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CONTROL OF FUNGAL DISEASES OF SEED POTATOES WITH THIABENDAZOLE*

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Summary A literature survey showed that the incidence of both *Fusarium* dry rot and *Phoma* gangrene in stored seed potatoes can be reduced considerably by treatment with thiabendazole soon after harvest. On occasion, the incidence of gangrene in progeny tubers was also reduced. Similar treatment with thiabendazole also gave good control of skin spot (*Oospora pustulans*) and silver scurf (*Helminthosporium solani*), both in storage and in progeny tubers. A pre-plant treatment with thiabendazole gave good control of black scurf (*Rhizoctonia solani*) in the subsequent crop. Thiabendazole can be applied by dusting, dipping, mist-spraying or with "Pulsfog" or "Swingfog" equipment.

INTRODUCTION

In the U.S.A., potato tuber dry rots caused by *Fusarium spp*. may cause major losses each year to the producers and users of seed potatoes (Ramsey *et al*., 1932; Leach, 1975). Some three decades ago in Europe, according to Moore (1945), *Fusarium* dry rots were second in importance only to late blight tuber rot (*Phytophthora infestans*) as a cause of fungal wastage in stored potatoes. *Fusarium spp*. still cause significant losses in Europe (Boyd, 1967; Murdock & Wood, 1972) but in recent years other pathogens have become equally or more important as a cause of waste. In the United Kingdom, gangrene is reported to be the most serious disease of stored potatoes at the present time (Logan, 1974a). The disease is caused mainly by *Phoma exigua* var. *foveata* and on occasion by *P. exigua* var. *exigua*. Significant losses may also occur as a result of skin spot (*Oospora pustulans*), silver scurf (*Helminthosporium solani*) and black scurf (*Rhizoctonia solani*) (Hide *et al*., 1969).

The present paper reviews research into the chemical control of these five potato tuber diseases, with special reference to the use of the fungicide thiabendazole.

DISEASE EPIDEMIOLOGY

In *Fusarium* dry rot and *Phoma* gangrene, infection of the tuber takes place mainly through wounds caused at harvest, during handling and especially during riddling (Small, 1944; Boyd, 1967; Malcolmson & Gray, 1968b; Logan, 1974a). Pathogenic *Fusarium* spores are probably present in the soil in most areas where potatoes are grown, and may remain viable in dry soil for over one year; thus, contaminated tubers can become infected any time during storage (Small, 1944).

Many factors affect the occurrence of dry rot and gangrene. In general, damage

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during harvest and grading increases the incidence of both diseases (Small, 1944; Malcolmson & Gray, 1968b). The extent of bruising will vary greatly from year to year, depending on conditions at the time of harvest. Cold dry weather is conducive to bruising because a cold tuber has a less resilient and more brittle skin than a warm one. Dry soil is more abrasive than moist soil. Thus, bruising is lessened if soil is moist and warm temperatures prevail at the time of harvest.

After potatoes have been dug and moved into storage, infection by *Fusarium* occurs during suberization while the wounds are healing. Tubers are most susceptible immediately after wounding and are less readily infected through clean cuts than through scarified wounds (McKee, 1954). After suberization is complete (1-3 weeks), *Fusarium* activity then becomes largely a function of the temperature at which potatoes are stored (Boyd, 1952b). Below 4.4°C the activity of the fungus is minor. At 7.2°C the fungus is slightly active and at 10°C it is moderately active. During storage, tuber susceptibility slowly increases, possibly because there is some conversion of starch to reducing sugars (Boyd, 1967).

No commercial cultivars of potato are completely immune to infection by *Fusarium* (Boyd, 1952a). They range from highly resistant (e.g. Arran Banner) to very susceptible (e.g. Russett Burbank and Arran Pilot).

Normally, gangrene also develops during storage although on a few occasions in Scotland it has been present at the time of lifting in mid-August (Malcolmson & Gray, 1968a). The disease is soil-borne, but haulm debris and storage equipment are also likely sources of infection (Foister *et al.*, 1945; Malcolmson & Gray, 1968a). Lesions usually develop at wounds made during or after lifting, as a result of inoculum present on the tuber surface or in adhering soil (Griffith, 1970).

Unlike *Fusarium* dry rot, gangrene is most evident in tubers which have been stored cold or moved when cold. Thus, in Northern Ireland, most gangrene develops after riddling because most potatoes are riddled during the colder winter months. Warmer storage at some stage usually reduces its incidence and severity (Malcolmson & Gray, 1968b).

Oospora pustulans can infect all underground parts of the growing potato plant (Hirst & Salt, 1959) but macroscopic skin-spot symptoms do not normally appear until at least 2 months after lifting (Allen, 1957). Disease severity increases during bulk storage. Severely infected seed potatoes may fail to produce plants or produce them late (Boyd & Lennard, 1961; Hide *et al.*, 1969).

Both black scurf (*Rhizoctonia solani*) and silver scurf (*Helminthosporium solani*) become increasingly prevalent on tubers during growth after July and during bulk storage (Hide *et al.*, 1969).

CHEMICAL CONTROL

a) Dry rot

Careful handling of seed tubers to minimize mechanical injuries and the provision of optimal storage conditions will help to reduce, but not eliminate losses due to *Fusarium* dry rot. Early studies into the possibility of controlling this rot by means of chemical treatment were made by Foister (1940), who used formaldehyde dips, and Small (1945, 1946) who used an organo-mercurial fungicide. With these compounds the only satisfactory time for treatment was immediately after lifting. Small (1945) emphasized the need to re-treat transported tubers immediately on arrival.

The introduction of systemic fungicides in the 1960s prompted several investigators to study their efficacy against potato tuber diseases. Thiabendazole (2-(4-thiazolyl)-benzimidazole), widely used as an anthelmintic since 1961, is active against many fungi, and it is now known to be both curative and protectant against many plant diseases (Weinke et al., 1969).

Preliminary laboratory trials by Leach (1971) in Maine, U.S.A. in 1968 and 1969 showed that thiabendazole and benomyl (methyl 1-(butylcarbamoyl)-2-benzimidazole-carbamate), applied as pre-storage dusts or dips, effectively controlled Fusarium rot in wounded, inoculated whole tubers. From the results of many further trials in Maine (1970-1972) including some carried out under commercial conditions, Leach (1975) concluded that of all chemicals tested, only thiabendazole and benomyl at 1500 ppm provided satisfactory control of Fusarium rot. Thiabendazole was the most effective material tested as a pre-storage treatment. Leach (1975) recommended that potatoes taken out of storage for shipment should receive a further treatment since at this time they are highly susceptible to Fusarium rot.

Leach & Nielsen (1973) reported that certified seed potatoes received in North Carolina from Maine were more highly contaminated with Fusarium than those from other sources. Experiments were conducted to determine methods of reducing such contamination. Highly contaminated whole potatoes (Pungo cultivar) were misted by Microsol Fog Generator with flowable thiabendazole (1500 ppm) and sent to North Carolina for planting. Results showed that thiabendazole reduced the number of infectious propagules to fewer than 0.5 per seed, as compared to 15.5 for untreated controls, and resulted in significantly higher stand counts and yields.

Another method of applying thiabendazole is by means of "Pulsfog" or "Swingfog" fumigation units. In Germany, Bommer & Pätzold (1972) inoculated whole seed potatoes with Fusarium and then fumigated them inside the storage room by means of a "Pulsfog" unit. Some were fumigated on the day of inoculation and others 10 days later. Potatoes were then stored at 10-12°C for 5 to 6 weeks. A flowable formulation of thiabendazole applied at the rate of 270 g a.i./t of tubers provided excellent control when applied on the same day of inoculation, but not when applied 10 days after inoculation.

In further experiments, Pätzold & Gehre (1972) stored tubers of 24 potato cultivars in the dark at 4°C from September 1971 to the end of March 1972. The temperature was then raised to 10°C. On April 27 some tubers were inoculated by dipping in a spore suspension of Fusarium. Several hours later one half of the inoculated tubers were treated by fogging (with a "Pulsfog" unit) with a flowable formulation of thiabendazole at the rate of 270 g a.i./t of potatoes. All potatoes were planted on May 2. Thiabendazole treatment gave good control of Fusarium and resulted in more rapid emergence, better growth and significantly higher yields than in the plots planted with untreated, inoculated tubers. In the latter there was a high incidence of malformed tubers.

b) Gangrene

Until recently an organo-mercurial dip treatment immediately after harvest was the only large-scale method of chemical control of gangrene (Foister, 1940; Boyd, 1960; Logan, 1967). The method was effective, but the toxicity of mercury and the necessity to dry tubers before placing them in storage limited the use of this treatment. In 1968, Hide et al. (1969) included systemic fungicides for the first time in potato tuber disease trials at Rothamsted. Both thiabendazole and benomyl, applied as pre-storage dips or dusts showed promise for decreasing the incidence of several tuber-borne fungus pathogens, but, because of the low level of Phoma inoculum, evidence for gangrene control was scanty. In subsidiary experiments thiabendazole dips and dusts greatly decreased the incidence of gangrene in tubers that had been stored for 3 months at 5°C after they had been washed, treated, dried and each given four uniform crush wounds in December (Hide et al., 1969; Hirst et al., 1970).

In Northern Ireland, Copeland & Logan (1975) screened systemic and non-systemic fungicides, applied to tubers as post-harvest dusts and dips, for their effectiveness in controlling gangrene in storage, and for their ability to improve the health of progeny tubers. Thiabendazole, benomyl and fuberidazole were the most effective. All three controlled gangrene in storage as effectively as 0.15% a.i. organo-mercurial dip treatment. On occasion, the incidence of gangrene in progeny tubers was also reduced, but as found by Hide et al. (1969) the effect in progeny tubers was not consistent. On the other hand, disinfection of seed tubers with organo-mercury normally reduces the incidence of gangrene in their progeny (Logan, 1967) and repeated treatment over several years can therefore greatly improve the health of a stock.

