies of chemical seed and soil treatments for common scab control in ground infected by soilborne scab inoculum.

Trial 1 was conducted at Bellfield, where the trial area was inoculated with a common scab pathogen (cultured in vermiculite, sand, sucrose and yeast extract mixture), at a rate of 42g/m^2 and worked into soil (20cm deep) with a rotera. Trial 2 was conducted at Red Hills, in a field where severe common scab occurred in a potato crop 4 years before.

3: Control of both seedborne and soilborne common scab (Cont.)

Table 3.1.3: The effects of chemical treatments on the percentage of plant emergence, scab incidence, and deep scab.

No.	Product Treatment	Application Method	% Plant emergence at 47 days after planting*	% Tubers with common scab *	% Tubers with deep scab **
1	Penncozeb	Soil	96.0	88.7	61.1 bc
2	Tato Bark & Penncozeb	Seed & Soil	92.8	94.2	72.2 bc
3	Shirlan	Soil	93.6	94.0	62.4 bc
4	Shirlan	Seed & Soil	88.8	91.0	57.3 bc
5	Scablok	Soil	91.2	90.3	58.1 bc
6	Scablok	Seed & Soil	97.6	88.3	52.0 abc
7	Nylate	Soil	98.0	93.9	49.9 ab
8	Shirlan & Nylate	Seed & Soil	94.4	85.3	32.6 a
9	Control	N/a	92.8	82.7	57.6 bc

* Not significantly different at the 5% level according to analysis of variance.
** Means followed by the same letter are not significantly different at the 5% level according to Duncan's Multiple Range Test.

It appeared that the rate of *S. scabies* inoculum mixed into the soil was successful in causing both high common scab incidence and severity. As a result of soil inoculation with *S. scabies*, consistent levels of scab were noted in all treatment plots. Many of the infected tubers had deep-pitted scab lesions, ranging from 32 to 72% (Table 3.1.3). The common scab lesions were irregular in shape. All infected tubers had low numbers of scab lesions with scab coverage of 15% or less.

In this trial, none of the seed, soil, or combined seed and soil chemical treatments used in the trial, was successful in reducing the percentage of tubers with common (Table 3.1.3). This may be due to the high levels of soilborne scab inoculum mixed into the soil.

In the disease severity based on deep scab incidence, only the combined Shirlan seed and Nylate soil treatments (Treatment 8) significantly reduced the percentage of deep scab tubers compared to the untreated control (Table 3.1.3). Tubers from the combined Shirlan seed and Nylate soil treatment at this site tended to have thicker skin. No such effect was observed in the separate Shirlan seed treatment or the Nylate soil treatment, which had little or no effect in scab control. However, the percentage of tubers with deep scab (32.6%) in the combined Shirlan seed and Nylate soil treatments is still considered too high.

3: Control of both seedborne and soilborne common scab (Cont.)

Trial 2

As in Trial 1, although the plant emergence was not affected by all the chemical treatments, there was a delay in the emergence of the Shirlan treated setts.

The number of tubers with scab was very high for all treatments, ranging from 90 to 96% (Table 3.1.4). None of the chemical treatments showed significant reduction in the percentage of infected tubers compared to the untreated control.

Almost all infected tubers had low numbers of scab lesions, with scab coverage of 15% or less. The common scab lesions that developed were circular and slightly raised, which was different to the irregular lesions in Trial 1.

The scab disease was variable between replicate plots. No significant differences could be found between the chemical treatments and the untreated control. The worst scab tended to be found in the Penncozeb soil treatment. No explanation could be given for this observation.

Table 3.1.4: The effects of seed or soil chemical treatments on the percentage plant emergence, scab incidence and deep scab

No.	Product Treatment	Application Method	% Plant Emergence *	% Scab incidence *	% Deep scab *
1	Tato Bark	Seed	92.0	94.6	47.7
2	Shirlan	Seed	91.0	94.8	39.1
3	Scablok	Seed	92.0	96.0	54.0
4	Penncozeb	Soil	91.0	96.2	60.8
5	Shirlan	Soil	92.5	89.7	45.5
6	Nylate	Soil	92.5	96.0	46.6
7	Control	N/a	92.0	92.2	33.4

* Not significantly different at the 5% level according to analysis of variance.

3: Control of both seedborne and soilborne common scab (Cont.)

Table 3.1.3: The effects of chemical treatments on the percentage of plant emergence, scab incidence, and deep scab.

