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A comparative evaluation of different materials used for cut potato seed treatments

H Pung and S Cross
Serve-Ag Research

Project Number: PT00033

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

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A comparative evaluation of different materials used for cut potato seed treatments

Final Report

Conducted on behalf of

Horticulture Australia Limited

Project PT00033
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by

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and

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Media Summary

This project was conducted to compare different seed coating materials for their drying and healing or suberisation properties on cut seeds. A range of mixtures containing mancozeb based products was also evaluated to determine whether they would produce the desired drying and suberisation, while providing protection from *Fusarium* dry rot and *Erwinia* soft rot. The outcomes of this study will enable processors and growers to make an informed choice on the type of product they use for reducing seed-piece breakdown and improving consistency in plant emergence and establishment.

Properties of drying materials

- PM fir bark, Nubark, and Tato dust have excellent water absorption properties, and are capable of holding water greater than their weight. PM fir bark has the highest water absorption capacity, more than double that of Nubark, which has the second highest.
- Of the materials tested, Tato dust, Penncozeb, Coal dust and Cement have high affinity for water, and are therefore likely to increase the loss of water from cut seeds. Therefore, if using these materials, they should be applied in mixture with materials that have low affinity for water, e.g. Nubark, to reduce their adverse effect on wound healing.
- Cement is also caustic with a very high pH of 13.5, which may be detrimental to the suberisation process.
- Materials that appear to be ideal for seed coating are the two Douglas fir bark products, PM fir bark and Nubark, followed by Dolomite and Lime.
- PM fir bark and Nubark are acidic (both pH 4.0) and have very low affinity for water and hence are unlikely to cause moisture loss from cut seeds.
- Dolomite and Lime are alkaline (pH 8 & 9, respectively) and are moderate in their affinity for water.

Consistency in the performance of seed treatment

- In order to induce rapid healing of cut seeds, high humidity is required, and moisture loss must be kept to a minimum.
- An ideal type of seed coating material or mixture must be non-toxic and able to absorb excess sap from the cut seeds, without causing moisture loss, while creating a suitable environment for rapid healing.
- Nubark + Tato dust gave excellent as well as consistent results, followed by Dolomite + Tato dust. Other treatments tended to give more variable results.
- Low levels of mancozeb (Tato dust or Penncozeb), ranging from 6 to 10%, when mixed with an appropriate drying material, appeared to be adequate in effectively reducing rot on cut seeds.
- This project showed that although suitable seed treatments may help reduce the level of rot on cut seeds, seed quality appeared to have the greatest impact on the healing of cut seeds, and hence their susceptibility to bacterial and fungal invasion.
- Currently, there is a lack of suitable indicators to define and determine seed quality. This study indicates that specific gravity may be a useful indicator of seed quality, as seeds with a higher specific gravity tended to heal faster when cut, making them less susceptible to rot. Therefore, further studies are recommended to investigate the use of specific gravity and other measurements that may be indicative of seed quality.

Technical Summary

Drying materials are often dusted onto the cut seeds in order to absorb the sap, to prevent the cut surfaces from sticking together, and to improve air flow over the cut surfaces. This project was conducted to compare different seed coating materials for their drying and healing or suberisation properties on cut seeds. A range of mixtures containing mancozeb based products was also evaluated to determine whether they would produce the desired drying and suberisation, while providing protection from *Fusarium* dry rot and *Erwinia* soft rot. The outcomes of this study will enable processors and growers to make an informed choice on the type of product they use for reducing seed-piece breakdown and improving consistency in plant emergence and establishment.

Properties of drying materials

The properties of drying materials, as defined by specific gravity, water absorption capacity, affinity for water, and water repellency, were determined in laboratory tests.

PM fir bark, Nubark, and Tato dust have excellent water absorption properties, and are capable of holding water greater than their weight. PM fir bark has the highest water absorption capacity, more than double that of Nubark, which has the second highest.

Of the materials tested, Tato dust, Penncozeb, Coal dust and Cement have a high affinity for water, and are therefore likely to increase moisture loss from cut seeds. Therefore, if using these materials, they should be applied in a mixture with materials that have low affinity for water, e.g. Nubark, to reduce their adverse effect on wound healing.

Cement is also caustic, with a very high pH of 13.5, which may be detrimental to the suberisation process.

Materials that appear to be ideal for seed coating are the two Douglas fir bark products, PM fir bark and Nubark, followed by Dolomite and Lime.

PM fir bark and Nubark are acidic (both pH 4.0) and have very low affinity for water and hence are unlikely to cause moisture loss from cut seeds. Dolomite and Lime are alkaline (pH 8 & 9, respectively) and are moderate in their affinity for water.

Effects of seed treatments

In two trials, tuber seeds were cut and treated with different drying materials and/or mancozeb based fungicides. Different seed lines were used in each trial: an approved seed line (Seed lot A) for Trial 1 and a certified seed line (Seed lot B) for Trial 2. All treated and untreated cut seeds were inoculated by spraying *Fusarium sulphureum* spores and bacterial cells that were obtained from tubers infected by *Fusarium* dry rot and *Erwinia* soft rot.

Twenty treatments were evaluated in each trial, with 100 cut tuber seeds per treatment. The drying materials, including mixtures, were applied at the rate of 4g/kg seed (i.e. 4kg/tonne). The untreated or treated tuber seeds from each treatment were then subjected to three separate tests to determine the level of rot on seeds stored under relatively ideal conditions, under adverse conditions, or planted in the ground under field conditions.

The percentage of seeds with rot on their cut surfaces in the two storage tests, and the percentage of plant loss due to seed decay in the field were determined. The outcomes of the three tests were then combined to obtain a mean percentage tuber loss due to rot. Finally, the performance of seed treatments evaluated in both trials was compared in order to examine the consistency of treatment effects over the two trials.

Technical Summary (Cont.)

The greatest difference in seed performance on tuber loss or yield was between the two different seed lots. Seed lot A (Trial 1) was an approved seed lot (but not from a certified seed crop), while seed lot B (Trial 2) was from a certified seed crop. The average specific gravity of seeds was 105.28g/100ml from seed lot A and 107.65g/100ml from seed lot B, indicating that the certified seeds were denser. This indicates that specific gravity may be a useful indicator of seed quality. Further studies are recommended to investigate the use of specific gravity, as well as to gain a better understanding of what factors indicate seed quality.

There appeared to be more sap from cut seeds in seed lot A than in B. The cut seeds of seed lot B also appeared to heal more rapidly compared to those from seed lot A. In the storage tests, conducted under similar conditions, untreated cut seeds from seed lot A had a much higher percentage of tubers with rot compared to those from seed lot B.

In Trial 1, cut seed treatments containing mancozeb appeared to drastically reduce the incidence of rot on tubers stored under ideal conditions. Mancozeb treated tubers from seed lot A had 0 to 10% tubers with rot, compared to 25 to 70% on those without mancozeb. However, under adverse conditions, the incidence of rot on tubers was very high (50 to 100%), irrespective of the seed treatments. Under field conditions, the average plant loss (26%) for the whole field trial was considered to be high by commercial standards. As field conditions were considered to be ideal, poor seed quality, slow healing of cut seeds, and bacteria and fungal invasions are believed to have been important factors in the plant loss.

In Trial 2, under ideal conditions, all treatments except for Cement + PM fir bark and Cement + PM fir bark + Tato dust treatments resulted in relatively little or no rot (0 to 15% tubers with rot). Under field conditions, the average plant loss (4%) for the whole field trial was considered to be low by commercial standards. With the onset of rapid healing on cut seeds from seed lot B, the use of different materials or mixtures appeared to have less influence on plant establishment. This highlights the importance of good seed quality.

Differences between the two seed lots were also noted in the field trials. Seed lot A had plant losses ranging from 13% to 38% due to seed decay and marketable yields ranging from 37 to 53 tonnes/ha. Seed lot B had plant losses ranging from 2% to 8% and marketable yields ranging from 56 to 71 tonnes/ha.

When comparing the consistency in performance of seed treatments in both trials, most performed well in one trial, but poorly in the other. This may have been due to differences in the seed response to wounding, e.g. cut seeds of seed lot A used in Trial 1 appeared to be more susceptible to fungal and bacterial invasion. Rapid development of a barrier over the cut surfaces makes them resistant to bacteria and fungal invasions.

