Screening systemic fungicides for potato wart disease[1]

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Nine registered or experimental systemic fungicides were evaluated in pot and field tests for control of potato wart disease. Potato tubers were treated by dipping and inoculated by growing them in soil infested with European races 2 or 8 of Synchytrium endobioticum. There was a high degree of random infection and in some instances treatments reduced infections considerably but none scored zero infection consistently. It was concluded that the fungicides were of little value in controlling wart disease.

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On a evalue en pot et en plein champ neuf fongicides endotherapiques enregistres ou experimentaux dans la lutte contre Synchytrium endobioticum. Les tubercules ont ete traites par trempage et inoculés par plantation en sol infect6 par la tumeur verruqueuse de la pomme de terre. Les races europeennes 2 et 8 ont servi d'inoculums. On a constaté un taux d'infection aléatoire élevé et, dans certains cas, les traitements ont considérablement réduit l'infection, mais aucun n'a reussi a l'éliminer completement et de façon permanente. L'auteur conclut que les fongicides étudiés n'ont pratiquement aucune valeur dans la lutte contre la tumeur verruqueuse de la pomme de terre.

Potato wart disease, caused by ***Synchytrium endobioticum*** (Schilb.) Perc., is remarkably resistant to fungicides. More than 120 inorganic or organic chemicals, singly or in combination, have been assayed (1, 3, 5-9, 11-15) but the only successful treatments reported were either phytotoxic or acted as soil sterilants.

Early workers were quick to point out a weak link in the disease cycle: the migration of zoospores from resting sporangia to susceptible host tissue. Fungitoxic materialls must permeate the soil-zoospore environment to be effective. Fungicides used to coat tuber surfaces could be rendered ineffective by leaching. Systemic fungicides offer the possibility of conferring 'immunity' on plants in wart-infested soil throughout the season.

Materials and methods

Cela W524 (20% triforine), FMC Corporation; NF44 (70% thiophanate-methyl), Ciba-Geigy Canada Ltd.; Bay Dam 18654 (50% cypendazole), Chemagro Ltd.; BAS 3460F (50% carbendazim), and BAS 3270F (50% cyclafuramid), BASF Canada Ltd.; Vitavax 75-W (75% carbathiin) and Uniroyal 1049 (37.5% Vitavax plus 37.5% captan, Uniroyal Chemical, Uniroyal Ltd.; Mertect Flowable (41.8% thiabendazole), Merck and Co., Inc.; and Benlate (50% benomyl), E. I. Dupont de Nemours and Co., Inc. were applied as dips to tubers of a susceptible cultivar. Tubers were dipped either at post harvest and at post sprouting, or after sprouting only. Concentrations as specified by the manufacturer and greater concentrations were tried.

For pot work, wart-free tubers of the cultivars Arran Victory and Pink Pearl were sprouted at 27°C and 80% RH. The lateral sprouts were removed and the tubers dipped for 15 min in test solutions. The dried tubers were potted in 15.3-cm (6-inch) pots with perlite:peat moss (1:2 v/v) and covered with potting mix containing sporangia or rotted wart compost. The inoculated tubers were grown in a controlled environment room (21°C 80% RH, 12 000 lux, 14-h day), watered daily, and fertilized weekly (4) for 4 wk. After a further 4 wk on a greenhouse bench, the plants were harvested. Symptom expression was measured as the weight of the tumor excrescences divided by the weight of the green plant tops per treatment (WTI), and as the percentage of tumor-bearing plants per treatment (PIV). Five tubers comprised an experimental unit for all treatments, except in one experiment where ten tubers were used.

For field work a field was selected known to produce large masses of tumorous galls on Arran Victory. BASF compounds were excluded from this test due to short supply. Four levels of active ingredient (a.i.) were prepared: 250, 1000, 2000 and 4000 ppm. Fifteen Arran Victory tubers were dipped for 15 min in each of the chemical concentrations and planted in duplicate rows, with three control rows in each plot.