Combinations, in pairs, of dusts of benomyl, thiabendazole, fuberidazole, thiram, and captafol were tested as post-harvest treatments (Copeland & Logan, 1975). Some combinations were no more effective than either constituent alone but others, notably 1% a.i. benomyl + 1% a.i. captafol and, to a lesser extent, 1% a.i. thiabendazole + 1% a.i. captafol, appeared to act synergistically to give enhanced control of gangrene in storage. However, disease control in progeny tubers was not improved. Copeland & Logan (1975) suggested that the use of fungicide combinations may decrease the chances of development of benzimidazole-resistant strains of potato tuber pathogens.

The very promising results obtained for control of gangrene in stored seed potatoes by ULV mist application of thiabendazole have already been discussed by Logan (also Logan, 1974b and Logan et al., 1975).

c) Skin spot and silver scurf

In the experiments reported by Hide et al. (1969) and Hirst et al. (1970) most of the disinfectants tested as a pre-storage treatment gave good control of both *O. pustulans* and *H. solani* on tubers throughout the storage period. However, only thiabendazole and benomyl caused any appreciable reduction in skin spot and silver scurf on progeny tubers.

Copeland & Logan (1975) also observed a marked reduction in the incidence of silver scurf in progeny tubers as a result of pre-storage seed tuber treatment with 1% a.i. thiabendazole or 1% a.i. benomyl dust.

In France Jouan et al. (1974) showed that a 4-5 min pre-plant dip in a suspension of thiabendazole (2400 ppm) gave excellent control of silver scurf in the subsequent progeny, not only at harvest but also during subsequent storage.

d) Black scurf

Recent experiments in the United Kingdom, Holland, Denmark, Greece, New Zealand and Peru indicated that treatment of seed tubers just before planting gave good control of *R. solani*. Treatment improved emergence, reduced the incidence of infection on sprouts and stems, and in progeny tubers (Merck Sharp & Dohme, unpublished). Rates of application ranged from 6 to 100 g a.i./t and both thiabendazole dusts and dips were tested.

In New Zealand, Bolkan & Milne (1975) found that thiabendazole, benomyl and carboxin (all applied as 2.5% a.i. dusts just before planting) were absorbed and translocated to the shoots and leaves produced by treated tubers. The accumulation of fungicide at high levels in the base of shoots is of particular significance because this is the region where *R. solani* infections frequently occur.

CONCLUSIONS

The efficacy of thiabendazole for the control of dry rot and gangrene in stored seed potatoes is now well established from the results of many experiments. For effective control of both diseases it is important that treatment is carried out as soon as possible after harvest, and that fungicidal coverage of each tuber is as complete as possible (Leach, 1975; Logan, 1974b).

Thiabendazole treatment of dormant tubers can also improve the health of progeny tubers, particularly in respect of skin spot and silver scurf. However, results for the control of gangrene in progeny tubers have so far been inconsistent.

Thiabendazole has many advantages for use against diseases of seed potatoes. Various methods are available to suit individual needs. Dusts containing different amounts of active ingredient can be formulated, and wettable powders are available for dip treatments. Flowable formulations can be used for dipping tubers, applying by means of ULV mist sprayers, or for application with "Swingfog" or "Pulsfog" equipment. Another possible method of application which requires further investigation is fumigation with thiabendazole by igniting thiabendazole thermal dusting tablets or powders.

At recommended dosage rates thiabendazole is a safe product with low residue levels in the tuber. It is not phytotoxic to whole tubers.

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POTATO GANGRENE - ITS CONTROL DURING STORAGE BY MIST APPLICATION OF THIABENDAZOLE

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Summary The Newforge Potato Mister which produces an aqueous fungicidal mist by means of an ultra low volume sprayer is briefly described and results are given of mist treatments using 2% a.i. thiabendazole carried out over the roller table of potato graders. These treatments effectively controlled gangrene in storage and produced a significant reduction of the disease in the progeny of five out of the nine stocks treated. Silver scurf and skin spot were also reduced in the progeny but the incidence of common scab and black scurf was not. Preliminary trials indicated that water soluble and water dispersable formulations of thiabendazole were more effective in reducing gangrene than a wettable powder.

INTRODUCTION

At present gangrene is the most serious disease of stored potatoes in the United Kingdom. The disease is caused mainly by *Phoma exigua* var. foveata and on occasion by *P. exigua* var. *exigua* (Logan, 1967a) infection taking place mainly through wounds caused at harvest, during handling and especially during riddling (Logan, 1967b). Low temperatures at harvest in the store and during handling or transportation favour the development of the rot (Logan, 1973). Because infection may be latent (Todd, 1963) and slow to develop into visible rots, apparently healthy consignments of seed potatoes may pass inspection on the farm and at the docks yet show signs of gangrene on arrival at the customer's farm.

Various methods of chemical treatment such as dips in organo-mercury (Boyd, 1960; Logan, 1967c), dusts and dips with benzimidazole compounds (Hide *et al*, 1969; Copeland & Logan, 1975), or fumigation with 2-aminobutane (Graham & Hamilton, 1970) have been found to inactivate the pathogen on the tuber surface. However, when these treatments are carried out under large scale commercial conditions certain drawbacks become evident and to overcome these an alternative method of disinfection was developed whereby fungicides are applied as mists to the surface of tubers (Logan 1974a). Laboratory and farm trials have shown that effective control of gangrene in storage can be achieved by applying a mist of thiabendazole (2% a.i.) at 2 ℓ/t of tubers (Logan *et al*, 1975).

A commercial unit called the Newforge Potato Mister has been designed in conjunction with the Agricultural Trust for Northern Ireland for use on potato graders or roller tables. This paper contains the results of trials carried out with this machine (1) on farms during the autumn of 1974, and (2) in the laboratory using different concentrations of various thiabendazole (TBZ) formulations. Data are also presented showing the development of diseases in the progeny of TBZ misted parent tubers.

METHODS AND MATERIALS

The Newforge Potato Mister incorporates a Turbair Scamp (with modified heavy duty motor)ultra low volume sprayer set in a hood adjustable for conveyer belts from 33-56 cm wide and held in a steel welded construction adjustable for height and angle of a grader or roller table. It is essential that tubers rotate as they pass through the fungicidal mist. The fungicide is contained in a storage tank of 18 ℓ capacity and is kept in aqueous suspension by a Reva air pump. Unless otherwise stated seed potatoes were misted as described by Logan et al, (1975) using 2% a.i. TBZ (Tecto RPH: 60% w/w a.i. thiabendazole) applied at 2 ℓ/ton as they moved through the mist at 50 kg/min. At this rate the mist just dampened the surface of tubers so that drying after treatment was unnecessary.

In the selection of seed potato crops for treatment on a large scale (Table 1) preference was given to those known to be gangrene risks and growers were requested to retain tubers in bags or pallets for 2-3 days to allow excess soil to dry. All the stocks listed in Table 1 were misted 1-3 weeks after harvest and a half ton of each stock was left untreated as a control. At least four samples each of sixty-five tubers were withdrawn from both misted and untreated lots at the time of disinfection. To determine the gangrene potential of these samples each tuber was uniformly damaged (Logan 1967c) in four places 24 h after treatment and stored at 5°C for at least 12 weeks when the incidence of gangrene was recorded as the percentage of wounds that developed gangrene rots.

The tubers of cultivars Majestic and Ulster Sceptre used in the laboratory scale trials (Table 2) were selected from gangrene-prone stocks. Ten samples each of 25 kg were withdrawn from each cultivar and allocated at random to each treatment. The three concentrations (1, 2 and 10% a.i. TBZ) of each TBZ formulation (wettable-powder, flowable, water-soluble) were prepared in aqueous suspension or solution and applied as mists to each 25 kg sample using the Newforge Potato Mister. One sample was misted with water as a control. After treatment four samples each of 25 tubers were withdrawn from each treatment and 24 h later each tuber was uniformly damaged as described above, then stored at 5°C and the gangrene potential of each sample determined. The remaining tubers of each treatment were boxed to observe the effects of the chemicals on sprouting.

The tubers used to investigate the development of gangrene (Table 3) and other diseases in the progeny of TBZ misted seed were selected from stocks treated in autumn 1973 (Logan et al, 1975). They were planted in May 1974 in an experimental layout comprising a split plot design of four randomized blocks with untreated and misted stocks as main plots and cultivars as sub-plots. Two guard rows planted with disinfected seed separated each main plot. Each sub-plot was a single drill 3m long; drills were 0.7m apart and tubers spaced 0.3m apart. Six weeks after planting counts were made of emergence and 4 weeks later the number of stems per plant was recorded. Haulm was destroyed when it was estimated that 90% of the tubers exceeded 32mm in diameter and the crop was harvested by fork 4 weeks later. After yield assessments, 25 seed size (32-57 mm diameter) tubers from each sub plot were damaged and stored as previously described to determine gangrene potential and a further sample of 20 tubers from each sub plot were used to assess the incidence of surface diseases such as common scab (*Streptomyces scabies*), black scurf (*Rhizoctonia solani*), silver scurf (*Helminthosporium solani*) and skin spot (*Oospora pustulans*). The severity of common scab, black scurf and skin spot was assessed on a 0-3 scale where 1 = <5% cover, 2 = 5% cover and 3 = >5% cover; silver scurf was assessed on a similar scale where 1 = 1-25% cover, 2 = 25-50% cover and 3 = 50-100% cover.