Drying materials for seed treatments must perform consistently well in aiding the healing process, irrespective of seed lots and storage or planting conditions. There were two treatments that tended to perform well in both trials. Tubers treated with Nubark + Tato dust gave excellent results in both trials, followed by Dolomite + Tato dust. Other treatments tended to give more variable results.

Cement is incompatible with mancozeb, even at low levels. A mixture of cement and mancozeb causes blackening of cut seed surfaces and delays their healing.

In this study, low levels of mancozeb, at 6% and 10% in drying material mixtures, were sufficient to reduce *Fusarium* dry rot.

Introduction

Background

When a tuber is wounded, healing begins in the undamaged cells just beneath the wounded area. Firstly, phenolic compounds, such as suberin, are deposited into the walls of the outer two or three layers of intact cells beneath the wound (Nolte 1997). This suberin layer, which resembles common bottle cork, helps to seal off the wound to prevent the loss of moisture, thus providing protection from bacteria and fungal invaders.

The final stage of wound healing involves the formation of a new and permanent wound barrier, very similar to the original skin or periderm of the potato tuber, both in appearance and ability to protect the healed area (Nolte 1997). The temporary suberin layer will collapse as its cells are cut off from the moisture supply within the tuber, to be replaced by the new 'skin'.

Under ideal conditions, the complete wound healing process takes about a week. The first healing stage, also known as suberization, usually takes two to four days, while the final stage takes another two to four days to occur (Nolte 1997). Wound healing also requires temperatures from 10 °C to 16 °C, oxygen, and high relative humidity from 90% to 95%. Although wounds heal at a faster rate at higher temperatures, with an optimum temperature of 21 °C, the activity of most potato pathogens is also accelerated at these temperatures, and the wound healing system cannot react rapidly enough to prevent infection.

Cut tuber seeds are widely used in the production of processing potatoes. Wound healing must take place after potato tubers have been subjected to seed cutting. This is likely to be the most serious damage that seeds are ever likely to suffer. As healing of the cut seeds takes time, seed piece treatment with Douglas fir bark powder is often recommended to enhance the healing process. Douglas fir bark contains several phenolic compounds that enhance wound healing.

There are, however, several different types of fir bark powder that are available commercially in the United States of America. Recent studies conducted in Tasmania on cut seeds treated with two different types of fir bark powder, showed significant differences in the level of bacterial and fungal rot between treatments (Pung & Cross, 2001a, 2001b). These preliminary studies, which showed that vast improvements could be made in cut seed quality, are highly significant to the potato industry in Tasmania.

Different types of drying materials are currently used during the cutting process, to dry the cut surfaces and to help keep the cut pieces separate. To date, there have been no studies on the properties of the different drying materials used on cut seeds in Australia. There has been anecdotal evidence that some of these materials could be delaying the curing of the cut surface and increasing seed-piece breakdown. Some materials have superior drying properties (e.g. cement), while others are better at maintaining high humidity and facilitating the healing of the cut surface (e.g. fir bark). An ideal type of material or mixture of appropriate materials could effect the removal of excess sap, and also assist in the healing process of cut seeds.

A limiting factor in potato production is seed-piece breakdown. *Fusarium* dry rot, the most common cause of seed-piece decay, can result in uneven and poor crop establishment. Cutting of potato seeds prior to planting increases the potential for transmission of infection. Mancozeb has long been recognized for its protective ability against *Fusarium* dry rot. Recent studies also showed that mancozeb is effective in controlling seedborne common scab disease.

Aims

The aim of this project was to compare the properties of different seed coating materials and to examine their effects on drying and healing or suberisation on cut seeds. A range of mixtures containing mancozeb based products, were also evaluated to determine whether their combination would produce the desired drying and suberisation, while providing protection from fungal and bacterial invasion.

Materials & Methods

Product Formulations

Product	Active Ingredient (a.i.)	Concentration of a.i.	Formulation
Coal dust	Nil	Nil	Dust powder
Clay (Bentonite)	Nil	Nil	Granular particles
Cement	Nil	Nil	Granular particles
Dolomite	Nil	Nil	Granular particles
Lime	Nil	Nil	Dust powder
PM fir bark	Nil	Nil	Dust powder
Nubark	Nil	Nil	Dust powder
Pine bark	Nil	Nil	Coarse granular particles
Eucalyptus bark	Nil	Nil	Coarse granular particles
Nubark + 6% Mancozeb	Mancozeb	6%	Dust powder
Tato dust	Mancozeb	20%	Dust powder
Penncozeb	Mancozeb	80%	Wettable powder

Materials & Methods (Cont.)

Treatment lists

Trial 1

NO.	TREATMENT	PRODUCT MIXTURE	MANCOZEB CONCENTRATION	
		Ratio (weight : weight)	Active ingredient in formulation	Active ingredient in mixture
1	Untreated Control	N/a	Nil	Nil
2	Clay (Bentonite)	N/a	Nil	Nil
3	Coal dust	N/a	Nil	Nil
4	Cement	N/a	Nil	Nil
5	PM fir bark	N/a	Nil	Nil
6	Nubark	N/a	Nil	Nil
7	Pine bark	N/a	Nil	Nil
8	Eucalytus bark	N/a	Nil	Nil
9	Dolomite	N/a	Nil	Nil
10	Cement + PM fir bark	50 : 50	Nil	Nil
11	Dolomite + PM fir bark	50 : 50	Nil	Nil
12	Cement + Nubark	50 : 50	Nil	Nil
13	Cement + Penncozeb	87.5 : 12.5	80%	10%
14	Dolomite + PM fir bark + Penncozeb	55 : 20 : 25	80%	20%
15	Dolomite + PM fir bark + Penncozeb	30 : 20 : 50	80%	40%
16	Dolomite + Penncozeb	87.5 : 12.5	80%	10%
17	Dolomite + Tato dust	50 : 50	20%	10%
18	Nubark + Tato dust	50 : 50	20%	10%
19	PM fir bark + Tato dust	50 : 50	20%	10%
20	Clay + Tato dust	50 : 50	20%	10%

Materials & Methods (Cont.)

Trial 2

NO.	TREATMENT	PRODUCT MIXTURE	MANCOZEB CONCENTRATION	
		Ratio (weight : weight)	Active ingredient in formulation	Active ingredient in mixture
1	Untreated Control	N/a	Nil	Nil
2	Lime	N/a	Nil	Nil
3	Cement	N/a	Nil	Nil
4	Dolomite	N/a	Nil	Nil
5	PM fir bark	N/a	Nil	Nil
6	Nubark	N/a	Nil	Nil
7	Cement + PM fir bark	50 : 50	Nil	Nil
8	Cement + Nubark	50 : 50	Nil	Nil
9	Cement + Penncozeb	50 : 50	80%	40%
10	Cement + Tato dust	70 : 30	20%	6%
11	PM fir bark + Penncozeb	50 : 50	40%	40%
12	PM fir bark + Tato dust	70 : 30	20%	6%
13	Nubark + Tato dust	70 : 30	20%	6%
14	Nubark + Mancozeb	Pre-formulated	N/a	6%
15	Nubark + Penncozeb	92.5 : 7.5	80%	6%
16	Nubark + Penncozeb	50 : 50	80%	40%
17	Cement + PM fir bark + Tato dust	40 + 30 + 30	20%	6%
18	Cement + PM fir bark + Penncozeb	40 + 30 + 30	80%	24%
19	Dolomite + Penncozeb	75 : 25	80%	20%
20	Dolomite + Tato dust	70 : 30	20%	6%

Pathogen inoculation

All treated and untreated cut seeds were inoculated by spraying *Fusarium sulphureum* spores and bacterial cells that were obtained from tubers infected by *Fusarium* dry rot and *Erwinia* soft rot. Two different seed lines were cut and treated with different drying materials and/or mancozeb based fungicides. Different seed lines were used in each field trial.

Treatment application

In Trials 1 and 2, 100 cut tuber seeds were treated in each treatment. Drying materials and/or mancozeb fungicides were applied by measuring the required quantity and dusting them onto tuber seeds by mixing in a plastic bag. The drying materials, including mixtures, were applied at the rate of 4g/kg seed (i.e. 4kg/tonne).

