Influence of Three Systemic Insecticides on Verticillium Wilt and Rhizoctonia Disease Complex of Potato

S. S. LEACH, Research Plant Pathologist, ARS, USDA, University of Maine, Orono 04469; and J. A. FRANK, Research Plant Pathologist, ARS, USDA, and Associate Professor of Plant Pathology, The Pennsylvania State University, University Park 16802

ABSTRACT

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The systemic insecticides/nematicides aldicarb and carbofuran and the systemic insecticide disulfoton, which are registered for use on potatoes, were evaluated for their effects on the development and severity of Verticillium wilt and the Rhizoctonia disease complex of potatoes. Granular formulations of these insecticides were applied preplant as an in-furrow treatment. Results obtained in 1976 and 1977 indicated that Verticillium wilt was not significantly affected by these chemicals. In both years, however, severity of the Rhizoctonia disease was significantly higher in plots treated with aldicarb than in the control plots. In 1978, aldicarb was applied in the seed furrow or the fertilizer band with either a gypsum or corncob diluent. The most significant increase in disease severity compared with the control was observed in the corncob diluent-fertilizer band aldicarb treatment. The most significant loss was a reduction in number of marketable tubers.

Most potato acreage in Maine has been treated with systemic insecticides in the past few years to control the green peach aphid (*Myzus persicae* Sulz.) and the Colorado potato beetle (*Leptinotarsa decemlineata* Say) (1). Systemic insecticides are widely used because of their easy, single application and effective early season protection.

In addition to their insecticidal properties, systemic pesticides may also affect other soilborne organisms such as nematodes (10) and fungi (12). When pesticides are added to the soil, they may affect soilborne pathogens in addition to other microorganisms, and in turn affect plant diseases (2,4–6,8,9,11). This study was conducted to determine the possible effects of systemic insecticides on *Rhizoctonia solani* Kühn and *Verticillium albo-atrum* (Reinke and Berth) and resultant incidence and severity of disease on potatoes.

MATERIALS AND METHODS

In 1976, a field study was initiated where the potato cultivar Superior, susceptible to *R. solani* and *V. albo-atrum*, was used to evaluate effects of systemic insecticides on disease incidence and severity. Plots were 7.75 m long with 91.4 cm between rows and 30.4 cm between plants and were arranged in a randomized complete block design replicated four times. Buffer plants of the cultivar Norland were planted between test plants in the row to separate treatments, maintain continuity, and reduce border effect. A two-row potato planter was used to apply a 10-10-10 fertilizer at 151 kg of nitrogen per hectare and to open the furrows. The systemic insecticide applications of aldicarb (10 G at 33.6 kg/ha) and disulfoton (15 G at 22.4 kg/ha) were applied in the seed furrow before planting and inoculation with *V. albo-atrum* or *R. solani*.

The field inoculum of *R. solani* (AG-3) was prepared by growing the fungus on sterile barley seed at 20 C for 6 wk prior to planting. Five infected barley seeds were placed in the furrow adjacent to each potato seed piece 2.5 cm below the soil surface. The *V. albo-atrum* isolate used was a nonmicrosclerotial, dark mycelial type. Inoculum was prepared by growing the fungus for 2 wk in potato-dextrose broth shake culture at 20 C. Before planting, the cultures were pooled and adjusted with water to a concentration of 80,000 spores per milliliter. Seed pieces (42–56 g) were cut in the field, dipped into the spore suspension, planted, and covered immediately. Plants were treated as necessary with mancozeb to control early and late blight.

To evaluate severity of Verticillium wilt, individual plants in the plots were rated weekly after the first trace of wilt was detected. Evaluations were made on a 1–5 scale, with 1 = no disease and 5 = plant death. Evaluations of symptoms induced by *R. solani* on the plants were made at 4, 6, and 10 wk after planting, and tuber symptoms were evaluated after harvest. Ratings were made on a 0–10 scale as previously described (7), with 10 signifying the most severe damage. Field plots were located in Presque Isle, ME, in 1976 and repeated in 1977 at Newport, ME.

To gain further information, a large-scale test was conducted in 1978 at Newport. This experiment was designed to investigate the possible phytotoxic effects of aldicarb formulations and to evaluate the increase in *R. solani* damage observed in 1976 and 1977. Aldicarb, formulated with ground corncobs or gypsum, was tested to determine effect of the diluent on phytoxicity. The aldicarb 15 G formulation was applied at 7.84 kg/ha with a Gandy applicator mounted on a potato planter at the time of fertilizer application and opening of the seed furrow.

The recommended placement for aldicarb application is in the seed furrow. Observations in growers' fields indicated that damage induced by *R. solani* was reduced when aldicarb was applied in the fertilizer band. Therefore, depending on the treatment, aldicarb was placed either in the fertilizer band or in the seed furrow or divided equally between the two sites. Carbofuran and disulfoton were placed only in the fertilizer band at the same rates described above. In several treatments, a pentachloronitrobenzene (PCNB) 75% WP seed treatment was used (100,000 ppm liquid dip) to reduce disease induced by seedborne *R. solani*.