RESULTS

Mists containing either 1% or 2% a.i. TBZ (Tecto RPH) applied by the Newforge Potato Mister effectively reduced the gangrene potential of all seed potato stocks

Table 1

Gangrene development in tuber samples misted with 2% a.i. TBZ (Tecto RPH) on the potato grader using the Newforge Potato Mister

Cultivar	Stock No.	No. tonnes treated	% infection Untreated	% infection 2% TBZ Mist
Home Guard	1	5	24.1	0.6
	2	8	27.5	4.0
	3	32	40.6	4.8
	4	15	58.9	2.4
Ulster Sceptre	1	9	23.4	3.3
	2	9	41.8	2.1
	3	5	54.6	6.6
Arran Banner	1	2	28.0	3.3*
	2	3	35.2	0.7
	3	1	42.4	0.3
Desiree	1	1	42.2	2.0*
Dunbar Standard	1	3	43.0	4.0
		1	43.0	0.5+
Up to Date	1	1	81.0	3.3+

* = 1.0% a.i. TBZ (Tecto RPH) + = 2.0% a.i. TBZ (TBZ/G water soluble)

(Table 1) to a very low level. The results of the comparison of Tecto RPH (wettable powder) with TBZ/G (water soluble) in a stock of Dunbar Standard indicate that the water soluble formulation was more effective in reducing gangrene than the wettable powder. This was confirmed by the laboratory trial comparing three TBZ formulations using cultivars Majestic and U Sceptre (Table 2) in which at each concentration the flowable and water soluble formulations were more effective than the wettable powder. Observations indicated that the sprouting of tubers was unaffected by any of the treatments listed in Table 2.

Table 2

Gangrene development in tuber samples after mist treatments with different concentrations of various TBZ formulations

Thiabendazole formulation	% a.i.	% infection Majestic	U Sceptre
Nil (control)	0	35.5 -	15.9 -
Tecto RPH	1	3.7(11.1)*	1.0(5.7)*
(wettable powder)	2	1.6(6.7)	1.0(5.7)
	10	0.4(2.5)	0.5(2.8)
Form. Mean		(6.8)	(4.7)
Tecto RPH	1	1.0(5.7)	0.0(0.0)
(flowable)	2	0.7(4.6)	0.5(2.7)
	10	0.0(0.0)	0.0(0.0)
Form. Mean		(3.4)	(0.9)
TBZ/G	1	1.2(6.3)	0.4(2.4)
(water soluble)	2	0.4(2.4)	0.0(0.0)
	10	0.0(0.0)	0.5(2.8)
Form. Mean		(2.9)	(1.7)

SE of formulation mean (± 0.62)
SE of form. x conc. mean (± 1.51)
* Data in parentheses are arcsin transformations
- = not included in analyses of variance

Emergence counts showed 89% and 98% of the untreated and misted seed potato stocks listed in Table 3 produced plants respectively. Untreated parent seed produced on average 4.9 stems per plant whilst the corresponding figure for misted parent seed was 4.5 stems per plant. Differences between these means for plant number and stems per plant were not statistically significant. Differences in yield and size distribution of progeny tubers were small and not significant. The overall tuber weight and number from untreated parent seed was 9.3 kg and 96 tubers per sub-plot and from misted parent seed 10.2 kg and 106 tubers per sub-plot.

Table 3

Gangrene development in the progeny of untreated and TBZ misted parent tubers (Misted, autumn 1973)

		% infection*			
		Untreated		Misted	
Cultivar	Stock	Parent Seed	Progeny	Parent Seed	Progeny
H Guard	1	30.3	46.5	7.9	25.7
	2	5.7	35.6	3.6	34.5
U Sceptre	1	26.5	42.1	9.3	34.0
	2	26.6	48.4	5.4	28.5
	3	19.9	50.7	2.6	37.2
A Banner	1	15.0	34.6	2.3	16.1
	2	37.0	41.7	7.7	23.3
U Prince	1	12.0	28.2	5.7	29.8
D Standard	1	33.5	44.1	12.3	34.6
Treatment means		22.9	41.3	6.3	29.3
Retransformed means (%)		(15.1)	(43.5)	(1.2)	(23.9)

SE of treatment mean (progeny) ± 2.94
SE of treatment x stock mean (progeny) ± 4.37
* Data are arcsin transformations of means of four replicates

There was an overall reduction of almost 50% in the incidence of gangrene in the progeny of misted tubers compared with that in the progeny of untreated tubers (Table 3). However, only five out of the nine stocks showed a significant reduction in the gangrene potential due to mist treatment. Furthermore the correlations between gangrene incidence in parent and progeny tubers in both untreated (r = 0.60, 7 d.f.) and misted (r = 0.23, 7 d.f.) seed were not significant.

The results of grading tubers for the incidence of surface diseases showed that seed tuber TBZ mist treatments made no difference in the levels of either common scab or black scurf in the progeny tubers but reduced the incidence of silver scurf in all nine stocks, the overall grade being 1.2 for untreated stocks and 0.6 for misted stocks. Although only traces of skin spot were present in both untreated and misted stocks it was noted that the TBZ mist treatment did reduce the level of this disease in the progeny tubers.

DISCUSSION

Most stocks retained by growers as seed for next year's crop are carefully handled and not subjected to the damage and chilling that predispose tubers to gangrene. Thus the disease potential of treated or untreated stocks is difficult to evaluate unless samples are subjected to uniform damage and cold storage as described by Logan (1967c). However, following the exceptionally wet and cold conditions of September 1974 higher than usual incidences of gangrene were found in some of the seed stocks retained on farms. For instance, in the stock of Up to Date (Table 1) about 50% of tubers were infected with gangrene whilst the level of disease in the TBZ misted lot was reduced to 3%. This case is of particular interest as most infection occurred, not through wounds but through lenticel and eye tissue and the mist treatment still gave effective control.

It is clear from the results that both the water soluble and flowable (water dispersable) formulations of thiabendazole reduced the gangrene potential of tubers to a lower level than the wettable powder and it is probable that 1% a.i. mists of either would be as effective as the wettable powder at 2% a.i. In practice the water soluble formulation would be preferred to the flowable as the need for an agitator in the Newforge Potato Mister would then be eliminated.

It is also clear that whilst mist treatments effectively control gangrene during storage this reduction in disease is not always carried through to the progeny of misted seed tubers. Similar results have been obtained by Boyd (1971) and Griffith et al (1974) who observed that gangrene on progeny tubers after storage was not always related to the amount of gangrene visible on the seed. Griffith et al (1974) and Logan (1974b) also found that symptomless (clean) tubers selected from gangrene affected stocks carry sufficient inoculum to produce progeny with a high gangrene potential. The results in Table 3 illustrate the rapidity with which gangrene can build up in stocks and also the complexity of the relationship between disease control in storage and that in the progeny.

In contrast to gangrene, control of the surface diseases silver scurf and skin spot with thiabendazole is carried through to the progeny confirming the results of Hide et al (1969) who used 5 min dip in 0.01% TBZ lactate. However, it appears that the mist treatment in contrast to the dip does not control black scurf. Although dips of TBZ are also more effective in controlling gangrene than mists (Logan et al 1975) the advantages of being able to treat tubers continuously and the elimination of drying makes mist application preferable under farm conditions.

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EXPERIENCES WITH THIABENDAZOLE IN CONTROL OF POTATO STORAGE DISEASES IN HOLLAND

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Summary In 1973/1974 and 1974/1975 storage trials were conducted with ware potatoes of the variety Bintje. These potatoes were stored in 15-ton bins filled to a height of 3.50 m. Thiabendazole (TBZ) was administered in dosages of 10-50 g of active ingredient (a.i.) per ton of potatoes either shortly after harvesting, or in divided doses after harvesting and in the spring after grading.This was done by using a Pulsfog apparatus, fumigation, and spraying the tubers while the bin was being filled. The potatoes were stored at temperatures of 5-7°C from October/November to March, and some up until mid June.
In those trials, thiabendazole treatment controlled silver scurf well to very well and dry rot fairly well. Spraying the tubers at the time of filling the bin at a dosage of 10 g a.i./ton apparently yielded the best results in the 1974/1975 season. Treatment with thiabendazole three weeks after lifting and after grading in spring had less effect than treatment shortly after lifting.

INTRODUCTION

In storing seed and ware potatoes in the Netherlands, the following mould diseases are usually encountered: silver scurf (*Helminthosporium solani*), black scurf (*Rhizoctonia solani*), and dry rot (*Fusarium spp.*) mostly *F.solani* var. *coeruleum*, but sometimes also *F. culmorum*. To limit the spread of silver scurf and black scurf the techniques of rapidly blowing and keeping seed potatoes dry have been used. Nevertheless, silver scurf is very common on potatoes, and black scurf occurs occasionally. Until recently the occurrence of dry rot in the Netherlands was generally of little significance. However, in the spring of 1975, this disease occured in many crops of seed potatoes to a rather serious degree, the mild winter probably being a contributing factor owing to germinating tubers. In 1971 and 1972 our Institute undertook trials to study whether silver scurf and black scurf could be controlled by treatment of the potatoes with 2-aminobutane during storage (Meijers, 1975); however, this product is not permitted for use on potatoes in the Netherlands. Since 1973 trials with the systemic product (fungicide) thiabendazole (TBZ) have been performed.