Untreated or treated tuber seeds from each treatment were divided into three lots for separate tests, as described in the following:

Trials 1 & 2

Test	Type of test	Sample size	Conditions	Details	Assessment
A	Storage	20 seeds	Ideal conditions	Incubation test under ideal condition, where the seeds were placed in an opened paper bag and kept in a well-aerated and dry store at ambient temperatures of 20°C to 28°C, 75% to 95% relative humidity (RH), and good aeration.	The numbers of seeds with rot were recorded after 2 weeks, and a descriptive assessment was also conducted on cut surface drying and moisture loss.
B	Storage	20 seeds	Adverse conditions	Incubation test under adverse condition, where the seeds were placed in a sealed plastic bag and kept in an incubator with no circulated air and under high humidity at 10°C to 15°C, 85% to 98% RH.	As in Test A above.
C	Field Trial	60 seeds	Field conditions	The treated seeds were planted within a commercial crop of the same variety for field evaluation. The trial was managed as in the commercial crop. Soil temperature at 20cm deep ranged from 14°C to 16°C.	Plant emergence recorded and marketable yield determined at harvest.

Field Trial Details

See Appendix i

Assessments

1. Properties of drying materials

Measurement	Description
Specific gravity	Weight in 100ml volume of material.
Water absorption	Weight of water retained by 10g of material after soaking in 50ml water for 1 hour and then draining of excess water over filter paper.
Rapid water retention	Amount of water retained by 10g material instantaneously on contact with 50ml water. Water was poured over the material on a filter paper in a glass funnel. Water not retained immediately would drain through the material, filter paper and funnel into a flask.
Repels water when dry	Yes, when water rolls into a ball when in contact with the dry material. No, when there was no physical barrier between the material and water on contact.

2. Effects of drying materials/mixture on cut tuber surface

Dry rating	Toxicity & damage rating
0 = moist cut surface	0 = no visible damage
1= air-dry	1 = 1 to 5 setts with blackening of cut surface
2= dry - chalky firm layer	2 = many with blackened surfaces
3= very dry, sunken and dehydrated cut surface	3 = almost all with blackened surfaces

Assessments (Cont.)

3. Effects of drying materials/mixtures on cut tuber seeds

Assessment	Terminology	Definition
Test A	% Tubers with rot *(ideal condition)*	Percentage of tubers with rot on their cut *surfaces.*
Test B	% Tubers with rot (adverse condition)	Percentage of tubers with rot on their cut surfaces.
Test C	% Plant loss (field condition in field trial)	Percentage of plants that were lost due to non-sprouting tuber seed piece.
(A + B + C)/3	Mean % tuber loss	Define the overall seed piece loss due to rot in storage assessments of A and B, and decay in the field in assessment C.
Seed treatment (S.T.) performance	S.T. rating based on Mean % tuber loss	A rating system was applied on the treatments, based on mean % tuber loss.
Marketable yield	tonnes/ha	Marketable tubers are those of acceptable size and shape, with no obvious rot or deep lesions. Total yield/plot was converted to tonnes/ha for easy reference.

4. Statistical Analysis

Statistical analysis was performed on arcsine transformed data values on % plant loss and marketable yield in both trials, using SPSS statistical computing package. Pair-wise comparisons using least significant difference (LSD) procedure were applied to the mean values.

Table 1: Properties of drying materials

Drying material	Formulation	Specific gravity (s.g.) g/100ml	Water absorption g/100g product	Rapid water retention g/100g product	Repels water when dry	pH	pH after leaving 48 hrs
Coal dust	Dust powder	75.2	100	93	No	8.5	8.5
Clay (Bentonite)	Granular particles	130.0	Cannot be measured		No	10	10
Cement	Granular particles	133.6	93	59	No	13.5	13
Dolomite	Granular particles	188.0	47	38	No	8.5	8
Lime	Dust powder	130.8	61	37	No	9	8
PM Fir bark	Dust powder	42.8	272	24	Yes	4	4
Nubark	Dust powder	58.5	122	25	Yes	4	3.5
Nubark + 6% mancozeb	Dust powder	57.7	NT	NT	Yes	NT	NT
Pine bark	Coarse granular particles	37.4	NT	NT	NT	NT	NT
Eucalyptus bark	Coarse granular particles	11.0	NT	NT	NT	NT	NT
Tato dust	Dust powder	58.3	115	95	NT	6.0	7.2
Penncozeb WSP	Wettable powder	45.4	86	90	NT	7.0	7.5