No.	Product Treatment	Application Method	% Plant emergence at 47 days after planting*	% Tubers with common scab *	% Tubers with deep scab **
1	Penncozeb	Soil	96.0	88.7	61.1 bc
2	Tato Bark & Penncozeb	Seed & Soil	92.8	94.2	72.2 bc
3	Shirlan	Soil	93.6	94.0	62.4 bc
4	Shirlan	Seed & Soil	88.8	91.0	57.3 bc
5	Scablok	Soil	91.2	90.3	58.1 bc
6	Scablok	Seed & Soil	97.6	88.3	52.0 abc
7	Nylate	Soil	98.0	93.9	49.9 ab
8	Shirlan & Nylate	Seed & Soil	94.4	85.3	32.6 a
9	Control	N/a	92.8	82.7	57.6 bc

*Not significantly different according to 95% confidence level.
**Same letters down the column is not significantly different according to 95% confidence level according to Duncan's Multiple Range Test.

It appeared that the rate of *S. scabies* inoculum mixed into the soil was successful in causing both high common scab incidence and severity. As a result of soil inoculation with *S. scabies*, consistent levels of scab were noted in all treatment plots. Many of the infected tubers had deep-pitted scab lesions, ranging from 32 to 72% (Table 3.1.3). The common scab lesions were irregular in shape. All infected tubers had low numbers of scab lesions with scab coverage of 15% or less.

In this trial, none of the seed, soil, or combined seed and soil chemical treatments used in the trial, was successful in reducing the percentage of tubers with common (Table 3.1.3). This may be due to the high levels of soilborne scab inoculum mixed into the soil.

In the disease severity based on deep scab incidence, only the combined Shirlan seed and Nylate soil treatments (Treatment 8) significantly reduced the percentage of deep scab tubers compared to the untreated control (Table 3.1.3). Tubers from the combined Shirlan seed and Nylate soil treatment at this site tended to have thicker skin. No such effect was observed in the separate Shirlan seed treatment or the Nylate soil treatment, which had little or no effect in scab control. However, the percentage of tubers with deep scab (32.6%) in the combined Shirlan seed and Nylate soil treatments is still considered too high.

3: Control of both seedborne and soilborne common scab (Cont.)

Trial 2

As in Trial 1, although the plant emergence was not affected by all the chemical treatments, there was a delay in the emergence of the Shirlan treated setts.

The number of tubers with scab was very high for all treatments, ranging from 90 to 96% (Table 3.1.4). None of the chemical treatments showed significant reduction in the percentage of infected tubers compared to the untreated control.

Almost all infected tubers had low numbers of scab lesions, with scab coverage of 15% or less. The common scab lesions that developed were circular and slightly raised, which was different to the irregular lesions in Trial 1.

The scab disease was variable between replicate plots. No significant differences could be found between the chemical treatments and the untreated control. The worst scab tended to be found in the Penncozeb soil treatment. No explanation could be given for this observation.

Table 3.1.4: The effects of seed or soil chemical treatments on the percentage plant emergence, scab incidence and deep scab

No.	Product Treatment	Application Method	% Plant Emergence *	% Scab incidence *	% Deep scab *
1	Tato Bark	Seed	92.0	94.6	47.7
2	Shirlan	Seed	91.0	94.8	39.1
3	Scablok	Seed	92.0	96.0	54.0
4	Penncozeb	Soil	91.0	96.2	60.8
5	Shirlan	Soil	92.5	89.7	45.5
6	Nylate	Soil	92.5	96.0	46.6
7	Control	N/a	92.0	92.2	33.4

* No significant differences between treatments at the 95% confidence level.

3: Control of both seedborne and soilborne common scab (Cont.)

3.2: Field trials conducted in 1998/99

Trial details

	Trial 1	Trial 2
Location	Forth	Forth
Paddock history	Previous year's potato crop had a high incidence of common scab	Previous year's potato crop had a high incidence of common scab
Treatment Methods	Seed, soil and in-furrow treatments	Seed, soil and in-furrow treatments
Trial Design	Complete randomized block	Complete randomized block
Variety	Russet Burbank	Russet Burbank
Soil Type	Ferrosol	Ferrosol
Replicates	5	5
Plot Size	1 row x 10m	1 row x 10m
Plant Spacing	35cm (25 setts per plot)	35cm (25 setts per plot)
Row Spacing	80cm	80cm
Planting season	98/99	98/99

Introduction

Two field trials were conducted to examine different products and application methods for the control of both seedborne and soilborne common scab disease. Infected tubers from field trials conducted in 1997/98 were used. The trials were conducted in ground that had a previous potato crop where a high incidence of common scab was observed on tubers.