The cultivar Norchip was used in 1978 in place of Superior because of its greater susceptibility to *R. solani*. Seed designated for treatment with PCNB was dipped in a 100,000 ppm slurry of wettable powder (75 WP) for 20 sec before cutting.

One-half of all plots planted were inoculated with *R. solani* as previously described. The plots were fertilized with a commercial fertilizer 15-15-15 at 151 kg of nitrogen per hectare, and metribuzin (0.54 kg/ha) was applied for weed control. Additional agronomic practices were performed as required. The plots were 5.7 m long with 22.8 cm spacing between plants and 91.4 cm between rows. The experimental design was a randomized complete block with 25 seed pieces per replicate and four replicates.

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RESULTS

The effects of the three systemic insecticides on Verticillium wilt severity are reported in Table 1. The disease index is reported for the 8-wk reading following planting and inoculation, as well as the final index. Generally, in both 1976 and 1977, neither disease development nor final disease index was affected significantly by treatment. One exception occurred in 1976 when the disease index in disulfoton-treated plots was 4.5 compared with 2.9 for the inoculated control. This increase in disease severity was caused by the high degree of early blight infection in two of the disulfoton plots, which masked the true Verticillium symptoms and resulted in the higher observed value.

The effects of the three systemic insecticides on disease induced by *R. solani* are reported in Table 2. In both 1976 and 1977, the disease index was significantly greater in plots treated with aldicarb than in plots receiving any other treatment. In both years the amount of marketable tubers produced was reduced by all treatments, with aldicarb producing the least.

The 1978 plots were in an area where hay had been grown for 30 yr. We chose this area specifically so that the level of *R. solani* inoculum in the soil would be low. Results of this test showed lower than normal yields but allowed for comparisons between treatments. Nematode surveys in Maine have shown that very few are present in potato-producing areas; therefore, we do not believe that any difference in yields could be attributed to nematode control by aldicarb or carbofuran. Some of the increases in yields observed in 1978 may have been through insect control rather than any effect from disease incidence or severity. This is why the percentage of marketable yield is a more reliable measure of yield when studying the Rhizoctonia disease of potatoes.

The most significant results from the 1978 field experiment are reported in Table 3. Total yields were not adversely affected by the insecticide treatment, and in some cases yields were increased. Only aldicarb significantly reduced marketable yield. All inoculated plots produced lower percentages of marketable yields, and more variability was observed than in the uninoculated plots. Seed treatments in conjunction with aldicarb applied in the seed furrow increased yields in the uninoculated plots.

With high inoculum levels, plots where the aldicarb-gypsum formulation was applied totally with seed or fertilizer had significantly lower disease indices than plots with aldicarb-corncob formulations. The reverse occurred when the insecticide applications were split. However, in the low inoculum plots the only reductions in disease indices were detected when the aldicarb-gypsum formulation was compared with aldicarb-corncob in the fertilizer band and when the seed was treated with PCNB and the insecticide was put in the fertilizer band. Under high inoculum levels, there was a significant reduction in *R. solani* damage compared with the control when PCNB was applied as a seed treatment. This was not evident when PCNB was used in combination with aldicarb. However, at low inoculum levels, the combination of PCNB seed treatment and aldicarb resulted in the two lowest disease indices observed.

Under indigenous inoculum levels, aldicarb treatments generally provided a significant increase in disease severity. Aldicarb-treated plots had higher disease indices than carbofuran or disulfoton plots, as was also shown in the 1976 and 1977 tests. The significant increase in the disease index with the addition of aldicarb was primarily reflected in the reduction of marketable tubers. In all aldicarb treatments without PCNB, the percentage of marketable tubers was depressed and generally significantly lower than the control.

Table 1. Influence of three systemic insecticides on Verticillium wilt of potatoes in Maine in 1976 and 1977

	1976		1977	
Treatment	8-wk disease index	Final disease index	8-wk disease index	Final disease index
Not inoculated control	1.0[a]	1.5	1.5	3.0
Inoculated control	1.7	2.9	2.8	4.6
Disulfoton	2.0	3.5[b]	2.9	4.2
Aldicarb	2.3	3.3	2.8	4.2
Carbofuran	2.4	3.7	2.7	4.1
Bayes LSD ($P = 0.05$)	0.8	0.9	0.9	0.7

[a] Ratings based on a 1–5 scale, with 1 = no disease and 5 = plant death. Each figure represents the mean of four replicates and 10 hills per replicate.
[b] High index is probably not a true one because of a high degree of early blight infection in two plots.

Table 2. Influence of three systemic insecticides on the disease of potatoes induced by *Rhizoctonia solani* in Maine in 1976 and 1977

	1976		1977	
Treatment	Disease[a] index	% Marketable yield	Disease index	% Marketable yield
Not inoculated control	1.3	90.4	2.2	59.6
Inoculated control	3.0	78.5	3.5	60.1
Disulfoton	2.9	73.7	3.2	32.3
Aldicarb	3.8	44.6	5.6	11.7
Carbofuran	2.6	69.8	3.4	24.7
Bayes LSD ($P = 0.05$)	0.6	10.7	1.1	16.3

[a] Ratings based on a 0–10 scale as described by Frank et al (7), with 0 = healthy plants and 10 = most severe disease development.