NT = Not tested

Figure 1: Specific gravity of drying materials

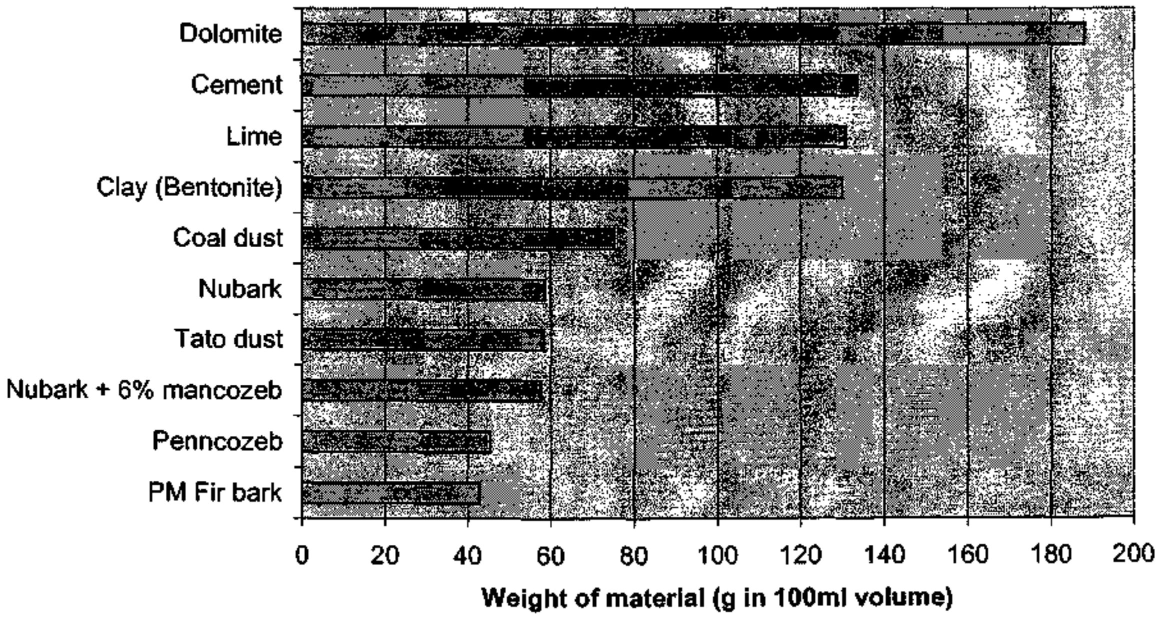


Figure 2: Water holding capacity of drying materials

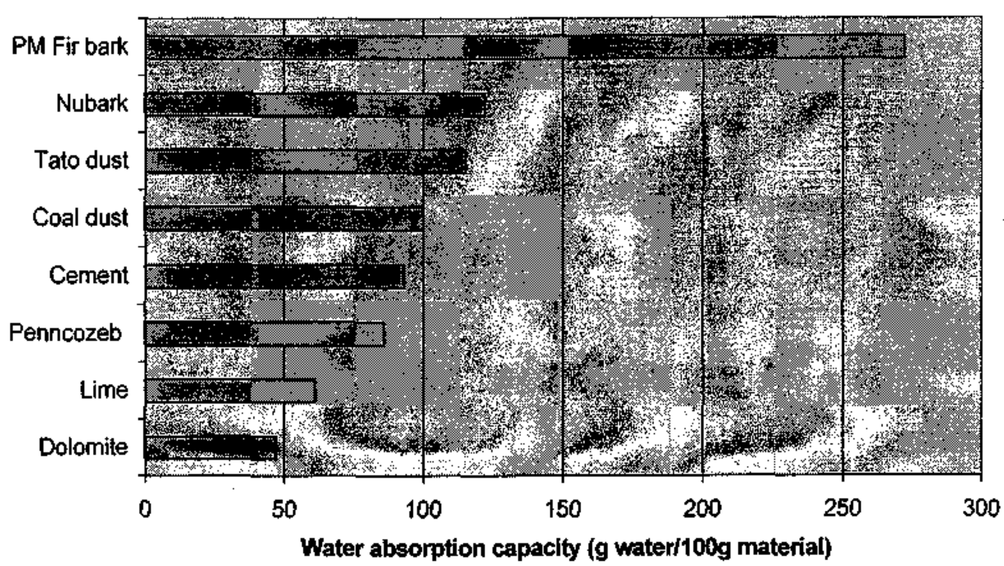


Figure 3: Affinity of drying materials for water

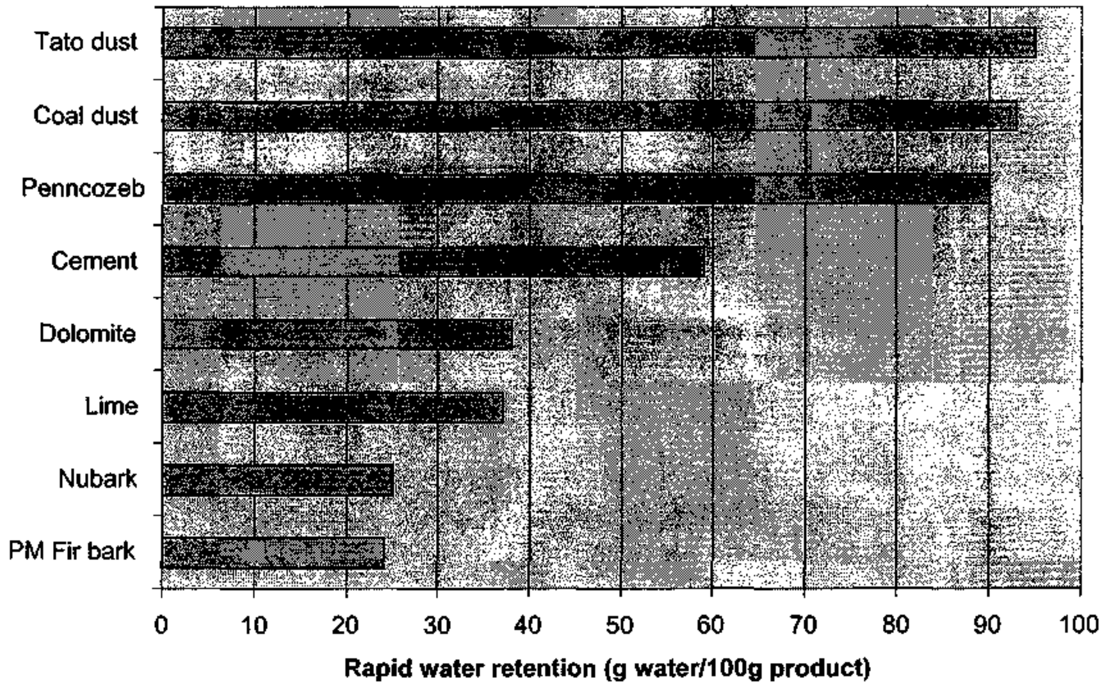


Figure 4: pH of drying materials in water

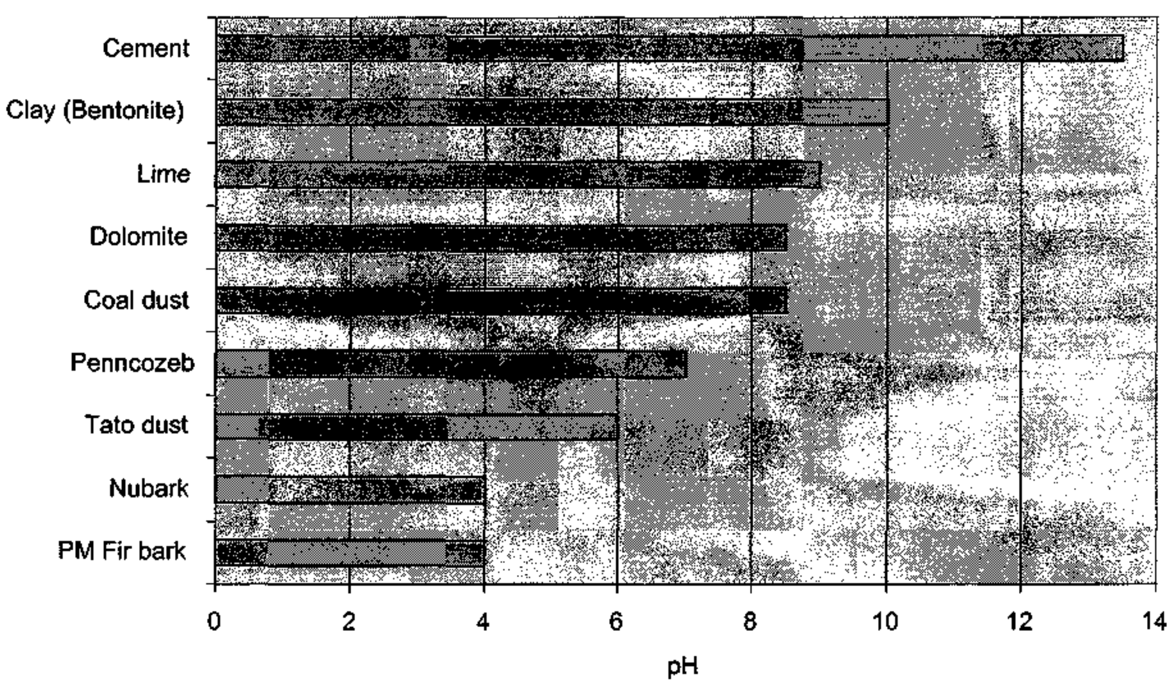


Table 2: Performance of seed treatments on Russet Burbank Seed lot A in Trial 1, under ideal and adverse storage conditions, and in the field.

NO.	TREATMENT	Mancozeb (a.i. in mixture)	Dry rating (ideal conditions)	Toxicity & Damage (ideal conditions)	Test A % Tubers with rot	Test B % Tubers with rot	Test C % Plants loss [a]	Mean % Tuber loss [bc]	S.T. performance Rating [bc]	Marketable Yield (tonnes/ha) [a]
13	Cement + Penncozeb	10%	1	3	0	50	23 a	24	1	53 a
18	Nubark + Tato dust	10%	1	0	5	50	33 a	29	2	45 a
19	PM fir bark + Tato dust	10%	1	0	0	95	13 b	36	3	45 a
17	Dolomite + Tato dust	10%	1	0	0	95	18 ab	38	4	45 a
15	Dolomite + PM fir bark + Penncozeb	40%	1	0	0	100	18 ab	39	5	45 a
14	Dolomite + PM fir bark + Penncozeb	20%	1	1	5	100	18 ab	41	6	52 a
16	Dolomite + Penncozeb	10%	1	1	10	95	22 a	42	7	43 a
20	Clay + Tato dust	10%	1	1	10	100	27 a	46	8	40 a
8	Eucalytus bark	Nil	1	0	25	90	33 a	49	9	46 a
9	Dolomite	Nil	1	0	30	100	20 a	50	10	46 a
6	Nubark	Nil	1	0	30	100	23 a	51	11	44 a
11	Dolomite + PM fir bark	Nil	0	0	40	95	22 a	52	12	47 a
7	Pine bark	Nil	0	0	30	100	28 a	53	13	43 a
12	Cement + Nubark	Nil	2	0	50	85	32 a	56	14	44 a
2	Clay	Nil	0	1	45	100	22 a	56	14	46 a
4	Cement	Nil	2	0	40	100	37 a	59	15	40 a
3	Coal dust	Nil	1	0	75	68	33 a	59	15	49 a
10	Cement + PM fir bark	Nil	1	0	55	100	38 a	64	16	37 a
1	**Untreated Control**	**Nil**	**0**	**0**	**70**	**95**	**27 a**	**64**	**16**	**45 a**
5	PM fir bark	Nil	0	0	70	100	25 a	65	17	45 a

[a] Within the same column, means followed by the same letter are not significantly different at the 5% level according to LSD Test.
[b] Note that the values are ranked in an ascending order.
[c] Note: 1 = best treatment with lowest overall tuber loss, 13 = highest level of overall tuber loss.

Table 3: Performance of seed treatments on Russet Burbank Seed lot B in Trial 2, under ideal and adverse storage conditions, and in the field.