METHODS AND MATERIALS

Storage trials were carried out with ware potatoes (variety Bintje). The potatoes were stored to a depth of 3.50 m in well-isolated 15-ton bins cooled with outside air, at the experimental farm "De Eest", Nagele, Netherlands. In 1973 three

TBZ formulations, one of which was the Tecto Flowable, were compared at a dosage of 50 g a.i./ton of potatoes. This amount was administered with a Pulsfog apparatus at two and nine days after lifting, in two batches of 25 g a.i./ton each. The Pulsfog is an apparatus resembling the Swingfog. The slow-flowing to mildly paste-like TBZ formulations were atomized in this apparatus to extremely fine particles (mist formation).

To test the effect of the treatment for dry rot, the potatoes were graded in spring and then re-stored until mid June. For this re-storage the contents of a bin were distributed over two bins (so that each contained 6,5 - 7 tons), one of these bins being additionally treated with 25 g TBZ a.i./ton of the formulation concerned.

The 1974 test lot could not be harvested until early November because of extremely wet weather conditions. At the time, an estimated 2 - 3 % of the green tubers (uncovered by rain) were damaged due to night frost. During storage these tubers soon started to rot, which was followed by secondary Fusarium infestation. The storage trial now comprised a total of nine bins, of which eight were filled with 15 tons and one with 10 tons (Lirotect bin) of potatoes. Table 1 shows the bins, doses, and times of treatment.

Table 1

Survey of the treatments in the experiment of 1974/1975

Bin number	Doses of TBZ in g a.i./ton		First treatment in days after lifting	Methods of application
	Autumn	Spring		
1. Untreated	-	-	-	-
2. Tecto Flowable	10	-	5	Pulsfog
3. id.	25	-	5	"
4. id.	50	-	5	"
5. TBZ formulation B	25	-	5	"
6. Tecto Flowable	10	-	0	Mist spray
7. id.	25	-	21	Pulsfog
8. id.	25 (1)	-	21	"
9. Lirotect fum.tablets	10	-	5	Thermal dust
10. Untreated (1) (2)	-	10	-	Mist spray
11. Tecto Flowable (3)	25	25	5	Pulsfog
12. id. (6)	10	10	0	Mist spray
13. id. (7)	25	25	21	Pulsfog

Footnotes to Table 1. (1) Other diluent
(2) Refers to the original bin

In the spring of 1975, the contents of four bins were graded and re-stored, and, as in the previous year, the contents of each of these four was again distributed over two bins, one of which received additional treatment. The contents of the other five bins were carried off after sampling.

In 1973 the TECTO Flowable used was diluted with water in the ratio 1 : 1. Despite this, however, clogging of the sprayer sometimes occurred.

In 1974, a triethylene glycol based diluent was used in a ratio of TBZ to diluent of 1 : 2; this time no clogging occurred. During administration of the liquid and up to 15 min. after, the bin was ventilated internally. To promote proper distribution of the product, the direction of rotation of the ventilator was changed every few minutes. The nozzle of the apparatus was about 1 m below the ventilator.

The 15 fumigating tablets required for the 10-ton bin (7.2 g TBZ a.i./tablet) were tied together with iron wire, after which the bottom tablet was made to glow with the aid of a gas burner. The set of tablets was under the internally rotating ventilator. During application of this product, the direction of rotation of the ventilator was turned regularly.

The fog spray was applied with a low-pressure knapsack blower (1.75 ato) provided with one nozzle (1,2 mm). The spraying-cone was aimed at the tubers falling from the truck onto the conveyor belt. The volume of liquid amounted to about 2 l./ton of potatoes. This hardly wetted the tubers, but in the long run a little more clay soil adhered to the conveyor belt. The potatoes were stored at a temperature of 5 - 7°C; in the months of May/June the temperature rose slightly. Shortly after the TBZ treatment and grading, a germination inhibitor based on propham and chloropropham was administered in the usual dosages with a Swingfog.

The silver scurf infestation was rated by using the method described by Mooi (1968), the mean percentage of affected tuber surface being determined for each sample of 25 tubers (scale 0 - 87.5).

The percentage of tubers affected by dry rot was determined by evaluating samples up to a total weight of about 300 kg of tubers from each bin. The non-affected tubers of said quantity of the 1974/1975 trial were kept in bags from early April to mid July, and re-evaluated for the occurrence of dry rot in June and July.

In addition, we used the cutting test described by Nielson and Johnson (1972) slightly amended by us during this trial to study the effect of TBZ on _Fusarium_. From each sample 50 tubers were cut, and the halves mixed intensively in a clean, multiwall paper bag, and subsequently stored in these bags at about 15°C for 2 weeks. The cut surface was then scraped, and the percentage of cut surface affected was determined. The tubers were assigned to the following six classes according to the degree of infestation : 0; 0 - 6.25; 6.25 - 12.5; 12.5 - 25; 25 - 50 and > 50 %. Thus a so-called _Fusarium_ index, whose maximum is 75, was calculated. The _Fusarium_ index provides an adequate impression of the contamination of the tubers with active _Fusarium_ spores. The later the test is done the higher will be the index value, because of the greater susceptibility of the tubers.

RESULTS

The results of the storage trials are shown in Tables 2 and 3.

Table 2

Incidence of silver scurf and dry rot in the experiment of 1973/1974

Bins	Doses of TBZ in g a.i./ton		Silver scurf av. % infected tuber surface(1)		% tubers with dry rot	_Fusarium_ index	
	Autumn	Spring	March	June	June	March	June
Untreated	-	-	16.9	26.1	1.0	11.8	70.2
TBZ formulation A	50	-	3.9	2.9	0.2	0.1	0.5
id. B	50	-	5.6	6.0	0.0	0.0	0.8
Tecto Flowable	50	-	6.0	3.7	0.4	0.1	3.6
Untreated	-	25	-	19.0	0.2	-	7.7
TBZ formulation A	50	25	-	4.9	0.2	-	0.1
id.	50	25	-	5.0	0.2	-	0.0
Tecto Flowable	50	25	-	4.5	0.0	-	0.1

Footnote to Table 2.
(1) Infection in autumn : 6.2 %.

Table 3

Incidence of silver scurf and dry rot in the experiment of 1974/1975

Bin number	Doses of TBZ in g a.i./ton		Silver scurf av. % infected tuber surface(1)		Dry rot % infected tubers			*Fusarium* index	
	Autumn	Spring	April	June	March	June(2)	July(3)	March	June
1.	-	-	54.0	55.1	5.4	14.5	27.9	70.0	75.0
2.	10	-	31.0	-	3.4	-	18.9	46.1	-
3.	25	-	23.3	22.9	4.0	8.5	15.1	21.6	74.1
4.	50	-	20.2	-	3.8	-	11.7	7.1	-
5.	25	-	21.7	-	3.7	-	13.4	14.0	-
6.	10	-	10.7	15.9	2.4	5.2	8.7	11.2	63.2
7.	25	-	33.3	34.8	6.4	19.7	19.1	27.4	73.7
8.	25	-	25.4	-	3.0	-	15.5	29.1	-
9.	10	-	13.5	-	2.5	-	15.6	32.8	-
10. (1)	-	10	-	69.0	-	8.5	-	-	51.1
11. (3)	25	25	-	33.6	-	8.3	-	-	27.-
12. (6)	10	10	-	16.0	-	3.9	-	-	7.2
13. (7)	25	25	-	40.1	-	6.8	-	-	40.6

Footnotes to Table 3.
(1) Infection in autumn : 10.4 %
(2) % of the re-stored bulk potatoes.
(3) Total % rotten tubers of the 300-kg samples, inclusive of the % of March.

In the first trial year, all the TBZ formulations used prevented the spread of silver scurf during storage almost completely. In the 1974/1975 season, this prevention occurred only when the fog spray was used during the filling of the bin. The effect of the Pulsfog treatments is obviously less marked, although a better result is usually obtained by using a higher dose.

Treatment three weeks after harvesting seems to be rather late. Considering the good result obtained by using the fumigating tablets, it should be noted that this bin was filled with only 10 tons of potatoes, thus rendering the storage conditions for spread of silver scurf less favourable. Spring treatment in the first year still had some effect, but this appeared to have no effect in the 1974/1975 season.

In the 1973/1974 season, only a few tubers infected with dry rot were found even three months after grading. The differences in the 1974/1975 storage trial were small in March/April. As might be expected, greater differences occurred after grading. However, the results obtained indicated that only a moderate to fairly well control of dry rot was obtained by using TBZ. As to this disease, despite the very low dose, the best results were again obtained by spraying the tubers while the bin was being filled.

Spring treatment had less effect on dry rot, but in the 1974/1975 season was still noticeable, especially when comparing the *Fusarium* indices.

The data obtained in March with the cutting test show reasonable correlation with the percentage of tubers eventually infected with dry rot.

This cutting test also provided us with interesting data on the distribution of the product over the pile of potatoes. On emptying the bins in March/April 1974/1975, samples were collected for this purpose from three levels : 0.5, 1.75 and 3.00 m from the bottom. For the sprayed bin, the Fusarium indices at the levels mentioned were 14.0, 11.7 and 7.9 respectively. These indices for the bins treated with Pulsfog and fumigating tablets were on average 19.5, 47.0 and 9.9, respectively. This indicates that the distribution of the product by the latter treatments was inferior, in spite of repeated switching of the direction of rotation of the ventilator.

No effect of thiabendazole treatment on black scurf or black dot (Collectotrichum coccodes) was observed in either year.

The residue levels in the whole washed potatoes varied from 0.8 to 1.4 ppm in 1973/1974 at the dosage of 50 g TBZ a.i./ton. In 1974/1975, residual values between 0.2 and 0.5 ppm were found with the various treatments. The residual content of triethylene glycol (the diluent used in 1974/1975) remained below the detection level of 2 ppm. On the ground of these residual values the Food Inspection Department gave permission to market them normally.