Materials and Methods

Two field trials were conducted in the 1998/99 season at Forthside Vegetable Research Station, Forth. Common scab infected tubers from the previous year's field trials were kept and used for these trials, with tubers from Bellfield used for Trial 1, and tubers from Red Hills used for Trial 2. Tubers were cut 5 days before seed treatments and 6 days before planting. All seed treatments were applied one day before planting.

Plants in the two trials were maintained in a similar manner to the adjacent commercial Russet Burbank crop. Ridomil Gold MZ (2.5kg/ha) was applied at 53 days after planting, for the control of late blight disease.

3: Control of both seedborne and soilborne common scab (Cont.)

Seed treatment

Dust application: Cut seeds treated by placing 25 cut tuber seeds in a plastic bag, then mixing thoroughly with an appropriate amount of chemical for an even coating.

Spray application: Cut seeds treated by placing them in single layer on paper on the floor, then spraying until run off with the appropriate chemical to completely cover the cut seeds. Treated seed allowed to dry overnight before planting.

Soil treatments

In-furrow applications: Chemical sprayed from a single nozzle onto seed and soil immediately after seed dropped and before soil covered the seed, during the planting process.

Treatment 8: Manganese sulphate applied onto each plot with a watering can, with 10L water per plot.

Treatment 15: Terraclor broadcast onto top of soil surface and then mixed in to 30cm depth.

Treatments 13 & 14: Agrifos applied in 3 sprays, at 2, 4 & 6 weeks after plant emergence.

Disease assessment

At harvest, all tubers from treatment plots were collected, washed, and checked for presence of common scab lesions. The tubers with common scab lesions were divided into superficial scab (lesions 1 to 3mm deep) and deep scab (lesions greater than 3mm deep). The percentage of tubers with common scab, superficial scab and deep scab were then tabulated.

Analysis

All data sets were log transformed to normalise the raw data, before conducting analysis of variance using StatGraphics Plus 2.0. Comparisons were made of mean values using Least Significant Difference (LSD) Test. Mean data presented in the results are based on means of non-transformed data.

3: Control of both seedborne and soilborne common scab (Cont.)

Table 3.2.1: Details of treatments for Trials 1 and 2.

No.	Treatment	Application method	Product Rate
1	60% mancozeb with fir bark	Seed - dust	2g/kg
2	40% mancozeb with fir bark	Seed - dust	2g/kg
3	20% mancozeb with fir bark	Seed - dust	2g/kg
4	10% mancozeb with fir bark	Seed - dust	2g/kg
5	Penncozeb - in furrow	In-furrow	4kg/ha
6	8% mancozeb in Tato bark	Seed - dust	2g/kg
7	20% mancozeb in Tato dust	Seed - dust	2g/kg
8	Manganese sulphate	Soil	1.88kg/ha
9	Flusulphamide	Seed - spray	20ml/L
10	Maxim	Seed - spray	13ml/L
11	Rizolex	Seed - dust	2g/kg
12	Shirlan	Seed - spray & In-furrow	40ml/L & 2L/ha
13	Aliette	Foliar sprays	5kg/ha
14	Agri-Fos	Foliar sprays	6L/ha
15	Terraclor	Soil	20kg/ha
16	Cement	Seed - dust	2g/kg
17	Fir bark	Seed - dust	2g/kg
18	Untreated	N/a	N/a

Treatment 1-4: Mixed appropriate amount of Dithane WP with Douglas fir bark.
Treatment 5: Used Penncozeb DF spray

Results & Discussion

Trial 1

There was no significant reduction in the percentage of tubers with common scab and deep scab between all chemical treatments and the untreated control (Table 3.2.2). Common scab infections between plots were variable due to uneven soilborne disease inoculum in the ground.

Most infected tubers in this trial had common scab incidence ranging from 19.5 to 41.6% (Table 3.2.2), which was lower than those in Trial 2, which ranged from 42.6 to 70.5% infected tubers. This may be related to the location of Trial 1, on a sloping ground below an adjacent crop that received frequent irrigation. Most of the infected tubers had low numbers of scab lesions (5-10% coverage) that were mainly superficial.

