EFFICACY OF SOIL FUMIGANTS FOR CONTROL OF VERTICILLIUM WILT OF POTATOES[1]

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ARSTRACT

Soil fumigation with materials containing methyl isothiocyanate, 1, 3-dichloropropene, or trichloronitromethane, alone or in combination, delayed "early maturity disease" symptoms caused by *Verticillium dahliae* Kleb, in potatoes and increased yields. Soil fumigation increased the crop value as much as $818 per acre, depending on the material and rate used when potatoes were grown for two consecutive years following fumigation. With the exception of trichloronitromethane, fall fumigation was as effective or more effective than spring fumigation.

INTRODUCTION

Verticillium dahliae Kleb. incites an "early maturity disease" of potatoes, causing serious reduction in potato yields and quality, in arid regions of the Pacific Northwest (8, 9). Many acres of valuable land in Oregon, Washington and Idaho are heavily infested, making potato production unprofitable. Disease severity is directly proportional to the inoculum density in the soil (9, 6). Soil fumigation for control of Verticillium wilt of potatoes has been shown to delay "early maturity" symptoms and increase yields (2, 3, 4, 8, 10, 11, 12) and is frequently used by potato growers to improve yields on land where Verticillium wilt is a factor limiting production. The experiments reported in this paper were conducted in the early 1960's, but the results are deemed applicable to the current search (2, 4, 10) for a more effective soil fumigant. This research demonstrates the comparative effectiveness of the active components of several soil fumigants and their potential for economic disease control.

METHODS AND MATERIALS

Experiments were conducted on farm land near Klamath Falls, Oregon, which had not been planted with potatoes for more than 10 years because of the severity of Verticillium wilt. The land had been planted in Alsike clover and barley during this period. The soil is classified as Klamath fine sandy loam, has a pH 6.2 and an exchange capacity of 16 meq. per 100 grams oven dry soil.

Prior to application of chemicals, barley stubble was plowed in, and the soil disced and packed with a smooth roller. Liquid soil fumigants were injected into the soil at 6-8 inches depth with a chisel applicator having seven chisels spaced 10 inches apart. The rate of chemical delivery was controlled by variation of applicator air pressure, orifice disc size, and tractor speed. Chemicals evaluated are listed in Table 1. Treatments were applied in the spring, except in one trial where a fall application was made. Plots

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TABLE 1.—*Chemicals tested for control of Verticillium wilt of potatoes.*

Trade Name	Manufacturer	Active Ingredient
DDD	Shell Chemical Co.	1,3-dichloropropene and related C_3 hydrocarbons (1,3-D)
Nemex	Morton Chemical Co.	50% trichloronitromethane (PIC) and 50% 1,3-dichloropropene and related C_3 hydrocarbons (1,3-D)
Picfume	Dow Chemical Co.	trichloronitromethane (PIC)
Telone	Dow Chemical Co.	1,3-dichloropropene (1,3-D)
Trapex	Morton Chemical Co.	15% methyl isothiocynate (MIT)
Vorlex	Morton Chemical Co.	20% methyl isothiocynate (MIT) and 80% 1,3-dichloropropene and related C_3 hydrocarbons (1,3-D)
Vapam	Stauffer Chemical Co.	sodium N-methyl dithiocarbamate (MIT)[1]

[1]Vapam, upon decomposition in the soil, can theoretically yield approximately two pounds methyl isothiocynate per gallon.

were 18 x 50 ft, replicated three times in a randomized block. Six rows of Russet Burbank seed pieces (treated with Semesan Bel) were planted in each plot. Fertilizer application consisted of 1 ton gypsum, 40 lb nitrogen as ammonium nitrate or ammonium sulfate broadcast, and 750 lb of 16-20-0 applied in the row per acre per year. Yield data were taken from the center 30 ft of the two internal rows of each plot. Plots treated and planted were replanted to potatoes the following year to determine carryover effectiveness of the treatments. In one experiment applications made in the fall were compared with those made in the spring. The "crop value" figures given in Tables 2, 3 and 4 were used to reflect the quality of the crop yields. Arbitrary values of $2 per cwt. for U.S. No. 1, $1 per cwt for U.S. No. 2 and $.25 per cwt for cull potatoes were assigned to the graded plot yields.

RESULTS

Experiment A. The purpose of this experiment was to determine the effective rates for chemically different soil fumigants. Vorlex, Vapam, Telone and Picfume delayed development of "early maturity" symptoms and significantly increased potato yields (Table 2). High rates of Telone (64 gpa) and Vorlex (40 and 80 gpa) gave the greatest yield increase. Telone at 22 gpa was as effective as Vapam 20-40 gpa, Picfume 11.4 gpa and Vorlex 20 gpa. Vorlex at 80 gpa delayed emergence of the crop; however, the growing season was almost 3 weeks longer than normal because of the lack of a vine-killing frost, the vines remained green until harvest, and hence, potato yields were increased 260 cwt per acre. The soil nematicide, Telone (22 gpa), which is chemically similar to the 1,3-dichloropropene and related C_3 hydrocarbon component of Vorlex, was as effective as Vapam (20-40 gpa), Picfume (11.4 gpa) and Vorlex (20 gpa). The crop value trends were similar to yields, except there was no increase with Picfume at 5.7 gpa.