DISCUSSION

Thiabendazole appears to be a product that counteracts the spread of silver scurf well to very well, and the occurrence of dry rot fairly well during storage, when applied shortly after harvesting. The data obtained in the 1974/1975 season suggest that, despite the very low dose, spraying the tubers while the bins are being filled is better than treatment with a Pulsfog apparatus or fumigating tablets, thanks to the better distribution of the product. Yet it has to be assumed that the spraying during the trial was not optimal.

Spraying the tubers on a roller conveyor (Logan, 1974) is certainly preferable, but feasible only for not too large quantities, e.g. 5 - 10 tons/hour. At harvest, lifting capacities of 50 - 60 tons/hour are common. These quantities then require a wide roller conveyor, which will also cake early in the presence of moist soil. In the Netherlands one is therefore thinking of a spraying system at the end of the conveyor belt after most of the soil has been removed. When the tubers are sprayed, a low dosage appears to give a good result; this treatment is therefore far cheaper than application with a Pulsfog apparatus or fumigating tablets.

Application of the product at the time of filling the bins, moreover, appears to be the optimal time. With Logan (1974), it may be concluded from these trials that treatment three weeks after harvesting or after grading in spring is less affective. This was also apparent from a subdivision of the 1974/1975 trial, in which at one and 17 days before the TBZ treatments bruised tubers artificially infected with Fusarium spores were hidden in nylon nets in the various potato piles. After three months' storage, obviously more tubers affected by Fusarium occurred in the untreated bin and in the samples treated 17 days after the introduction of the infected tubers. Bommer and Pätzold (1972) also stressed the need for treatment to take place very soon after infection.

When fumigating tablets or Pulsfog are used, it is necessary to fill the bins evenly and to divide the soil present in the bin well. When local accumulation of soil occurs this will have an adverse effect on the distribution of the product. There is often the additional practical problem that the bins present are insufficiently closed for proper dosage.

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PREVENTION OF GANGRENE AND FUSARIUM DRY ROT BY PHYSICAL MEANS AND WITH THIABENDAZOLE

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Summary Observations were made on the effects of storage conditions and treatment with thiabendazole on infection with gangrene (Phoma exigua var. foveata) and Fusarium coeruleum. The level of infection with gangrene was high in tubers with crushed wounds. It increased with decreasing storage temperature and with increasing relative humidity. Infection with F. coeruleum depended much less on the temperature but, like gangrene increased at high relative humidity.

Treatment of naturally or artificially-inoculated tubers with thiabendazole generally prevented infection with gangrene if the fungicide was applied within the first 10-14 days after inoculation. The effect rapidly decreased if it was applied later. Little infection occurred when the treatment was carried out two or more months before contaminated tubers were wounded. The best results were achieved by mist application of the fungicide.

INTRODUCTION

Observations were made on the effects of storage conditions and treatment with thiabendazole on potato tubers. It has generally been found that infection with gangrene (Phoma exigua var. foveata) increases with decreasing storage temperature, but the effect of relative humidity in the potato store has not been thoroughly studied. Malcolmson (1958) found that the diameter of tissue infected was least at a high relative humidity. Kranz (1959) found that the relative humidity in the store had no essential influence on the depth of the lessions, whereas he found that the number of infections in stab wounds in tuber flesh was lowest at high relative humidity (Kranz 1958).

Infection with Fusarium dry rot generally increases if the relative humidity is increased, although different Fusarium species may not react equally to changes in relative humidity. High humidity also promotes healing of wounds, but, because of the danger of dry rot, the ideal storage conditions may not be those that best promote wound healing. The possibility of the fungi germinating and growing must be small compared with the possibility of the wounds healing.

The rate of fungal infection can also be decreased by applying a fungicide. Copeland and Logan (1975) recently tested some fungicides against gangrene, and Leach (1975) some against Fusarium tuber dry rot. Their investigations confirmed earlier work which showed that thiabendazole is one of the fungicides effective against both gangrene and dry rot. Our experiments concentrated on the effect of thiabendazole on gangrene when applied at different times and under different conditions of storage of potato tubers.

MATERIALS AND METHODS

The varety 'Bintje' was used unless otherwise stated. In experiments with artificial inoculation, two wounds were made in each tuber, one at the top and one at the rose end. The wounds were about 1 cm^2, and there were 20-25 tubers in each sample. Wounds were made with sandpaper ($1\frac{3}{4}$), a clean piece being used to make each wound. Only in one experiment, that described first, were tubers wounded by other methods, either by peeling off a 1 mm layer or by striking lightly with a wooden hammer fitted with a countersink-auger of 12 mm diameter. Each kg of potato tubers was sprayed with 3 ml of a suspension of spores of P. exigua or F. coeruleum.

Thiabendazole was used at 4 g active ingredient per kg of tubers. It was applied in one af three ways: by the mist application method described by Logan (1974), by fumigation with 60 g of tablets containing 7 g thiabendazole, or by fogging with a Pulsfog-generator. Fans circulated the air in the potato samples during the second two treatments, and for one hour afterwards. Fogging by the Pulsfog technique for preventing potato tuber dry rot has been described by Bommer and Pätzold (1972). The experiments were made with small ventilated boxes containing about 1.6 t of tubers stacked to a height of 2.1 m. The effect of the treatment was measured on 8-24 five kg samples placed in nylon nets at different heights in the potato stack. Before the potatoes were placed in the nets and loaded in the boxes they were wounded by grading three times over a 1.35 m long wire riddle.

This method of wounding, called 'grading' in the text, was also used in another series of experiments with thiabendazole where 25 or 50 kg of potato tubers were stored in sacks. The treatments were replicated three or four times in these experiments. Thiabendazole was applied just after grading by the mist method, at a rate of 2 ml of 2 % solution per kg. The same amount of fungicide was sprayed on the tubers when they were artificially inoculated. The natural infection in the experiments was mainly with gangrene.

RESULTS

Influence of physical conditions on infection

Degree of wounding and infection with gangrene. The influence of the physical conditions during storage on infection with gangrene was studied after artificial inoculation of potato tubers. The percentage infection with gangrene depended on the degree of wounding; it was very high after crushing, much less after abrasion, and small after cutting.

Infection with gangrene at 4-16°C and r.h. of 95-100 or 75-80. At equal relative humidity, the percentage infection with gangrene decreased with increase of temperature. At a given temperature the number of lesions depended on the relative humidity.

During storage at r.h. 95-100, the infection rate with gangrene was 99 % at 4°C, 75 at 8°, 12 at 12° and 3 % at 16°C. At r.h. about 75-80 it was only 20 % at 4°C, 28 at 8°, 0 at 12° and 1 % at 16°C. Infection increased when the humidity increased from the lower level to the high one within 14 days of inoculation. When the increase in relative humidity occurred between the second and fourth day after inoculation at 8 or 12°C it became even higher than among those potato tubers which had been stored at the high relative humidity throughout the experiment.

A change in the humidity from 95-100 % to 75-80 % if it occurred within the first two to four days after inoculation greatly decreased the number of infections, but had little effect if it occurred 14 days later.

Effect of temperature and humidity on infection with F. coeruleum. When the storage temperature was between 4° and 12°C and the relative humidity was high, temperature had little influence on the number of infections with F. coeruleum.

Artificially-infected tubers were stored at 4°, 8° and 12°C and r.h. of about 95 %, and 62 %, 53 % and 54 % of the tubers respectively became infected with F. coeruleum, whereas 70 %, 43 % and 7 % became infected with gangrene. Clearly temperature had much more effect on gangrene than on F. coeruleum at a high relative humidity.

The number of infections after wounding by abrasion and inoculation with F. coeruleum was studied at a r.h. of 95-100 % or of about 75-80 %. In two experiments, between 77 and 83 % of the inoculated wounds became infected on average when the tubers were stored at 4°, 8°, 12° or 16°C at a high relative humidity. At a lower relative humidity only about 50 % were infected at 8° and 12°, and 10 % at 16°C.

Only a few infections occurred when tubers inoculated with F. coeruleum were stored for the first 14 days after inoculation at 16°C and a r.h. of about 75-80 % and then changed to 4° or 8°C and r.h. of about 75-80 % or 95-100 %, but if the tubers were stored at 16° and r.h. 95-100 % for 14 days and then moved to the lower temperature, the number of infections increased and became as large as among tubers stored at the lower temperature from the date of wounding.

Treatment with thiabendazole

Effect of thiabendazole and other fungicides. The effect of six commercially available fungicides on infection with gangrene was compared. They were applied after wounding and artificially infecting potato tubers. Thiabendazole and benomyl were applied as a mist with 2 ml of a 2 % solution per kg of potato tubers, and 70 % thiophanate, 80 % mancozeb, 80 % cuprihydroxychloride and a combined fungicide containing 60 % maneb and 15 % methylbensimidazole were applied as powders with 1 g of the fungicide per kg. The tubers were wounded, inoculated with gangrene and stored at 4° or 8°C. They were treated with the fungicide immediately after inoculation or 7, 14 or 21 days later.

The chemicals cannot be compared directly because they were applied in different ways, but thiabendazole, thiophanate, mancozeb and the combined fungicide were effective when applied immediately after, or 7 days after inoculation. Thiabendazole was the most effective of the fungicides when applied 14 or 21 days after inoculation. Benomyl was the least effective of the fungicides, and cuprihydroxychloride increased the rate of infection.