3: Control of both seedborne and soilborne common scab (Cont.)

Table 3.2.2: Treatment effects on common scab incidence and severity in Trial 1

No.	Treatment	Application method	% Scab incidence *	% Tubers with deep scab *
1	60% mancozeb with fir bark	Seed - dust	34.5	1.2
2	40% mancozeb with fir bark	Seed - dust	37.1	1.2
3	20% mancozeb with fir bark	Seed - dust	36.2	1.1
4	10% mancozeb with fir bark	Seed - dust	38.4	2.9
5	Penncozeb - in furrow	In-furrow	41.6	2.6
6	8% mancozeb in Tato bark	Seed - dust	31.2	1.6
7	20% mancozeb in Tato dust	Seed - dust	25.0	1.5
8	Manganese sulphate	Soil	36.6	2.0
9	Scablok	Seed - spray	33.5	1.8
10	Maxim	Seed - spray	22.2	1.5
11	Rizolex	Seed - dust	30.7	4.0
12	Shirlan	Seed - spray & In-furrow	19.5	1.3
13	Aliette	Foliar sprays	24.2	3.1
14	Agri-Fos	Foliar sprays	26.0	3.4
15	Terraclor	Soil	29.0	3.4
16	Cement	Seed - dust	36.5	1.9
17	Fir bark	Seed - dust	31.2	2.9
18	Untreated	N/a	35.4	4.9

* Not significantly different at the 5% level according to analysis of variance.

Note that Terraclor, the only product currently registered in Australia for soil application to control common scab, did not caused a significant reduction in the percentage of tubers with common scab or deep scab in Trials 1 and Trial 2.

Maxim seed treatment (Treatment 10) and the combined Shirlan seed and in-furrow treatment (Treatment 12) appeared to have lower common scab incidence compared to other treatments, including the untreated control.

3: Control of both seedborne and soilborne common scab (Cont.)

Trial 2: Red Hill

Trial 2 was conducted on drier ground than Trial 1. As a result, common scab incidence and the percentage of tubers with deep scab were higher than those produced in Trial 1 (Table 3.2.3).

Common scab incidence in all chemical treatments remained high, ranging from 42.6 to 70.5%. No significant reduction in disease incidence could be found between the different products and treatment application methods, or the untreated control (Table 3.2.3). As in Trial 1, common scab infections between plots in this trial were variable.

Unlike Trial 1, the Maxim seed treatment (Treatment 10) and the combined Shirlan seed and in-furrow treatment (Treatment 12) did not appear to have any lowering effect of common scab incidence compared to other treatments, including the untreated control.

Table 3.2.3: Treatment effects on common scab incidence and severity in Trial 2

No.	Treatment	Application method	% Scab incidence *	% Tubers with deep scab *
1	60% mancozeb with firbark	Seed - dust	50.7	7.4
2	40% mancozeb with firbark	Seed - dust	42.6	4.8
3	20% mancozeb with firbark	Seed - dust	53.4	8.2
4	10% mancozeb with firbark	Seed - dust	49.7	5.4
5	Penncozeb - in furrow	In-furrow	57.7	9.2
6	8% mancozeb in Tato bark	Seed - dust	53.0	6.6
7	20% mancozeb in Tato dust	Seed - dust	49.3	8.0
8	Manganese sulphate	Soil	60.9	10.5
9	Flusulphamide	Seed - spray	46.3	5.9
10	Maxim	Seed - spray	67.8	12.6
11	Rizolex	Seed - dust	48.3	7.0
12	Shirlan	Seed - spray & In-furrow	70.5	9.3
13	Alliette	Foliar sprays	51.4	7.3
14	Agri-Fos	Foliar sprays	63.3	8.3
15	Terraclor	Soil	57.4	8.2
16	Cement	Seed - dust	63.3	4.7
17	Fir bark	Seed - dust	59.4	7.9
18	Untreated	N/a	66.8	9.1

* Not significantly different at the 5% level according to analysis of variance.

Section 4: Field conditions

Introduction

Local conditions and cultural practices can have an important influence on disease epidemiology. Field conditions or practices that can influence common scab disease need to be identified. Influencing factors that can be modified can then be taken into account in developing an integrated management practice to complement chemical control methods.