The plots were replanted to potatoes the next year and only those fumigated with the high rates of Telone and Vorlex gave a significant carryover yield and crop value response. In the second crop year after

TABLE 2.—*Experiment A. Effectiveness of soil fumigation treatments for control of Verticillium wilt of potatoes as indicated by yield and crop value for 2 years following treatment.*

Fumigant-rate/acre[1]	Total yield — cwt/acre[2] 1st Year	2nd Year	Crop value $/acre[3] 1st Year	2nd Year
None	106 a[5]	109 a	118 a	114 a
Vorlex 20 gal (40 lbs MIT + 160 lbs 1,3-D)[4]	284 cd	188 a	463 bc	260 abc
Vorlex 40 gal (80 lbs MIT + 320 lbs 1,3-D)	353 e	282 b	608 d	442 d
Vorlex 80 gal (160 lbs MIT + 640 lbs 1,3-D)	366 e	296 b	619 d	360 bcd
Vapam 20 gal (40 lbs MIT)	251 bc	171 a	386 bc	214 ab
Vapam 40 gal (80 lbs MIT)	278 cd	139 a	426 bc	143 a
Picfume 5.7 gal (80 lbs PIC)	200 b	146 a	277 a	167 a
Picfume 11.4 gal (160 lbs PIC)	268 cd	192 a	431 bc	276 abc
Telone 22 gal (220 lbs 1,3-D)	249 bc	175 a	376 b	235 abc
Telone 64 gal (640 lbs 1,3-D)	314 de	279 b	517 cd	407 cd

[1]Application was by injection into the soil at 6-8″ depth with a chisel applicator, followed by sealing with a smooth roller.

[2]Yield is based on potatoes harvested from 30 feet of the two center rows of each 18 x 50 foot plot and includes US No. 1, US No. 2 and cull potatoes.

[3]Crop value is based on $2/cwt. for U.S. No. 1, $1/cwt. for U. S. No. 2 and $.25/cwt. for cull potatoes.

[4]Approximate amount of active components.

[5]Values followed by the same letter are not significantly different at the 5% level according to Duncan's Multiple Range Test.

treatment, Vorlex at 40 and 80 gpa gave yield increases of 173 and 187 cwt per acre, respectively, and Telone at 64 gpa increased the yield 170 cwt per acre over the yields in untreated plots. The crop value for 2 years production was increased $818 per acre with 40 gpa of Vorlex and $692 per acre with 64 gpa of Telone.

Experiment B. The purpose of this experiment was to further evaluate the disease control previously obtained with Telone and to evaluate treatments based on plots receiving equal amounts of active chemical ingredients.

Fumigants containing methyl isothiocynate (Vorlex, Vapam and Trapex) or trichloronitromethane (Picfume and Nemex), alone or in combination with 1,3-dichloropropene, delayed "early maturity" and significantly increased yields (Table 3). Telone and DD at 32 gpa did not give a significant yield increase the first year but showed a significant carryover effect during the second crop year. Carryover effectiveness of Telone was outstanding, with a yield increase of 206 cwt per acre for the second crop year. During the first season poor growing conditions prevailed and only Trapex at 54 gpa gave a significant increase in crop

TABLE 3.—*Experiment B. Effectiveness of soil fumigation treatments for control of Verticillium wilt of potatoes as indicated by yield and crop value for 2 years following treatment.*

Fumigant-rate/acre[1]	Total yield — cwt/acre[2] 1st Year	2nd Year	Crop value $/acre[3] 1st Year	2nd Year
None	212 a[5]	194 a	271 a	309 a
Vorlex 20 gal (40 lbs MIT + 160 lbs 1,3-D)[4]	364 cd	382 c	446 ab	606 bc
Vorlex 40 gal (80 lbs MIT + 320 lbs 1,3-D)	328 bcd	378 c	404 ab	555 bc
Trapex 27 gal (40 lbs MIT)	275 abcd	293 abc	403 ab	478 abc
Trapex 54 gal (80 lbs MIT)	372 d	381 c	505 b	676 c
Nemex 11 gal (80 lbs PIC + 55 lbs 1,3-D)	308 abcd	278 abc	401 ab	481 abc
Picfume 5.5 gal. (80 lbs PIC)	267 abc	248 ab	362 ab	400 ab
Picfume 11.0 gal (160 lbs PIC)	357 cd	325 bc	468 ab	417 abc
Vapam 20 gal (40 lbs MIT)	302 abcd	327 bc	440 ab	550 bc
Vapam 40 gal (80 lbs MIT)	360 cd	358 bc	510 ab	559 bc
Telone 16 gal (160 lbs 1,3-D)	242 ab	304 abc	296 a	494 bc
Telone 32 gal (320 lbs 1,3-D)	321 abcd	400 c	471 ab	676 c
D-D 32 gal (320 lbs 1,3-D)	323 abcd	312 bc	446 ab	498 abc

[1]Application was by injection into the soil at 6-8" depth with a chisel applicator, followed by sealing with a smooth roller.