Effect of time of treatment. In the above experiments thiabendazole had its greatest effect when applied soon after inoculation, and the effect was small when it was applied more than 14 days after inoculation. Dr. Sirag Lashin at our Institute inoculated potato tubers with P. exigua or F. coeruleum and treated them with thiabendazole up to 28 days afterwards. He found that the effectiveness of the treatment decreased rapidly, especially among tubers inoculated with F. coeruleum, if it was applied more than seven days after inoculation.

Method of treatment with thiabendazole. When storing potato tubers in boxes the best results were achieved by the mist application method. Smoking with the fungicide tablets had a slightly greater effect than fogging with a Pulsfoggenerator.

The effect of treatment on the number of infected tubers at the time of emptying the boxes or sacks ranged from large to insignificant. In all experiments the treatment decreased the number of infection of wounds produced by light hammer blows two or more months after the treatment.

Treatment of potato tubers of different origin. Tubers from four different lots, three of the var. 'Bintje' and one of the var. 'Primula' were treated by mist application method in October or November to examine the possibility of treating potato tubers when they are graded in the store or transfered from clamps to the storehouse. All tubers with rotten spots were removed before treatment. After treatment the potatoes were stored in sacks

The effect of treatment differed from lot to lot. Two and a half months after treatment 29 % of the treated tubers and 39 % of the untreated tubers had rotten spots. In the lot where treatment had its greatest effect (lifted 18 days before treatment) 4 % of the tubers in the treated and 13 % in the untreated sample developed rotten spots. The lot where treatment had the least effect (lifted 2 months before treatment) had 20 % of the tubers discarded before treatment, and 70 % of the tubers in treated and in untreated samples developed rotten spots.

The permanence of the effect of thiabendazole treatments was checked by wounding with the hammer fitted with a countersink-auger. Two to more months after the treatment 3 samples of 20-50 tubers from all lots were wounded by 4 strokes by the hammer. Then they were placed one week at 4^{o}C and r.h. 95-100 followed by 4-5 weeks at 12^{o} C and r.h. 95-100. The number of infections in the wounds after storage at these conditions was found to be just as high as at 4^{o}C in 12 weeks.

Although treatment did not decrease the very high percentage of infection in the lot with 70 % infections, it had a marked effect on infection after wounding with the hammer. After wounding, $2\frac{1}{2}$ months after treatment with thiabendazole, 15 % of the wounds became infected in the treated sample and 58 % in the untreated. The proportion of wounds infected was decreased still further in the other potato lots, to only sixth.

Effect of treatment in the presence of infected tubers. The presence of 23 % naturally-infected tubers at grading, mist application of thiabendazole and storage in sacks from 22 November to 3 February increased the total loses by 26 % in the untreated samples, but by only 2 % in those treated with thiabendazole.

On 6 March samples of treated and untreated healthy tubers were wounded by hammer blows. The presence of infected tubers during the grading and storage increased the percentage of infected wounds from none in the treated to 34 in the untreated samples.

In another experiment, 17 % of tubers were infected when graded on 20 February. They were treated with thiabendazole up to 28 days later and stored in sacks until 14 May. The presence of infected tubers increased the percentage of infected tubers at the end of storage by 12.5 among the untreated samples and 6-7 % among the lots treated with fungicide 0-14 days after grading. The latest treatment with thiabendazole tended to increase the number of tubers with rotten spots.

DISCUSSION

It is difficult to explain why in several experiments we have obtained opposite results from those of Kranz (1958), e. g. he obtained the highest rate of infection with gangrene at a r.h. of about 78 %, and a lower rate at r.h. of 100 % or at about 64 % or lower, whereas we obtained a higher rate of infection at r.h. 95-100 % than at 75-80 %. His method differed from ours in the potato variety tested, fungus isolate, method of cleaning, wounding and inoculating the tubers. Kranz did not record the temperature of the store, but it was probably 10^{o}C as he used this in another experiment (Kranz 1959). He wounded tubers by a 5-7 mm deep and 1.5 mm broad stab into the tuber, and inoculated by dipping the tubers in a suspension of spores for 5 minutes.

Although it is impossible to explain the differences in the conclusions reached by Kranz and by us, it may be assumed, according to the investigations by Kranz, that storage at r.h. of 100 % in at least some instances decreases the infection of deep wounds. On the other hand, it seems reasonable to assume that inoculation of surface wounds is the most frequent natural method of infection by P. exigua, and probably by F. coeruleum, and that an atmosphere with a high humidity is needed in or around the wounds for germination and growth of rot-causing fungi. From these results we make the following recommendations for commercial storage and handling of potato tubers:

Lift and handle tubers under dry conditions, and when they are dry. Aim for at least 12, and preferably 16°C for at least the first week of storage, and for slow drying conditions in the first 2-3 weeks after any handling of the tubers. In these 2-3 weeks wounds should be kept dry, but without much further drying-up of the wounds or the tubers.

Avoid a decrease in temperature from about 14°C to about 6°C in the first 10-15 days after any handling. If the air in the store is saturated, or practically saturated with water at this time the temperature will be decreased.

If it is not possible to keep the temperature at a minimum of 12°C, a draft of air may be used to slightly dry the tubers during the first three weeks after handling.

By proper management of the store much may be done to decrease infection in contaminated tubers, but sufficient control may not be achieved, and, because large loses have been caused by gangrene in recent years, the use of fungicides is recommended.

The effect of treatment with thiabendazole depends greatly on time of treatment. The greatest and most certain effect against gangrene was achieved within the first 8 days after inoculation, and treatment 14-21 days after wounding and inoculation had little or no effect. These results are in accordance with the general statement in the literature that treatment with a fungicide against gangrene should be performed soon after lifting, preferably within the first 8 days if thiabendazole is used.

Treatment just after lifting may give technical problems and increase the need for labour when the demand is high. For these reasons the fungicide may have to be applied some time after lifting, but it can only be expected to give protection against gangrene in wounds produced during handling at, or after treatment. Thiabendazole showed a marked long-term effect, and good control of infection in such wounds can be expected, and further, more than one treatment should be unnecessary. Application of fungicides ought to be considered as a supplement to, and not as a substitute for good management of the store however.

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EFFECTS OF FOLIAR SPRAYS ON POTATO COMMON SCAB

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Summary The incidence of potato common scab, caused by soil-borne Streptomyces scabies, was decreased by spraying the foliage with solutions of daminozide, DL-ethionine (glasshouse tests and field trials), or gibberellic acid (glasshouse tests only). Soil- or root-applications of daminozide also decreased scab incidence. The effects of DL-ethionine were much less consistent than those of daminozide in the glasshouse, but in field trials it consistently decreased scab incidence. None of the chemicals gave a practical degree of control, such as was given by quintozene as a conventional soil-treatment.

Daminozide caused very slight distortions of tubers, but with gibberellic acid the distortions were very severe; DL-ethionine caused temporary chlorosis of foliage.

Possible mechanisms of action of these chemicals on scab incidence are discussed.

Résumé L'incidence de la galle commune de la pomme de terre causée par Streptomyces scabies decroit lorsque les fannes sont pulverisées de daminozide, DL-ethionine (essais en pots sous verre et essais en plein air) ou d'acide gibbérellique (essais uniquement en pots sous verre).

L'incorporation au sol ou l'application à la racine de daminozide diminu aussi l'incidence de la galle. Sous verre les effets de la DL-ethionine sont moins constants que ceux obtenus avec daminozide, mais en plein air la DL-ethionine agit d'une manière assez constante. Aucune des substances n'a donné des resultats comparables à ceux obtenus avec la quintozene.

La daminozide cause de legères irregularités dans la forme du tubercule; des déformations plus graves sont obtenues après le traitement avec l'acide gibbérellique.

Le mode d'action de ces substances est discuté.

INTRODUCTION

The causal organism of potato common scab (Streptomyces scabies) is largely soil-borne. It infects stolons when they are just beginning to swell, but does not continue to infect fully-formed tubers. Thus, crops of susceptible varieties are vulnerable for about three weeks around mid-June in southern England (Lapwood, 1973). The process of infection is favoured in dry soil, and inhibited in moist soil (Lewis, 1970).

The incidence of the disease can be decreased by various soil-treatments: application of quintozene, sulphur or green manure to the soil before planting, or by increasing the soil moisture by irrigation during the critical period (Lapwood et al, 1973). These treatments are inconvenient and bulky. Quintozene, the least bulky, has to be used at about 50 kg/ha; in an unconfirmed report, it was said to be carcinogenic (Searle, 1966).

In trying to find alternative methods for control of the disease, we examined chemicals which either affect stolon growth or have some downward-moving systemic action (Zentmyer et al, 1962; Humphries and Dyson, 1967a; McIntosh, 1973, 1974, 1975). This paper is an interim summary of glasshouse and field tests of three of these chemicals: daminozide (a synthetic plant growth regulator), DL-ethionine (a synthetic homologue of DL-methionine) and gibberellic acid, each of which decreased scab incidence after application to foliage only.

MATERIALS AND METHODS

Daminozide was of technical grade: 99% a.i., m.p. 160-162°C; DL-ethionine and gibberellic acid (GA_3) were of laboratory grade.

A method for testing soil-applied chemicals for possible control of scab in the glasshouse has been described (McIntosh, 1970); it was used in this series of experiments for testing quintozene, which was included in all tests at 50 ppm in soil, as internal standard. Some of the experimental chemicals were also applied to the soil in a few tests, but in most they were applied as foliar sprays. For this, plants (var. Majestic) were grown in the same way, but in untreated instead of treated soil, and were sprayed before or during the critical period, i.e. 2-3 weeks after potting, when the stolons were swelling. Simple aqueous solutions (i.e. without wetter or other adjuvant) were sprayed to run-off, the soil being protected from direct spray and run-off drops by absorbent cotton towels. In all tests, yields of tubers and scab indexes (Large & Honey, 1955) were measured at harvest, 9-11 weeks after potting. All effects on yield were negligible, and are not reported here. Some other characteristics were recorded in tests of daminozide. In each glasshouse test there were about six treatments with fifteen replicate pots per treatment; all tests were repeated several times.