Materials and Methods

A survey was conducted of 25 growers who had scab problems on their properties in 1997. A total of 37 sample lots from different paddocks were examined. Samples were taken from various parts of northern Tasmania - Bishopsbourne, Don, Forest, Forth, Kindred, Smithton, Sulphur Creek, Thirlstane, Carrick, Symmons Plains, Deloraine, West Pine, Westbury, Bridport, Scottsdale and Winnaleah.

The survey included field inspections and sampling of tubers from different parts of the paddock to assess for disease distribution and severity, as influenced by local conditions such as irrigation, terrain, previous crops, soil structure, etc. Potato tubers with scab were also examined thoroughly in the laboratory under a light microscope to determine and differentiate between the two types of scab, common scab and powdery scab. Information on the cultural and crop management practices on the scab-infected crops was obtained from growers, and compiled into a database. Maps of each paddock were also sketched, stored in the database, and used to assist in pointing out different field profiles such as paddock terrain, soil type and drainage in relation to scab disease. Field factors that may contribute to scab disease incidence and severity were identified for each paddock. A general overview could then be drawn on the key factors in scab disease development.

Outcomes:

This survey indicated that the potato cultivars grown for processing, Russet Burbank, Shepody and Kennebec, were infected by common scab as well as powdery scab. Many field and extension officers, agronomic consultants, and growers had difficulty in distinguishing and identifying these two types of scab on potatoes. The ability to distinguish between them is critical in determining the water management practice required. Some common scab lesions have physical characteristics that resembled pustules caused by powdery scab making it difficult to differentiate the two types of scabs in the field.

Tubers affected with common scab have rough and circular or irregular lesions that may be raised, level with the surface or sunken. Various types of common scab symptoms were found: russet scab (Photo 1), irregular-shaped scab (Photo 2), circular scab (Photo 3), and deep-pitted scab (Photo 4), and lesions may be superficial or deep (Photo 4-5). The different strains of Streptomyces, inoculum levels or the age of the lesions may influence the types and severity of symptoms (Doering-Saad et al. 1992, Healy & Lambert, 1991, Keinath, A.P. & Loria, R. 1991). Lesions due to powdery scab are consistent in their symptoms and usually small, circular and surrounded by torn edges of the skin (Photo 6). ***(Note: Please refer to photos on the page before the Tables of Contents for Photos 1-6)***

In the field survey of Russet Burbank crops; 64% of the 25 properties were affected by common scab, 24% by powdery scab and 12% by both types of scab. This indicates that in Tasmania, common scab is more prevalent than powdery scab. The type of scab affecting tubers appeared to be related to paddock terrain, soil type, water drainage, and location. For example, powdery scab tended to be prevalent in the Forest-Smithton area, which is usually

cold and wet, as well as in poorly drained soil. Conversely, common scab tended to be prevalent in the drier and warmer North-East, and in well-drained soil.

In putting together the detailed information of each paddock, common trends of certain field factors could be identified with high disease incidence and severity. These included soil type and drainage (Figure 1), ground compaction and irrigation (Figure 2), different previous crop and subsequent soil quality (Figure 3), seed lines (Figure 4), years between potato crops (Figure 5), or a combination of soil drainage and other factors within a paddock (Figure 6).

Figure 1: An illustration of a paddock, where soil type and drainage determined the type of scab.

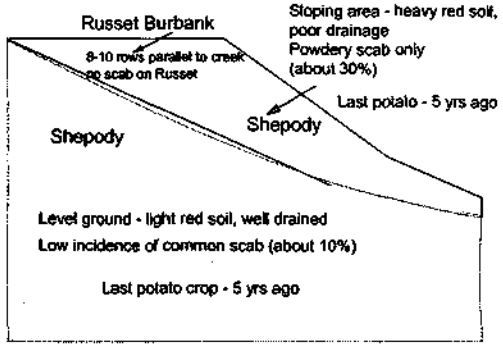


Figure 2: An illustration of a paddock, where scab incidence and severity appeared to be influenced by soil compaction and irrigation.