NO.	TREATMENT	Mancozeb (a.i. in mixture)	Dry rating (ideal conditions)	Toxicity & Damage (ideal conditions)	Test A % Tubers with rot	Test B % Tubers with rot	Test C % Plants loss [a]	Mean % Tuber loss [bc]	S.T. performance Rating [bc]	Marketable Yield (tonnes/ha) [a]
11	PM fir bark + Penncozeb	40%	0	1	0	0	3.3 a	1	1	62 a
14	Nubark + Mancozeb	6%	1	0	0	0	6.7 a	2	2	67 a
13	Nubark + Tato dust	6%	1	0	0	0	5.0 a	2	2	69 a
3	Cement	Nil	2	0	0	5	3.3 a	3	3	63 a
15	Nubark + Penncozeb	6%	1	0	0	5	5.0 a	3	3	63 a
19	Dolomite + Penncozeb	20%	1	1	0	5	5.0 a	3	3	63 a
4	Dolomite	Nil	1	0	0	5	5.0 a	3	3	71 a
20	Dolomite + Tato dust	6%	1	0	0	15	1.7 a	6	4	62 a
7	Cement + PM fir bark	Nil	1	0	5	10	1.7 a	6	4	63 a
2	Lime	Nil	1	1	0	15	6.7 a	7	5	63 a
16	Nubark + Penncozeb	40%	1	0	5	20	5.0 a	10	6	71 a
5	PM fir bark	Nil	0	0	5	24	3.3 a	11	7	61 a
1	**Untreated Control**	**Nil**	**1**	**0**	**15**	**15**	**3.3 a**	**11**	**7**	**67 a**
17	Cement + PM fir bark + Tato dust	6%	0	1	30	10	3.3 a	14	8	66 a
6	Nubark	Nil	1	0	10	35	3.3 a	16	9	62 a
8	Cement + Nubark	Nil	2	0	15	45	6.7 a	22	10	56 a
12	PM fir bark + Tato dust	6%	0	0	60	15	8.3 a	28	11	62 a
10	Cement + Tato dust	6%	0	3	0	90	5.0 a	32	12	60 a
9	Cement + Penncozeb	40%	0	3	0	100	1.7 a	34	13	58 a
18	Cement + PM fir bark + Penncozeb	24%	0	3	0	100	1.7 a	34	13	59 a

[a] Within the same column, means followed by the same letter are not significantly different at the 5% level according to LSD Test.
[b] Note that the values are ranked in an ascending order.
[c] Note: 1 = best treatment with lowest overall tuber loss, 13 = highest level of overall tuber loss.

Table 4: Consistency in the performance of seed treatments (Trials 1 & 2)

TREATMENT	Mancozeb (a.i. in mixture in Trials 1 & 2)	Trial 1 Mean % tuber loss	Trial 2 Mean % tuber loss	Trials 1 & 2 Overall % tuber loss	Trial 1 S.T. performance [a]	Trial 2 S.T. performance [a]	Trials 1 & 2 Overall S.T. performance [ab]
Nubark + Tato dust	10% & 6%	29	2	16	2	2	2
Dolomite + Tato dust	10% & 6%	38	6	22	4	4	4
Dolomite + Penncozeb	10% & 20%	42	3	23	7	3	5
Dolomite	Nil	50	3	27	10	3	7
Cement + Penncozeb	Nil	24	34	29	1	13	7
Cement	Nil	59	3	31	15	3	9
PM fir bark + Tato dust	10% & 6%	36	28	32	3	11	7
Nubark	Nil	51	16	34	11	9	10
Cement + PM fir bark	Nil	64	6	35	16	4	10
Untreated Control	**Nil**	**64**	**11**	**38**	**16**	**7**	**12**
PM fir bark	Nil	65	11	38	17	7	12
Cement + Nubark	Nil	56	22	39	14	10	12

[a] Note: 1 = best treatment with lowest overall tuber loss, 17 = highest level of overall tuber loss.
[b] Overall S.T. performance = Average of S.T. performance in Trials 1 and 2.

Figure 5: Means of % tuber loss for Trials 1 & 2

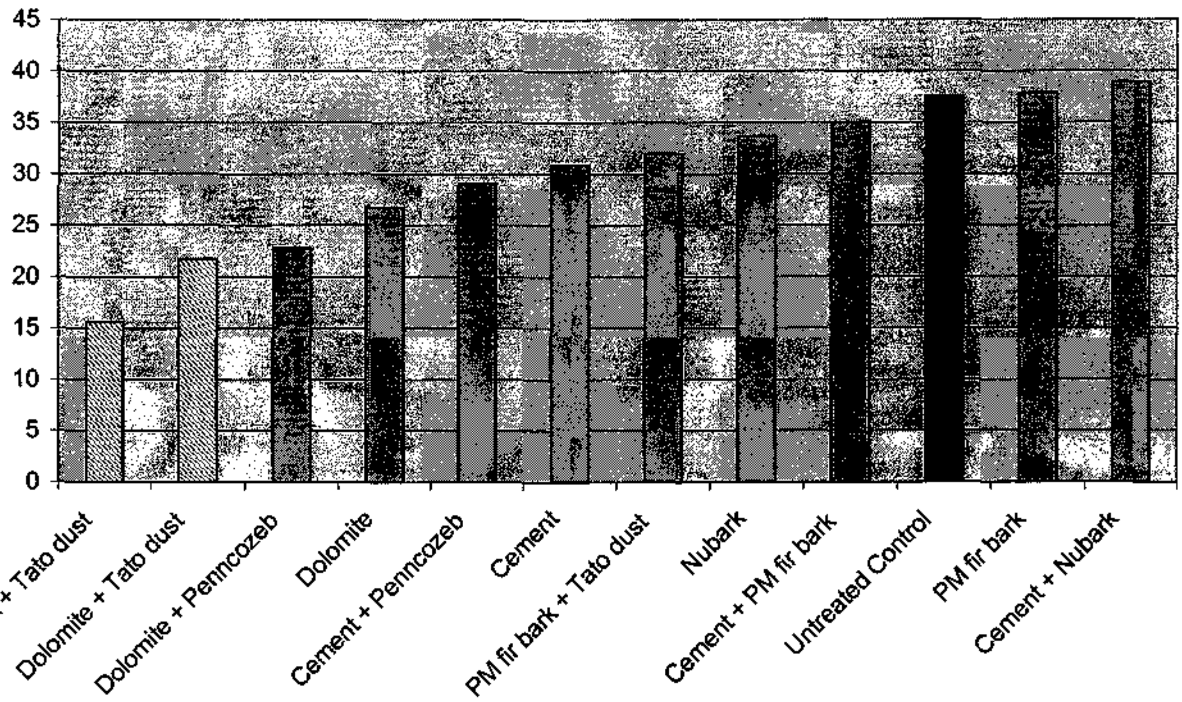
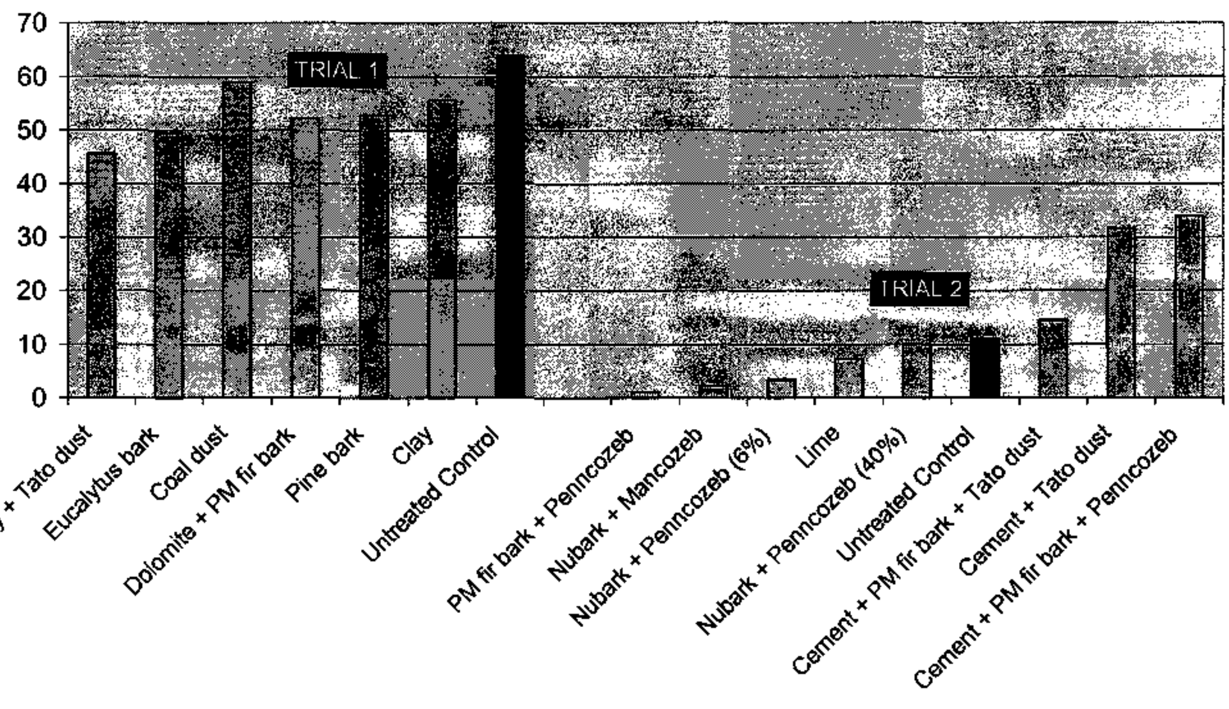