Small randomized-block field trials were done with var. Maris Piper in infected fields at Woburn Experimental Farm. The plots were sprayed with aqueous solutions to run-off, i.e. at about 1,400 l./ha, in mid-June but, in contrast to the glasshouse tests, the soil was not protected from spray material. Scab indexes (Large & Honey, 1955) were calculated at harvest from fifty ware tubers per plot (three plots per treatment per trial). As the plots were small (1 row x 4m), soil-treatment with quintozene before planting was omitted, and yields were not estimated.

RESULTS

Daminozide as foliar spray : glasshouse tests

Plants were sprayed once with daminozide solutions about two weeks after potting. Three weeks later the following measurements were made: heights of plants; total fresh weights of leaflets per plant (giving a measure of total leaflet area per plant); and soil moisture per pot.

Table 1

Effects of single daminozide sprays on growth of potato plants and on scab incidence in the glasshouse

Treatment	Height of plants, cm*	Fresh weight of total leaflets per pot, gm*	Soil moisture, %*	Scab index at harvest
nil	39	10.7	2.6	19
daminozide, 0.15% spray	28	9.7	2.5	14
daminozide, 0.3% spray	25	9.6	2.5	12
daminozide, 0.6% spray	22	9.0	2.6	10
daminozide, 1.2% spray	23	9.8	2.7	8
quintozene, 50 ppm in soil	33	-	-	2
No. of replicate tests	6	2	2	4
LSD, P = 0.05	-	0.9	0.3	4
0.01	-	1.1	-	5
0.001	2	1.5	-	6

* 3 weeks after spray-treatments

Table 1 shows the combined results from several tests. All concentrations of daminozide gave the well-known decrease in plant height, which was accompanied by a slight decrease in leaflet area, as measured by leaflet weight. The incidence of scab was progressively decreased by increasing concentrations of daminozide, although even the 1.2% spray did not decrease scab incidence so effectively as quintozene at 50 ppm in soil. The daminozide treatments often caused some of the tubers to be slightly deformed, viz. pear-shaped instead of oval.

Daminozide applied by other routes : glasshouse tests

In two tests, three routes of application were compared: (1) soil-treatment before potting; (2) root-treatment i.e. temporarily substituting aqueous solutions for the water which was given daily to the plants via the saucers; and (3) foliar sprays, the soil being protected, as before, from spray drops. The saucer- and spray-treatments were each applied once, 2 weeks after potting. Heights of plants were measured 3 weeks later.

Table 2

Effects of daminozide, applied once by various routes, on growth of potato plants and on scab incidence in the glasshouse

Treatment	Route	Rate			Height of plants, cm*	Scab index at harvest
		ppm in soil	g/pot	% in spray		
nil	-	-	-	-	37	28
daminozide	soil-mix	~30	0.025	-	29	23
daminozide	soil-mix	~120	0.1	-	23	17
daminozide	saucer	-	0.025	-	27	21
daminozide	saucer	-	0.1	-	23	14
daminozide	foliar spray	-	~0.1	1.2	22	14
quintozene	soil-mix	50	~0.04	-	37	3
No. of replicate tests					2	2
LSD, P = 0.05					2	7
0.01					3	9
0.001					4	12

* 3 weeks after saucer- and spray-treatments

Table 2 shows the combined results of two identical tests. All daminozide treatments decreased plant height. The foliar spray and the higher rate in the soil- and root-treatments each gave about 0.1g of daminozide per plant. Similarly, each had roughly the same effect on scab, lower rates being less effective. Soil-treatment with quintozene was, as before, more effective than any of the treatments with daminozide.

Daminozide as foliar spray : field trial

In a trial in 1974, plots were sprayed once with 1.0% daminozide in mid-June. The incidence of scab at harvest in this trial was slight: the indexes were 7.0 (unsprayed) and 3.1 (sprayed), the decrease being significant at $P = 0.001$. No distorted tubers were noticed.

DL-ethionine as foliar spray : glasshouse tests

Plants were sprayed about five times, at 3-4 day intervals, with 0.2% and 1.0% solutions of DL-ethionine, the first application being about 2 weeks after potting.

Table 3

Effects of repeated DL-ethionine sprays on scab incidence in the glasshouse

Treatment	Scab index at harvest	
nil	16	14
DL-ethionine, 0.2% spray	14	-
DL-ethionine, 1.0% spray	-	10
quintozene, 50 ppm in soil	4	2
No. of replicate tests	8	8
LSD, P = 0.05	3	4
0.01	4	5
0.001	5	6

Table 3 shows the combined results of several tests; the figures for the two concentrations of DL-ethionine (which were not always tested together) are shown separately in two columns. At 1.0% DL-ethionine slightly decreased scab incidence, but it had no significant effect in the tests at 0.2%, in which quintozene was also less effective. The DL-ethionine sprays sometimes produced mild temporary chlorosis, near the growing points of the plants.

DL-ethionine as foliar spray : field trials

In four trials, plots were sprayed three times, at 3-4 day intervals, with 0.2% or 1.0% solutions, in mid-June.

Table 4 shows scab indexes at harvest; DL-ethionine, even at 0.2%, significantly decreased scab incidence in all four trials. The temporary chlorosis was more noticeable in all field trials than in the glasshouse tests.

Table 4

Effects of repeated DL-ethionine sprays on scab incidence in field trials

Treatment	Scab index in 1972a	1972b	1973	1974
nil	47	34	21	7.0
DL-ethionine, 0.2% spray	32	24	11	3.8
DL-ethionine, 1.0% spray	-	-	-	1.6
LSD, P = 0.05	7	9	8	1.8
0.01	11	13	12	2.5
0.001	18	-	-	3.5

Gibberellic acid as foliar spray : glasshouse tests

Plants were sprayed with 0.01% gibberellic acid about 2 weeks after potting. They became abnormally tall within a few days, but later their growth rate decreased. At harvest, the mean scab indexes from two tests were 22 (untreated) and 10 (sprayed), the decrease being significant at $P < 0.001$. However, about half of the tubers from the sprayed plants were severely distorted. In other tests, lower concentrations of gibberellic acid had less effect on scab, but still produced almost as many distorted tubers.

DISCUSSION

Daminozide, DL-ethionine or gibberellic acid, sprayed on foliage before or during the critical period for infection, decreased the incidence of potato common scab caused by soil-borne S. scabies. The point of interest is not that they gave good practical scab-control, such as was given by soil-treatment with quintozene, but that they seemed to have downward-moving systemic action. Beneficial effects of daminozide and DL-ethionine are not entirely new. Application of daminozide to roots, soil or foliage of various other plants has decreased the incidence of some fungal or bacterial diseases of foliage (Wiebel et al, 1965; Tahori et al., 1965; van Andel, 1966; Buchenauer, 1971); in such cases daminozide appeared to have an upward-moving or local systemic protective action. Ethionine is translocated both upwards and downwards in avocado seedlings; foliar sprays thus have some effect on Phytophthora root-rot of seedlings grown in infected soil (Zentmyer, 1962).

Daminozide, applied to foliage, generally decreases plant height by shortening internodes (George, 1975). In our tests, this was accompanied by a comparatively slight decrease in leaflet area, which had no effect on soil moisture content (Table 1). Although scab can be controlled by large increases in soil moisture, daminozide clearly did not exert its effect in this way.

The simplest way these chemicals could produce the observed effects would be by entering the foliage and moving unchanged to the stolons or into exudates, inhibiting infection by S. scabies on the stolon surfaces or in the rhizosphere. Daminozide is known to move unchanged to other parts of plants, including roots, after application to foliage of several species (Edgerton & Greenhalgh, 1967; Moore, 1968; Dicks, 1972-3; Thomas, 1974). The possibility that it can act as a direct fungicide in exudates is perhaps strengthened by the experiments showing that it decreased scab incidence after application to soil or roots (Table 2; similar experiments with DL-ethionine in progress). However, this does not exclude other mechanisms, e.g. those involving the formation, in soil, of metabolites which are fungitoxic, or which stimulate the growth of soil-borne organisms antagonistic to S. scabies.

Daminozide, an established growth regulator which can increase yields in potato crops (Bodlaender, 1968; Scott & Clayton, 1974), sometimes causes distortions of tubers (Humphries & Dyson, 1967b); however, these were uncommon in our tests. Its effects on scab were very consistent; e.g. in thirty-two separate single foliar applications in the range 0.3% - 1.2% in the glasshouse, only two failed to decrease scab incidence.

By contrast, DL-ethionine was less effective than daminozide. In the glasshouse, it was applied repeatedly to the same plants, but its effect was rather erratic, the mean decreases in scab incidence being slight (Table 3). However, in the field, its effects were much more marked and consistent (Table 4), possibly because different varieties were used: Majestic in the glasshouse, Maris Piper in the field. The degree of temporary chlorosis produced by DL-ethionine also varied greatly from one glasshouse test to another, sometimes being altogether absent; however, it appeared in all field trials, particularly in plots sprayed with 1.0% solutions. Such damage could be expected to decrease yield, but no such effect was detected in the glasshouse tests.

Gibberellic acid was much more active against scab than the other two chemicals: single 0.01% sprays were about as effective as single or repeated 1.0% or 1.2% sprays of the others. The obvious disadvantage of gibberellic acid was that it produced grotesquely distorted tubers, even at concentrations that had no effect on scab.