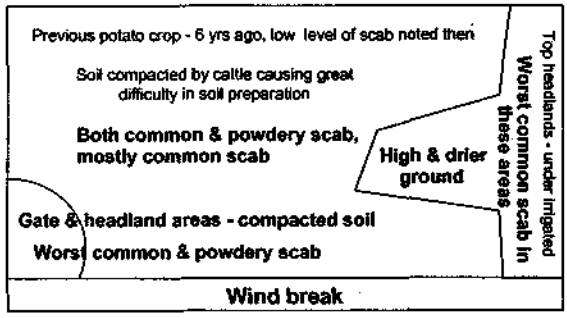
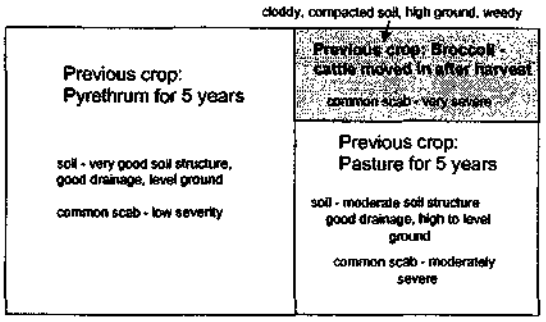
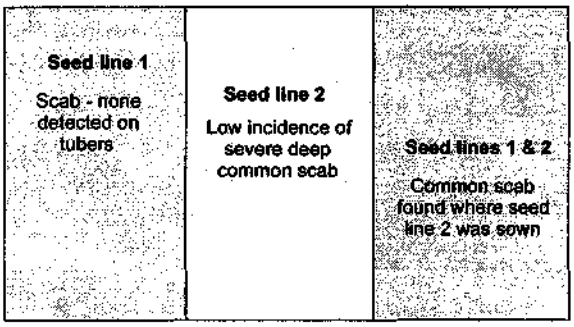


Figure 3: An illustration of a paddock, showing the influence of different previous crops on common scab severity.



Potato variety sown was Russet Burbank. High common scab incidence throughout the paddock (about 80%). Common scab Severity, however, was influenced by previous crops and soil

Figure 4: An illustration of a paddock where common scab was traced to the different seed lines used in different parts of the field



No obvious scab lesions noticed on both seed lots, but pathogen may be present on soil particles attached to seed. Possible key factors: seedborne inoculum or poor quality seed increasing crop susceptibility to scab infection.

Figure 5: An illustration of a potato crop, where common scab incidence appeared to be influenced by a previous potato crop.

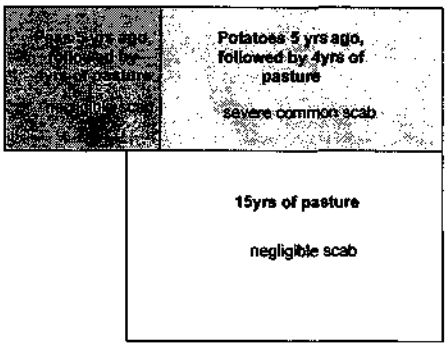
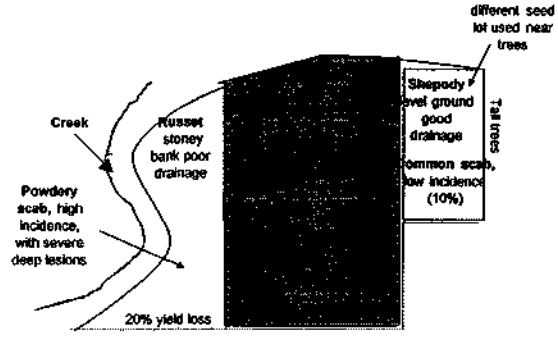


Figure 6: An illustration of a paddock, where scab type, incidence and severity appeared to be influenced by soil drainage, seed source and shading by trees.