Table 3. Effect of various insecticide and fungicide applications on Rhizoctonia disease of potatoes in Maine in 1978

	Mean total yield (kg)[a]		% Marketable yield[b]		Disease index[c]	
Treatment	I[d]	NI[e]	I	NI	I	NI
Aldicarb A[f] (seed)	7.6	7.4	18.4	29.7	6.0	3.3
Aldicarb A (fertilizer)	9.5	7.3	30.4	35.9	6.7	3.6
Aldicarb A (seed + PCNB)	7.6	8.5	18.4	83.6	5.9	1.9
Aldicarb A (1/2 seed, 1/2 fertilizer)	9.8	10.1	33.1	51.0	5.6	3.1
Aldicarb B (seed)	9.5	10.9	31.6	53.0	4.9	3.3
Aldicarb B (fertilizer)	8.7	10.9	22.0	47.3	5.3	2.8
Aldicarb B (seed + PCNB)	10.7	10.8	27.5	89.9	5.5	0.7
Aldicarb B (1/2 seed, 1/2 fertilizer)	8.4	10.1	14.2	36.0	6.5	3.5
Disulfoton (fertilizer)	11.1	9.6	58.5	83.9	5.1	2.2
Carbofuran (fertilizer)	9.8	8.8	59.9	69.3	4.1	2.5
PCNB seed treatment	8.1	9.0	50.6	79.3	3.6	2.3
Control	7.2	6.5	47.7	77.5	5.5	2.5
Bayes LSD ($P = 0.05$)	2.7		20.1		0.1	

[a] Mean of four 25-hill plots.
[b] Tubers without malformation, cracking, and less than two sclerotia per tuber.
[c] Based on a 0–10 scale, with 0 indicating no damage.
[d] I = inoculated.
[e] NI = not inoculated.
[f] Aldicarb A = corncob diluent, aldicarb B = gypsum diluent, seed = application in seed furrow, fertilizer = application in fertilizer band, 1/2 = half of recommended dosage.

DISCUSSION

Based on the results of this research and observations made during the last few years, the three systemic insecticides tested apparently did not significantly affect the soilborne populations of *V. albo-atrum* or the incidence of Verticillium wilt disease of potatoes. The report of Hoyman and Dingman (8) indicated that disulfoton gave some control of *V. albo-atrum*. A report by Busch (3) suggested that this same chemical had no effect on Verticillium wilt. The research by Hoyman and Dingman was conducted in the state of Washington where *V. dahliae* Kleb., the microsclerotial form, is the causal organism of the disease. In Maine, *V. albo-atrum*, the nonmicrosclerotial form, is the pathogen on potato. There may be two reasons for the differences we observed compared with results reported by Hoyman and Dingman: a) difference in fungal species and b) lack of nematodes, which are common in the western potato-growing areas.

The increase in disease induced by *R. solani* observed following the application of aldicarb was not totally unexpected. Many growers began to substitute aldicarb for disulfoton in 1975 because of its greater effectiveness in aphid control. Beginning in 1975, the incidence and severity of the Rhizoctonia disease began to increase; in subsequent years, several growers suffered severe losses. Environmental conditions in 1977 and 1978 were optimal for development of *R. solani* symptoms, and most seed lots provided significant inoculum in the form of sclerotia. Disease severity was reported to be greater in the past 3 yr when compared with 1971 and 1972, which also had optimal conditions for development of aldicarb plus the high degree of seedborne inoculum may be responsible for this observed disease increase. Unconfirmed reports from other potato-growing areas in the eastern United States tend to support this view (R. Cetas and O. Schultz, *personal communications*).

The increase in the Rhizoctonia disease index with aldicarb does not appear to be related to any direct effect on the pathogen or the soil microflora. Two of the disease evaluation categories, sprout and stolon pruning, had higher disease values when comparing aldicarb with the other insecticide treatments. When emergence data were recorded, the seed pieces of nonemerging plants were examined to confirm damage induced by *R. solani*. The increase in Rhizoctonia-affected tubers in the aldicarb-treated plots indicates that some unknown factor or factors were present that favored infection by *R. solani*. This increase in loss of saleable tubers is of major concern because percentage marketable yield is the most important factor to be investigated when studying the effects of *R. solani* on potato.

This study has shown that granular insecticide application, especially aldicarb, decreases the percentage of marketable tubers produced without adversely affecting total yield. Most research reported concerning *Rhizoctonia* does not distinguish between total and marketable yields; therefore, most results do not show the effects *R. solani* has on tuber quality and marketable yield. A more critical evaluation of the direct effect of these insecticides on plant growth should be undertaken. Findings from this and other studies indicate that if Rhizoctonia disease is a problem, some critical decisions may be necessary when selecting an insecticide.

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