Table 5: Seed treatments that were evaluated only in one trial

Trial	TREATMENT	Mancozeb (a.i. in mixture)	Overall % tuber loss	S.T. performance *
1	Clay + Tato dust		46	8
1	Eucalytus bark	Nil	49	9
1	Coal dust	Nil	59	15
1	Dolomite + PM fir bark	Nil	52	12
1	Pine bark	Nil	53	13
1	Clay (Bentonite)	Nil	56	14
1	**Untreated Control**	**Nil**	**64**	**16**
2	PM fir bark + Penncozeb	40%	1	1
2	Nubark + Mancozeb#	6%	2	2
2	Nubark + Penncozeb	6%	3	3
2	Lime	Nil	7	5
2	Nubark + Penncozeb	40%	10	6
2	**Untreated Control**	**Nil**	**11**	**7**
2	Cement + PM fir bark + Tato dust	6%	14	8
2	Cement + Tato dust	6%	32	12
2	Cement + PM fir bark + Penncozeb	24%	34	13

* Note 1 = best treatment with lowest overall tuber loss, 16 = highest level of overall tuber loss.
# Nubark + Mancozeb is a commercial blend of Nubark pre-mixed with mancozeb

Figure 6: Mean % tuber loss in seed treatments evaluated only in one trial



Discussion

Properties of drying materials

(Refer to Table 1 & Figures 1 - 4)

Apart from generating dust, the amount of materials needed for the drying of cut seeds is influenced by their specific gravity (s.g.) (ratio of mass of 100ml volume of the material). The higher the s.g., the less dust it generates, while more material is required. Cement, Clay, Dolomite and Lime, have high s.g. (>100 g/100ml); Coal dust, Nubark and Tato dust have moderate s.g. (100-50 g/100ml); and PM fir bark, Pine bark, Eucalyptus bark, and Penncozeb have low s.g. (<50g/100ml).

Of the two types of Douglas fir bark products, Nubark is denser (with a higher s.g.) than PM fir bark. In the USA, Nubark is promoted as being less dusty compared to the typical fir bark.

Of the two Mancozeb products, Tato dust, which contains a high level of talc powder as filler, is denser than Penncozeb.

Seeds often produce watery sap when cut. Drying materials are dusted onto the cut seeds in order to absorb the sap, to prevent the cut surfaces from sticking together, and to improve air flow over the cut surfaces. Two types of measurements were conducted in this study on how much water is absorbed (water absorption) and how rapidly water is absorbed (rapid water retention) by a drying material. The rapid water retention capacity is also an indication of the affinity or attraction of the material on water.

PM fir bark, Nubark, and Tato dust have excellent water absorption properties (272, 122, and 115g water/100g product, respectively), capable of holding water greater than their weight (>100g/100g product). These are followed closely by Coal dust, Cement and Penncozeb (100, 93, and 86g water/100g product, respectively). Of all the materials tested, PM fir bark has the highest water absorption capacity, more than double that of Nubark, which has the second highest.

Among the materials tested, Tato dust, Coal dust, Penncozeb and Cement showed a strong affinity for water, and hence were able to retain relatively high level of water as soon as they are in contact, with a rapid water retention rate ranging from 59 to 95g/100g products. In contrast, the rapid water retention rate of PM fir bark and Nubark are 24 and 25g/100g products.

The relatively low rapid water retention rate of these two Douglas fir bark products appears to be partly due to their low affinity for water. These materials are also unique in their water repelling property when very dry. This water repelling property, however, is overcome with time. These contrasting properties may explain why a mixture of Cement and fir bark powder seems to reduce dust and provides more instantaneous drying of sap, compared to when only fir bark powder was applied.

Moisture loss from the cut surface is considered to be detrimental to the healing of cut seeds. Therefore, materials that have a high affinity for water, such as Tato dust, Penncozeb, Coal dust and Cement, are likely to increase the loss of moisture from cut seeds. Therefore, if using these materials on freshly cut seeds, they should be applied in mixtures with materials that have a low affinity for water, e.g. Nubark and PM fir bark, to reduce their adverse effects on wound healing.

PM fir bark and Nubark, with their low affinity for water, did not draw moisture from the cut seeds. This makes them excellent materials for creating a moist environment for optimum suberisation of cut seeds.

Other materials such as Dolomite, Lime, and Penncozeb do not repel water, and are moderate in their water absorption capacity and rapid water retention rate. Hence, these materials are probably also suitable for use as mixtures with fir bark powder to improve their water absorption capacity and enhance instantaneous drying, while reducing the water repelling property of the fir bark powder.

Clay (bentonite) is unsuitable for use as a drying material, becoming sticky when very wet.

Tato dust when dry, repel water immediately on contact. However, the surface tension between Tato dust particles and water droplets dissipates very rapidly, and it stops repelling water within seconds.

Among the materials tested, the pH of Cement (pH 13.5) and Clay (pH 10) are considered to be very high. Coal dust (pH 8.5), Dolomite (pH 8.5), and Lime (pH 9.0) are also alkaline with moderately high pH. PM fir bark (pH 4.0) and Nubark (pH 4.0) are slightly acidic. Note that bacteria are usually inhibited by low pH.

Performance of seed treatments

Trial 1 (refer to Table 2)

In seed lot A, cut seed treatments containing mancozeb, appeared to drastically reduce the incidence of rot on tubers stored under ideal conditions. Mancozeb treated tubers from seed lot A had 0 to 10% tubers with rot, compared to 25 to 70% on those without mancozeb. However, under adverse conditions, the incidence of rot on tubers was very high (50 to 100%), irrespective of the seed treatments.

In Trial 1, the average plant loss (26%) for the whole field trial was considered to be high by commercial standards. The plant loss was due to non-emergence because of seed decay. The seeds were planted in ground where potatoes had been sown before, in relatively warm conditions and in moist but well-drained soil. As field conditions were considered to be ideal, poor seed quality, slow healing of cut seeds, and bacteria and fungal invasions are believed to be important factors in plant loss.

In the field, the lowest percentage of plant loss for Trial 1 was recorded on cut seeds treated with PM fir bark + Tato dust, which was significantly lower than the Untreated control. In contrast, Cement + PM fir bark, a commonly used mixture, appeared to give the highest percentage plant loss in this trial. Although not significantly different, three other seed treatments, Dolomite + Tato dust, Dolomite + PM fir bark + Penncozeb, and Dolomite + PM fir bark + Penncozeb, also appeared to reduce the percentage of plant loss.

There was no statistical difference in the marketable yield between all treatments. The average weight of marketable tubers was 86% of total yield. Most of the unmarketable tubers were due to small sizes and knobby or misshapen tubers. Among the unmarketable tubers, there were only about 1% tubers with pink rot and/or deep common scab.

Cut surface damage, evident by the blackening of cut surfaces, was noted on tubers treated with Cement + Penncozeb (10% mancozeb). However, in comparison to other treatments, this treatment also tended to result in lower incidence of rot on treated tubers that were stored under both ideal and adverse conditions. No explanation could be given for these contrasting effects.

Performance of seed treatments (Cont.)

Trial 2 (refer to Table 3)

In seed lot B, under ideal conditions, all treatments except for Cement + PM fir bark and Cement + PM fir bark + Tato dust treatments, resulted in relatively little or no rot (0 to 15% tubers with rot). Cement + PM fir bark and Cement + PM fir bark + Tato dust treatments, appeared to cause relatively high levels of rot (60% and 30% tubers with rot, respectively).