Results

Pot experiments

In exploratory work with cv. Arran Victory and race 2 of ***S. endobioticum*** Benlate at 100, 250, and 500 ppm a.i. resulted in PIV 25, 25, and 0, respectively. Control infection was PIV 14. In the pot experiments proper (Table 1A), all treatments except those with BAS 3270F yielded a PIV 100 value. Wide differences in WTI, i.e. amounts of infection/plant, were experienced. Confirming experiments yielded quite different results, often PIV 0. Control plants yielded wide differences in PIV. Results using Pink Pearl infected with race 8 (Table 1B) were

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Table 1. Wart tumour indices (WTI) and percent infection values (PIV) of Arran Victory and Pink Pearl cultivars 8 weeks after planting tubers treated with different concentrations of systemic fungicides in pots of soil mix infested to different levels with two races of *Synchytrium endobioticum*

Fungicide and rate (ppm active)		No. of treatments*	Sporangia: Age (days)	Sporangia: No./g soil	WTI**	PIV†
A. Arran Victory, S. endobioticum race 2						
Benlate	30	1	60	10^3	1.2	100
	30	2	60	10^3	0.4	100
	30	1	21	10^3	0.9	10
	30	2	21	10^3	0.0	0
	5,000	1	310	10^3	0.0	0
	10,000	1	240	3×10^3	<0.1	20
Mertect	3.15	1	60	10^3	0.1	100
	3.15	2	60	10^3	1.6	100
	3.15	1	21	10^3	0.7	25
	3.15	2	21	10^3	0.0	0
	4,200	1	310	10^3	<0.1	20
	8,400	1	240	3×10^3	<0.0	25
Vitavax	1.2	1	60	10^3	0.8	100
	1.2	2	60	10^3	0.7	100
	1.2	1	21	10^3	1.7	20
	1.2	2	21	10^3	0.0	0
	7,500	1	310	10^3	0.0	0
	15,000	1	240	3×10^3	0.2	75
Uniroyal 1049	0.63	1	60	10^3	0.4	100
	0.63	2	60	10^3	0.6	100
	0.63	1	21	10^3	<0.1	10
	0.63	2	21	10^3	0.0	0
	3,750	1	310	10^3	0.0	0
	7,500	1	240	3×10^3	<0.1	20
BAS 3460F	5	1	60	10^3	<0.1	100
	5	2	60	10^3	<0.1	100
	5	1	21	10^3	0.0	0
	5	2	21	10^3	0.0	0
	5,000	1	310	10^3	0.0	0
	10,000	1	240	3×10^3	0.1	20
BAS 3270F	5	1	60	10^3	0.6	100
	5	2	60	10^3	0.0	0
	5	1	21	10^3	0.2	10
	5	2	21	10^3	0.0	0
	5,000	1	310	10^3	0.7	67
	10,000	1	240	3×10^3	0.0	0
Cela W524						
	10,000	1	310	10^3	0.6	40
	20,000	1	240	3×10^3	0.2	50
NF 44	7,000	1	310	10^3	0.1	25
	14,000	1	240	3×10^3	<0.1	20
Bay Dam 18654	5,000	1	310	10^3	0.0	0
	10,000	1	240	3×10^3	0.0	0
Untreated Controls			60	10^3	1.0	100
			21	10^3	0.1	4
			310	10^3	0.0	0
			240	3×10^3	<0.1	11
B. Pink Pearl, S. endobioticum race 8						
Benlate	5.000	1	240	2×10^3	1.3	100
	10,000	1	200	6×10^4	<0.1	20
Mertect	4,200	1	240	2×10^3	1.3	100
	8,400	1	200	6×10^4	<0.1	25
Vitavax	7,500	1	240	2×10^3	0.9	100
	15,000	1	200	6×10^4	0.0	0

Table 1. (Cont.)

Fungicide and rate (ppm active)		No. of treatments*	Sporangia Age (days)	Sporangia No./g soil	WTI**	PIV†
B. Pink Pearl, S. endobioticum race 8 (cont.)						
Uniroyal 1049	3,750	1	240	2×10^3	<0.1	100
	7,500	1	200	6×10^3	0.0	0
BAS 3460F	5,000	1	240	2×10^3	0.5	100
	10,000	1	200	6×10^4	<0.1	20
BAS 3270F	5,000	1	240	2×10^3	0.0	0
	10,000	1	200	6×10^4	0.0	0
Cela W524						
	10,000	1	240	2×10^3	0.7	100
	20,000	1	200	6×10^4	0.0	0
NF44	7,000	1	240	2×10^3	0.7	100
	14,000	1	200	6×10^4	0.0	0
Bay Dam 18654	5,000	1	240	2×10^3	1.1	100
	10,000	1	200	6×10^4	0.0	0
Untreated Controls			240	2×10^3	1.0	100
			200	6×10^4	0.0	0

"Based on 5 or 10 tubers per treatment; untreated controls 5-60 tubers/experiment. Single treatments were applied following tuber germination; two treatments were applied following tuber harvest and following tuber germination.