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PREVENTION OF SPROUTING ON POTATO DUMPS

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Summary Prevention of growth on the surface of potato dumps can reduce the sources from which the potato blight fungus (Phytophthora infestans) spreads to potato crops. Application of herbicides after growth has commenced was never fully satisfactory in providing a rapid and complete kill but aminotriazole and sodium chlorate were the best of the materials tested. Even here, re-growth soon occurred in some seasons and the blight fungus was not killed. It was found essential to apply a herbicide before sprouting commenced and the use of chlorthiamid or dichlobenil granules provided complete control. Carbetamide or aminotriazole suppressed growth for 1-2 months compared with no treatment but the effects of other materials used were much less permanent. Successful control was also achieved by applying water to the dump and covering it with a polythene sheet.

INTRODUCTION

Prevention of growth on potato dumps is not by itself the ultimate objective of this work. It is the prevention of spread of potato blight of which dumps of discarded potatoes can be very important sources. Furthermore it has recently been found (Graham, 1974) that flying insects breeding in such conditions can commonly carry bacteria which cause blackleg and tuber soft rot, and such insects could spread infection over considerable distances. It is possible too that by harbouring aphids which colonise the sprouts potato dumps may act as sources of leaf roll or other aphid-borne virus diseases.

The importance of these discards in "cull-piles" was first recognised by Bonde and Schultz (1943) in the USA and has been demonstrated in England by Brenchley (1964) and by Boyd (1967) in Scotland.

Under Scottish conditions most dumps are made in spring when potato stores have been emptied after riddling of the stocks for seed separation. The discard heaps are thus seldom exposed to severe frost. It has been found (Boyd, 1974) in the east of Scotland that 2 out of 3 of the early outbreaks of blight recorded up to the end of July were associated with overwintering inoculum in such heaps of unwanted potatoes. There was circumstantial evidence also that spread from these sources can extend up to 1.2 km.

Since potatoes are grown on most of the arable farms in the area, heaps of waste potatoes are not uncommon, although sometimes in practice not easy to locate. The tubers are most frequently disposed of by being transported to the nearest disused quarry or wood, or to an out-of-the-way location and left in heaps of various sizes or, even more crudely although less frequently, at the site of an old clamp.

The importance of dumps is further increased by the fact that they usually contain a high proportion of unsaleable chats and it has been shown (Boyd, 1973) that the incidence of blight is higher in these than in larger tubers. Moveover, variety plays a part. King Edward is the most susceptible to the common race of the blight fungus of all the commonly grown varieties in the UK and it is the one involved in almost half of all the early outbreaks of blight in eastern Scotland (Boyd, 1974). Dumps containing discards of this variety thus present a particular hazard.

METHODS AND RESULTS

Growers who are aware of the role of potato dumps in the spread of blight sometimes cut down the haulm after considerable growth has occurred. This action may be too late. If blight is present, cutting the haulm does not eliminate the disease and the new growth which rapidly develops soon becomes infected. Blight has been detected in dense growth on a dump in Scotland as early as 23 May, before emergence in neighbouring potato fields.

A range of herbicides has been tested over a period of six years on small heaps of waste potatoes, each of about $\frac{3}{4}$ t and with a surface area of about 8 m^2. These potatoes were allowed to grow until the haulm was about 20-30 cm in height and covered all or most of the heap. The materials to be tested were then applied and the most promising of these together with their rates of application are shown in Table 1.

Table 1

Growth control on potato dumps 1972-75: treated 11-22 July

Material	Rate	Mean growth cover (%) : weeks after treatment 0	2	3	4	5
Chlorthiamid	255 g	80	73	25	4	0
Aminotriazole	28 ml : 9 l	66	52	21	25	4
Sodium chlorate	454 g : 9 l	72	20	31	38	21
Carbetamide	6 g : 9 l	83	85	80	54	65
Diquat	5 ml : 9 l	67	57	74	98	85
Untreated		79	94	100	100	100

Diquat was used as "Reglone", sodium chlorate as "Atlacide", aminotriazole as "Weedazol TL" and carbetamide as "Carbetamex". These were applied in solution by means of a watering can. Dichlobenil as "Casoron G" and chlorthiamid as "Prefix" were applied as granules sprinkled over the dump surface. Other materials used were sulphuric acid (12½%), maleic hydrazide as "Regulox" and the commercial product "Kilweed" (simazine, MCPA and aminotriazole).

Comparative differences in effect were assessed at intervals over a period of one to two months by estimating the percentage of green leaf and stem still remaining after treatment. Naturally there was a degree of fluctuation in reaction to the treatments between years because of stage of growth at the time of application and the vigour of the haulm and it was not possible to replicate treatments in any one season. Nevertheless, the treatment differences over the four year period 1972-75 were quite consistent.

Table 1 shows the mean percentage growth cover of the dumps at intervals up to 5 weeks after treatment over the years where the respective materials were used. Carbetamide was not used in 1974 nor was chlorthiamid applied in 1974 or 1975.

After application of the materials in solution there was usually an initial kill of haulm or retardation of growth, but in some seasons this was shortly overtaken by new growth which soon covered the dump. On other occasions, and with more effective chemicals, in spite of the regrowth all the haulm gradually died.

The most satisfactory were aminotriazole and 5% sodium chlorate, but the former tended to be slower in its initial effect although this was longer lasting. The effects of both diquat and carbetamide applied to the haulm were disappointing and the other materials mentioned previously and applied as solutions were also unsatisfactory. The application of chlorthiamid granules to the growing haulm had no visible effect for about 2 weeks, but thereafter this soil acting herbicide gradually destroyed all growth completely although this was not accomplished for at least a month.

The main objectives in destruction of the haulm are rapidity and permanence and none of the materials used adequately fulfilled both of these requirements. Active growth of the blight fungus has frequently been detected on the lower parts of stems scorched by herbicides and regrowth of the haulm necessitates further herbicide applications.

A more satisfactory approach to the problem is growth prevention, i.e. taking steps to eliminate sprout development immediately the potatoes are dumped. For this purpose the potatoes must be taken to an accessible site and made into as compact a heap as possible.

The same materials as used previously were applied to dumps of the same type immediately after these had been made. Treatments were assessed on the basis of the percentage growth cover which was derived from two factors, percentage area covered and the mean height of stems to a maximum of 30 cm.

Table 2 contains the results of the 1973 trial and it is clear that chlorthiamid and dichlobenil were outstandingly successful. Apart from the initial development of some 5 mm sprouts all further growth was suppressed. This was achieved whether or not a soil covering had been made after applying the herbicides. Collapse of the dumps followed from 6 to 8 weeks later.

Table 2

Growth prevention on potato dumps : treated 15 May 1973

Material	Rate	Growth cover (%) : days after treatment						
		22	31	42	59	68	76	87
Diquat	5 ml : 9 l	0.1	1.0	17	20	100		
Sodium chlorate	454 g : 9 l	0.1	1.0	7	38	70	100	
Aminotriazole	28 ml : 9 l	0.0	1.0	10	20	70	90	
Maleic hydrazide	14 ml : 9 l	0.1	2.0	15	50	100		
Carbetamide	6 g : 9 l	0.1	0.1	0.1	0.1	1R	1R	50
Chlorthiamid	255 g	0.1	0.1	0.1	0.1	R		
Dichlobenil	255 g	0.1	0.1	0.1	0.1	R		
Polythene sheet	-	0.1	R	2R	2R	2R	R	
Untreated	-	1.0	2.0	13	40	100		

R = rotting

Effective prevention of any blight spread by destruction of the dump was also achieved by the simple expedient of application of water to the dump surface and then covering the potatoes with a polythene sheet (1000 gauge). This was held down at the edges by soil and stones so that it was as air-tight as possible. Initial sprouting started, but after 4-5 weeks bacterial soft rot developed and the dump collapsed.

Of the five treatments applied in solution, carbetamide prevented growth longest and some rotting also occurred. In 1973 the delay was about 12 weeks after application, while that for aminotriazole, sodium chlorate and diquat were about 5 weeks, and about 4 weeks for maleic hydrazide.

In Table 3 the comparative growth retardation to an arbitrary 2% growth cover point for each of these materials is shown over the years 1972-75 and also the mean delay compared with the untreated dump.

Table 3

Growth delay : weeks to 2% growth cover

Material	1972	1973	1974	1975	Mean delay over untreated
Carbetamide	8	12	10	10	6
Aminotriazole	10	5	10	9	5
Sodium chlorate	7	5	6	7	2
Diquat	6	5	5	5	1
Maleic hydrazide	7	4	4	-	1
Untreated	3	4	4	5	-

Thus growth delay by aminotriazole was on average about 1 week shorter than with carbetamide, while sodium chlorate was the most effective of the others with a delay of about 2 weeks.

DISCUSSION

Clearly the simplest and most effective method of eliminating potato dumps as sources of blight is by treatment immediately they are made and not, as is frequently practised, after growth has already commenced. For this purpose, the simple application of chlorthiamid or dichlobenil granules suppresses virtually all growth and the tubers eventually rot. Solutions of carbetamide and aminotriazole watered on to the surface of the dump can also retard growth very considerably or if the application of chemicals is not suitable, a polythene sheet cover secured at the edges can be used successfully and can induce extensive bacterial soft rotting. Obviously a dump to be treated in this way must be compact and of a size which can be conveniently and adequately covered by the sheet. In this respect compactness of the heap when it is made is important whatever treatment is to be applied.

The location of the dump must be studied and care taken to ensure that the material used for treatment does not cause permanent damage to the surrounding vegetation.

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