Blackening of cut surface was noted on tubers treated with Cement + Tato dust (6% mancozeb), Cement + Penncozeb (40% mancozeb), and Cement + PM fir bark + Penncozeb (24% mancozeb). These treatments resulted in severe and high percentages of tuber rot (90-100%) on tubers stored under adverse conditions. However, under ideal conditions, surface damage by these treatments healed and no signs of rot were noted afterwards. Seed damage appears to be related to adverse reactions between cement and mancozeb. Commercial seed cutting operators have also noted, based on their experience, that cement is incompatible with mancozeb, causing blackening of cut surfaces.

In Trial 2, the average plant loss (4%) for the whole field trial, due to seed decay and non-emergence, was considered to be low by commercial standards. Seeds were planted in ground where potatoes had been sown before, under relatively warm conditions and in relatively dry soil.

In the field, there was no significant difference in the percentage of plant loss for Trial 2, between all the treatments. With the onset of rapid healing on cut seeds of Seed lot B, the use of different materials or mixtures appeared to have less influence on plant establishment. This highlights the importance of good seed quality.

There was no statistical difference in the marketable yield between all treatments. However, note that the three treatments, Cement + Tato dust, Cement + Penncozeb, and Cement + PM fir bark + Penncozeb, tended to have the lowest yield of marketable tubers. The average weight of marketable tubers was 86% of total yield. Most of the unmarketable tubers were due to size (too big or too small) and misshapen tubers. Among the unmarketable tubers, there were less than 0.1% tubers with pink rot. No common scab lesions were noted on any harvested tubers.

Trials 1 and 2

The greatest difference in seed performance on tuber loss or yield was between the different two seed lots. Seed lot A (Trial 1) was an approved seed lot (but not from a certified seed crop), while seed lot B (Trial 2) was from a certified seed crop. The average specific gravity of seeds was 105.28g/100ml from seed lot A and was 107.65g/100ml from seed lot B, indicating that the certified seeds were denser. This indicates that specific gravity may be a useful indicator of seed quality.

When cut, there appeared to be more sap from seed lot A than in B. The cut seeds of seed lot B also appeared to heal more rapidly compared to those from seed lot A. In the incubation tests, conducted under similar conditions, untreated cut seeds from seed lot A had a much higher percentage of tubers with rot compared to those from seed lot B. Under ideal and adverse storage conditions, untreated cut seeds from seed lot A had 70% and 95% tubers with rot (Table 2), while untreated cut seeds from seed lot B had 15% and 15% tubers with rot (Table 3), respectively.

Differences between the two seed lots were also noted in the field trials. Seed lot A had plant losses ranging from 13% to 38% due to seed decay and had marketable yields ranging from 37 to 53 tonnes/ha. Seed lot B had plant losses ranging from 2% to 8% and marketable yields ranging from 56 to 71 tonnes/ha. Although the differences in the suberisation of cut seeds are believed to have been the key factor, the different location and local field conditions may have had some influence on the field performance. The two trials were set up at the onset of relatively dry weather, where the soil in Trial 1 had higher soil moisture and was cooler than the soil in Trial 2.

Consistency in the performance of seed treatment

The performance of seed treatments evaluated in both Trials 1 and 2 were compared in order to examine the consistency of the seed treatment effects (Table 4). With most treatments, a seed treatment material performed well in one trial, but poorly in the other. For example, Cement treatment had a poor S.T. performance of 15 (with 59% tuber loss) in Trial 1, but an excellent performance of 3 (with 3% tuber loss) in Trial 2 (Table 4). The differences in treatment response in the two trials appeared to be due to the inherent properties of the tuber seeds, e.g. cut seeds of seed lot A appeared to be more susceptible to fungal and bacterial invasion. This may have been due to differences in the seed response to wounding. Rapid development of a barrier over the cut surfaces makes them resistant to bacteria and fungal invasions.

In choosing drying materials for seed treatments, they must perform consistently well in aiding the healing process, irrespective of seed lots and storage or planting conditions. When comparing treatments that were evaluated in both Trials 1 and 2, there are two treatments that tend to stand out in reducing rot in both trials. Tubers treated with Nubark + Tato dust gave excellent performance in both trials, followed by Dolomite + Tato dust (Table 4, Figure 5). Other treatments tended to give more variable results.

Among the treatment materials examined only in one trial, PM fir bark + Penncozeb (40% mancozeb), Nubark + Mancozeb (6% mancozeb), and Nubark + Penncozeb (6% mancozeb) (Table 5, Figure 6), are promising.

It is interesting that 40% mancozeb in PM fir bark + Penncozeb caused excellent healing of cut surfaces, but did not perform as well at the same rate in the Nubark + Penncozeb treatment (Table 5, Figure 6). It is possible that there may be interactive effects of water absorption rate and rapid water retention for optimum drying on the suberisation of cut seeds.

Cut seed treatments with only Penncozeb (80% mancozeb) or Tato dust (20% mancozeb) are known to cause blackening of cut surfaces on some seed lots. It should also be noted that Cement is also incompatible with mancozeb, even at low levels.

Trials conducted on mancozeb seed treatments indicated that a low level (10% in fir bark mixture) of mancozeb was just as effective as high levels (20% and 80%) for seedborne common scab control (Pung & Cross 2000a, 2000b). In this study, low levels of mancozeb, at 6% and 10% in drying material mixtures, were also effective in reducing tuber rot, especially in Trial 1 (Table 2). As a result, mancozeb at low rates, usually ranging from 6% to 10% in fir bark mixtures, is preferred.

Cut seeds treated with Nubark tended to be drier than those treated with an equal amount of PM fir bark. As a result, Nubark, when mixed with another drying material such as Cement, may have a detrimental effect. In order to induce rapid healing of cut seeds, high humidity is required, and moisture loss must be kept to a minimum. Apart from absorbing excess sap, Cement can also dehydrate cut seeds.

Comparison of commercial treatments

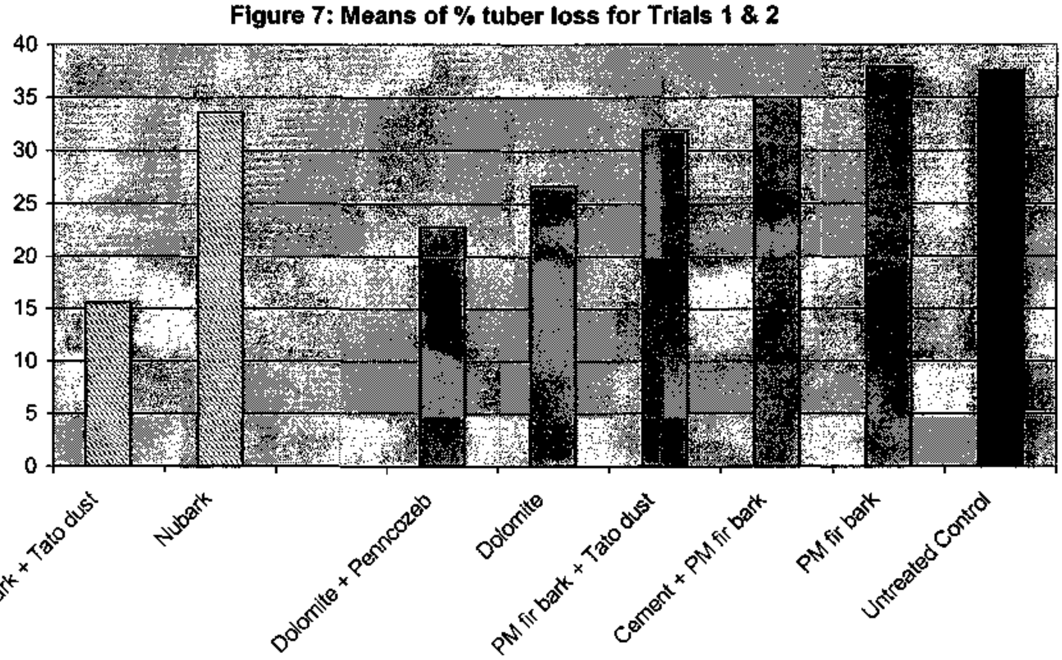
Table 6 lists treatment materials that are commonly used in current commercial practice. Two relatively new commercial treatments, Nubark, with and without Tato dust, are also included for comparison. Mixtures containing mancozeb, in the form of Tato dust or Penncozeb, helped reduce rot on tubers. Nubark + Tato dust gave the lowest level of rot in both Trials 1 and 2 (Table 6, Figure 7).

Table 6: Consistency in the performance of seed treatments that are used commercially, including Nubark treatments in Trials 1 & 2.