[2]Yield is based on potatoes harvested from 30 ft of the two center rows of each 18 x 50 ft plot and includes US No. 1, US No. 2 and cull potatoes.

[3]Crop value is based on $2/cwt. for U.S. No. 1, $1 cwt. for U.S. No. 2 and $.25/cwt. for cull potatoes.

[4]Approximate amount of active components.

[5]Values followed by the same letter are not significantly different at the 5% level according to Duncan's Multiple Range Test.

value. The crop quality was better the following year, with the high rates of all fumigants except Picfume and DD giving a significant increase in crop value the second crop year.

Experiment C. This experiment was established to compare the effectiveness of fall and spring applications .With the exception of Picfume, fall applications gave greater yield increase than spring applications; however, only fall applications of Telone and DD gave a statistically significant increase in both yield and crop value (Table 4).

DISCUSSION

Soil fumigation with materials having methyl isothiocyanate, 1,3-dichloropropene, or trichloronitromethane as an active component, alone

TABLE 4.—*Experiment C. Effectiveness of Fall and Spring soil fumigation treatments for control of Verticillium wilt of potatoes as indicated by yield and crop value.*

Fumigant-rate/acre[1]	Total yield — cwt/acre[2]		Crop value $/acre[3]	
	Fall	Spring	Fall	Spring
None	234 a[5]	234 a	344 a	344 a
Vorlex 40 gal (80 lbs MIT + 3212 lbs 1,3-D)[4]	296 ab	270 abc	498 ab	442 ab
Vapam 40 gal (80 lbs MIT)	324 ab	320 cd	556 b	532 bc
Picfume 11 gal (180 lbs PIC)	366 b	381 d	610 b	654 c
Telone 32 gal (320 lbs 1,3-D)	359*b	244 ab	498*ab	375 ab
Telone 48 gal (480 lbs 1,3-D)	377*b	303 bc	641*b	418 ab
DD 32 gal (320 lbs 1,3-D)	281*ab	216 a	485*ab	332 a
DD 48 gal (480 lbs 1,3-D)	298 ab	282 abc	507 ab	459 abc

[1]Application was by injection into the soil at 6-8" depth with a chisel applicator, followed by sealing with a smooth roller.

[2]Yield is based on potatoes harvested from 30 ft of the two center rows of each 18 x 50 ft plot and includes US No. 1, US No. 2 and cull potatoes.

[3]Crop value is based on $2/cwt. for U.S. No. 1, $1/cwt. for U.S. No. 2 and $.25/cwt. for cull potatoes.

[4]Approximate amount of active components.

[5]Values followed by the same letter are not significantly different at the 5% level according to Duncan's Multiple Range Test.

or in combination, delayed "early maturity" symptoms of Verticillium wilt of potatoes and increased yields. MIT (Vapam and Trapex) was more effective than PIC (Picfume) at comparable rates of active materials. Materials containing combinations of 1,3D and MIT (Vorlex) or (Nemex) gave highly effective disease control and were more effective than those materials whose active component was MIT (Vapam) or PIC (Picfme) alone. The relatively inexpensive 1,3D fumigants Telone and DD, at rates of 32 gpa or more, gave good control, with Telone generally outperforming DD.

The reduction of wilt severity and increased yields obtained with the nematocides Telone and DD could not be explained on the basis of direct plant parasitic nematode control. Several workers (1, 7, 13, 4) have shown, however, that Verticillium wilt severity of certain host crops is increased when root lesion nematodes are present in the soil. Soil samples taken from the experimental plot area and assayed for plant parasitic nematodes showed a low population of *Pratylenchus spp.*, ranging from 14 to 106 per quart of soil.

Carryover effects were demonstrated when a second crop of potatoes was grown in the test plots. In general, materials containing 1,3-dichloropropene enhanced carryover effectiveness, an added benefit which has been observed by other workers (2, 5, 10). Fall fumigation was as effective as or more effective than spring fumigation.

These trials have shown that soil fumigation will give economic yield increase on land where Verticillium wilt has been the limiting factor in production. The greatest economic return is realized when potatoes are grown two consecutive years following fumigation. The experience of potato growers and other research (unpublished) indicates that crop production can be maintained by supplemental fumigation with low rates (i.e., Telone 20 gpa) prior to planting subsequent potato crops.

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