Section 5: Technology Transfer

- For the duration of this project, assistance was provided to the potato industry in Tasmania to help identify the type of scab on tubers, with field and laboratory inspections, as well as demonstrations of typical symptoms.
- A general information leaflet (Appendix ii) on common scab disease has been prepared, and approximately 2000 copies have been distributed to growers and industry.
- A 3-hour potato scab research forum was held with Tasmanian potato industry representatives on 19th June 1997. Dr. Dolf de Boer also participated in the forum so that research on both common and powdery scab diseases could be discussed.
- Presentation and discussion with two Victorian seed growers' groups at Portland and South Gippsland on 31st August and 1st September 1998.
- Presentation at the 'Pre-Season Potato Pest & Disease Control' seminar series, organised by the Victorian Potato Crisping Industry, on the 20th-21st September 1998.
- Project findings were presented at Tasmanian vegetable extension days, held at Burnie on 28th May 1998 and at Ulverstone on 27th July 1999. These were well attended by Tasmanian growers, industry representatives and researchers.
- Project updates have been published in "Potato Australia" magazine and "Eyes on Potatoes" newsletter.
- HRDC milestone reports outlining progress of research studies were sent to industry representatives, and individual growers on request.
- Project findings were also presented at the following scientific conferences:
  - 11th Biennial Australasian Plant Pathology Society Conference held on 30th September – 2nd October 1997 in Perth. Title of the presentation - "Scab on potatoes grown for processing in Tasmania".
  - 1st Australasian Soilborne Disease Symposium held on 10th-12th February 1999, on the Gold Coast, Queensland. Title of the presentation - "The effects of soil environment on scab of potatoes grown for processing in Tasmania".
  - 12th Biennial Australasian Plant Pathology Society Conference held on 27th-30th September 1999, in Canberra. Title of the presentation - "An evaluation of chemical applications for the control of common scab disease on potatoes".
  - "Potato 2000 – Linking research to practice", held at Adelaide, South Australia on 31th July to 3rd August 2000. Title of the oral presentation – "Common scab – Incidence on seed potatoes and seed borne disease control".

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Appendix i - Avcare Fungicide Grouping

Fungicide activity grouping list based on mode of action (Developed by Avcare)

Fungicide group	Activity group	Chemical group
A	Benzimidazole	Benzimidazole
B	Dicarboximide	Dicarboximide
C	DMI	Imidazole Piperazine Pyrimidine Triazole
D	Phenylamide	Acylamine Oxazolidinone
E	Morpholine	Morpholine
F	Phosphoro-thiolate	Organo-phosphorous
G	Oxathun	Anilide
H	Hydroxy-pyrimidine	Pyrimidinol
I	Anilinopyrimidine	Anilinopyrimidine
J	Hydroxyanilide	Hydroxyanilide
K	Strobilurin	Strobilurin
L	Pyrrole	Fludioxonil
Y	Multi-site activity	Carbamate Phosphonate Inorganic Dithiocarbamate Phthalimide Chlorophenyl Quinone Hydroxyquinoline Pyradinaminae Cyclic imide
X	(Unspecified)	Cinnamic acid derivative Sulfamide Dinitrophenyl Organophosphate Guanidine Thiadiazole Quinoxaline

Common Scab on Potatoes – The Facts

What causes it?

- Common scab is caused by a bacteria-like organism called *Streptomyces scabies*.

When does it start?

- Young tubers are susceptible to infection (tuber initiation to about golf ball size).
- Mature tubers with well-developed skins are not susceptible.
- Scab lesions expand as the infected tubers grow.

What are the symptoms?

- Common scab symptoms can vary in extent and appearance.
- Typical lesions possess a raised margin and slightly depressed centre.
- The depths of scab lesions depend on pathogen, potato variety, soil conditions, and invasion of scab lesions by other organisms including insects.
- Some types of common scab lesions can be confused with lesions of powdery scab, a fungal infection. If in doubt, the potatoes have to be investigated by a pathologist.

What conditions are conducive?

- The scab pathogen is most aggressive under relatively dry and warm conditions.
- The optimum pH for the disease is from pH 6.0 to 7.5.
- Some strains of the scab pathogen can still be a problem at a pH below 5.
- Scab incidence is usually greater in lighter soils.
- The scab pathogen can build up following other root crops like radish, turnip, carrot and parsnips.

How does it spread?

- *Streptomyces* pathogens are widely distributed and persist in soil on decaying organic matter.
- The pathogen is spread through soil and on infected seed tubers.
- The pathogen can survive passage through cattle digestive systems.
- Multiple cropping of potatoes or other root crops in the same ground usually increases disease severity.

How to manage the disease?

- Scab control requires both, seed treatment and modification of soil conditions.
- Treating seed with an appropriate chemical before planting can reduce infections from seedborne scab. Use certified seed.
- Rotations with non-root crops to prevent the build up of aggressive scab types.
- Avoid the use of lime and other materials that raise the soil pH just preceding the potato crop.
- Ensure adequate nutrition for good crop health.
- Maintain high soil moisture levels in the soil at the tuber initiation period (about 80% field capacity for 4 to 6 weeks).
- If scab is widespread on tubers, keep soil moisture relatively dry during the bulking up period to prevent secondary invasion and rot of scab lesions by other soil organisms.
- If possible, harvest early.

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