TREATMENT	Mancozeb (Active ingredient in mixture in Trial 1 & 2)	Trial 1 % tuber loss	Trial 2 % tuber loss	Trials 1 & 2 Overall % tuber loss	Trial 1 S.T. performance *	Trial 2 S.T. performance *	Trials 1 & 2 Overall S.T. performance*
Nubark + Tato dust	10% & 6%	29	2	16	2	2	2
Nubark	Nil	51	16	34	11	9	10
Dolomite + Penncozeb	10% & 20%	42	3	23	7	3	5
Dolomite	Nil	50	3		10	3	7
PM fir bark + Tato dust	10% & 6%	36	28	32	3	11	7
Cement + PM fir bark	Nil	64	6	35	16	4	10
PM fir bark	Nil	65	11	38	17	7	12
Untreated	**Nil**	**64**	**11**	**38**	**16**	**7**	**12**

* Note: 1 = best treatment with lowest overall tuber loss, 20 = highest level of overall tuber loss.

Figure 7: Means of % tuber loss for Trials 1 & 2



Conclusions

Properties of drying materials

- Materials with high specific gravity tend to generate less dust. Cement, Dolomite and Lime have high specific gravity; Coal dust, Nubark and Tato dust have moderate specific gravity; and PM fir bark, Pine bark, Eucalyptus bark, and Penncozeb have low specific gravity.
- PM fir bark, Nubark, and Tato dust have excellent water absorption properties, capable of holding water that is greater than their weight. PM fir bark has the highest water absorption capacity, more than double that of Nubark, which has the second highest.
- Of the materials tested, Tato dust, Penncozeb, Coal dust and Cement have high affinity for water, and are therefore likely to increase the loss of water from cut seeds. Therefore, if using these materials, they should be applied in mixture with materials that have low affinity for water, e.g. PM fir bark or Nubark, to reduce their adverse effect on wound healing.
- Cement is also caustic with a very high pH of 13.5, which may be detrimental to the suberisation process.
- Materials that appear to be ideal for seed coating are the two Douglas fir bark products, PM fir bark and Nubark, followed by Dolomite and Lime.
- PM fir bark and Nubark are acidic (both pH 4.0) and have a very low affinity for water. Hence, they are unlikely to cause moisture loss from cut seeds. However, these materials, when very dry, have a tendency to repel water immediately on contact.
- Dolomite and Lime are alkaline (pH 8 & 9, respectively) and are moderate in their affinity for water.

Consistency in the performance of seed treatment

- In order to induce rapid healing of cut seeds, high humidity is required, and moisture loss must be kept to a minimum.
- The greatest difference in the treated as well as untreated seed performance on tuber loss or yield was between the different two seed lots. The cut surfaces of seed lot B appeared to heal faster than those of seed lot A, resulting in less rot.
- When comparing treatments that were evaluated in both Trials 1 and 2, Nubark + Tato dust gave excellent as well consistent performance, followed by Dolomite + Tato dust. Other treatments tended to give more variable results.
- Among the treatment materials examined only in one trial, PM fir bark + Penncozeb (40% mancozeb), Nubark + Mancozeb (6% mancozeb), and Nubark + Penncozeb (6% mancozeb), are promising.
- Low levels of mancozeb, ranging from 6 to 10%, when mixed in the form of Tato dust or Penncozeb WSP with an appropriate drying material, appeared to be effective in drastically reducing rot on cut seeds.
- Cut seeds treated with Nubark tended to be drier than those treated with an equal amount of PM fir bark. As a result, Nubark, when mixed with another effective drying material such as Cement, may have a detrimental effect.

Technology Transfer

- Project findings were presented and discussed at an extension forum on potato seed treatments held at Devonport on 25th July 2001. This forum was jointly held by Dr. H. Pung and Dr. Rudolf de Boer, and was well attended by Tasmanian growers, consultants and industry representatives.

- Project outcomes were also presented at a Tasmanian vegetable extension day held at Devonport on 15th August 2001. This was well attended by Tasmanian growers, industry representatives and researchers.

- Project findings were presented to a potato information day, organized by Serve-Ag Pty Ltd at Stanley on 21st August 2001.

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Acknowledgments

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Serve-Ag Research staff who assisted in this project include Sarah Lamprey and Mary Trebilco.

Appendices

Appendix i – Field Trial Details

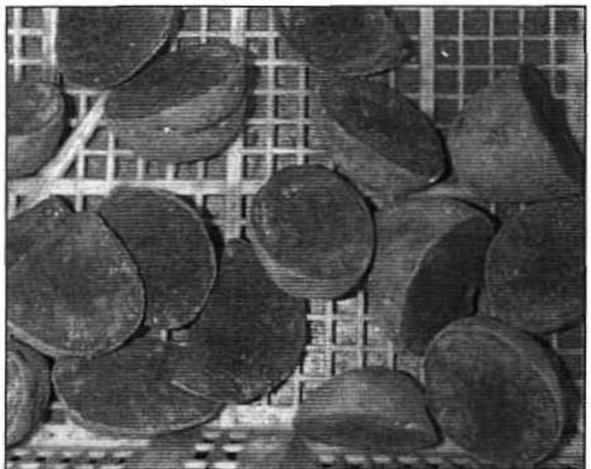
	TRIAL 1	TRIAL 2
Variety	Russet	Russet
Location	Gunns Plains	West Pine
Soil Type	Ferrosol	Ferrosol
Total No. Treatments	20	20
Trial Design	Randomised complete block	Randomised complete block
Replicates	6	6
Plot Size	3.5m x 1 row	3.5m x 1 row
Row Spacing	80cm	80cm
Plant Spacing	35cm	35cm
Planting Density	10 seeds/plot	10 seeds/plot
Total No. Plots	120	120
Potato Mould Formed	10/11/00	14/10/00
Seed Treatment Date	15/11/00	11/11/00
Planting Date	16/11/00	15/11/00
Harvest Date	10/04/01	30/4/01
Seed Origin & Cutting	Approved tuber seeds that were machine cut.	Certified tuber seeds that were machine cut.
Comment on Seeds	Even sized whole seeds. Long new shoots on the tubers before cutting.	Whole seeds varied in size. Short new shoots on the tubers before cutting.

Trial Layout for Field Trials 1 & 2

9	8	12	5	13	7	4	10	16	1	**REPLICATE 1**
20	14	6	19	11	18	3	17	2	15	
8	1	15	17	12	20	6	13	14	9	**REPLICATE 2**
3	10	7	16	4	19	2	11	5	18	
16	5	18	10	17	1	13	14	19	12	**REPLICATE 3**
9	8	2	15	3	7	4	20	6	11	
10	14	6	9	11	8	3	17	12	15	**REPLICATE 4**
18	1	5	7	2	20	16	13	4	19	
13	10	7	16	14	19	11	2	5	8	**REPLICATE 5**
6	15	20	18	17	1	3	4	9	12	
19	8	12	15	3	7	14	20	16	11	**REPLICATE 6**
10	4	6	9	1	18	13	17	2	5	

Appendix ii - Photographs

Photograph 1: Field Trial 2 at West Pine.

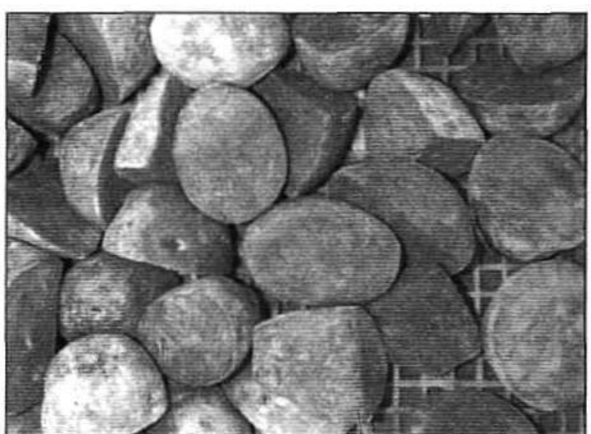


Photograph 2: Cut seeds coated with Cement + Penncozeb, Trial 1. Note blackening of cut surfaces

Photograph 3: Untreated Control, Trial 2. Note good healing of cut surfaces of seeds stored under relatively ideal conditions.

Photograph 4: Untreated Control, Trial 1. Note rot on some cut surfaces of seeds stored under relatively ideal conditions.

Photograph 5: Cut seeds treated with Dolomite + Tato dust, Trial 1.



Photograph 6: Cut seeds treated with Nubark + Tato dust, Trial 1.