**WTI - wart tumor index.

†PIV - % infection value.

Table 2. Percent infection values (PIV) of Arran Victory plants treated with systemic fungicides at different concentrations and grown in race 2-infested soil in the field for 12 weeks

Fungicide"	PIV for the following fungicide concentrations (ppm a. i.): 250	1000	2000	4000
Benlate	80	20	27	20
Mertect	100	50	27	20
Vitavax	73	53	20	53
Uniroyal-1049	53	40	40	13
Cela W524	73	53	20	13
NF44	93	40	47	7
Bay Dam-18654	93	40	20	47
Untreated check†	42	0	0	0

*Fifteen tubers/treatments.

Forty-five tubers at each fungicide level.

somewhat at variance with those using Arran Victory and race 2. Control plants were all infected in a trial using low a.i. levels, but none was infected in a later trial at higher a.i. levels. Low PIV values (0-25) were recorded for plants treated at the higher a.i. levels.

Field experiment

Higher levels of infection were found in treated than in untreated (check) rows (Table 2). As fungicide concentration rose, there was a general decrease in PIV. When pot and field tests were compared, it was found that in most cases PIV's were higher for treated than for untreated tubers. Although Bay Dam 18654 was the most effective treatment in pot tests (Table 1), it was among the least effective in the field tests. The only consistent result was with Vitavax, which was least effective in both cases.

Discussion

This work was undertaken with the knowledge (2) that systemic fungicides are least effective against Phycomycetes, but was carried out in the hope that a compound of value in respect of potato wart disease might come to light.

It is recognized that a difficulty with chemical control of potato wart disease is in getting the chemical to the infection court. Susceptible tissue - sprouts, stolon buds, eyes - is produced over a long time base. Through the use of systemic fungicides it was hoped that resistance to S. endobioticum may have been developed in infection courts.

In the present study, the initial dipping was expected to protect only the sprout infection courts. The pot experiments were terminated after 2 mo growth. Tumorous galls developed at stem bases, which leads us to believe that in these instances infections occurred in sprout tissue. No attempt was made to treat plants later in the

season since it became clear from the pot work that little success was being achieved in effecting control at the infection courts. Some control was developed as a.i. concentrations increased (Table 2). Infections still occurred, however, in pots at 20 000 ppm a.i. and in the field at 4000 ppm a.i., or 8960 kg/ha.

In potato wart disease fungicide control work, it is felt to be imperative that a fungicide consistently yield PIV 0, otherwise sporangia with a longevity exceeding 30 yr (5) will continue to be generated. None of the compounds gave this result consistently. It was concluded that under our experimental conditions the systemic fungicides assayed were not effective in controlling potato wart disease.

Attention is drawn to the observation of wide differences in symptom expression that do not appear to be related to the fungicides or the a.i. levels. Hunt et al. (6) first recorded the capricious nature of S. ***endobioticum*** in their work in Pennsylvania; wart disease appeared in check pots or 30 infested garden soils, but plants developed infection in only 13 of those plots; on another occasion a pot test of 70 soils showed no wart, while plants in 25 of the plots manifested the disease. Roach et al. (11) found that field testing was more conclusive than was pot work, since no infection occurred in check pots. In the work reported here, 60-day-old inoculum was associated with PIV 100, and 21-day-old inoculum with PIV 0. However in other work we have found young inoculum more infective than older inoculum. Increasing inoculum density did not necessarily increase the chances of succesful infection. Likewise, more tumorous gall tissue developed with PIV 10 than with PIV 100.

The peculiar distribution of levels of infection which developed in these trials merits explanation. Several hypotheses can be advanced for future experimental work. The function of sporangial age is ambivalent since conflicting results arose from using different ages of sporangia in this and other work. Likewise, inoculum densities do not appear to relate directly to infection levels. Very possibly the dormancy characteristic of the sporangium plays a role in infectivity, germinability of sporangia perhaps varying at different phases of the host plant, or at times of the year. The low levels of infection in check plants in the field experiments has recently been paralleled in an experiment involving Sinox, copper sulphate, and Vorlex, inter alia (P. Thompson, personal communication, 1977). An interesting hypothesis that should be followed up is that under natural field conditions in Newfoundland, a soil-inhabiting antagonist limits the activity of S. ***endobioticum,*** and that the fungicidal materials removed this natural control at the infection courts.

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