

FUMIGANTS, RATES, AND FUMIGATION METHODS AFFECTING
VERTICILLIUM WILT CONTROL AND POTATO YIELDS 1/

by
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ABSTRACT

A three year comparison was made between row application by a single shank, either at 9 inches (22.8 cm) or 18-20 inch (45.7-50.8 cm) placement, to a broadcast application (shanks 9 inches deep spaced 9 inches apart) of fumigants for control of Verticillium albo-atrum (microsclerotial type). The row was no more effective than the broadcast method when the same amounts of fumigants were applied calculated on a broadcast basis.

Fumigants (i) DD + Picfume (4:1), (ii) Telone + Picfume (4:1), (iii) Telone C, (iv) Terr-o-cide 30, (v) Terr-o-cide 30D, and (vi) Vorlex at 25 gal per acre (233.8 liters per hectare) gave maximum response as measured by fewer wilted plants and increased yields (120-160 hundred-weight per acre = 134 - 179 quintal per hectare). A rate of 12.5 gal per acre (116.9 liters per hectare) was sometimes effective, while rates above 25 gallons per acre were not advantageous. All fumigant combinations used were equally effective.

A single fumigation of soils infested with Verticillium albo-atrum Reinke and Berth, has increased yield of potatoes for either one or more years (1, 2, 3, 4, 5, 6, 7, 8) however, a comparison of methods of application has not been done.

Application of fumigants in narrow bands in the later developed root zone compared to a broadcast application would possibly conserve fumigant, lower cost per acre, and give equal control. Kunkel and Weller's (4) data showed that there were no significant reductions in yield by fumigating a 24 inch (60.96 cm) strip out of a 36 inch (91.44 cm) row using a mixture of Telone^(R) + Picfume^(R) at 20 + 5 gal/a (187 + 46.7 liters/hectare).

Studies were initiated in 1968 to determine the effect of fumigants, rates, and methods of application on control V. albo-atrum in infested soil and their subsequent effects on potato production.

METHODS AND MATERIALS

The soil in the field selected for the experiments was a Shano silt loam (38% sand, 54% silt and 8% clay). Prior to 1962 it had been cropped to dry land wheat for over 10 years. With the advent of irrigation, the field grew alfalfa in 1962 and 1963. The field was initially infested with V. albo-atrum (microsclerotial type) in 1963 by planting seed pieces of Russet Burbank potato dipped into a suspension of mycelia, conidia, and microsclerotia. Russet Burbank potatoes were grown in the experimental field in 1963, 1964 and 1966 without further intentional infestation of the soil. The 1968 and 1969 experiments followed a wheat crop; potatoes preceded the 1970 test.

1/ Any trade name used in these studies does not constitute either a guarantee or warranty of the product by Washington State University or that the behavior of similar products would be either the same or different from the ones used.

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The soil was prepared prior to fumigation in the spring by chiseling the field both cross-wise and lengthwise with a Glenco Model G chisel plow 13-16 inches deep (33.0-40.6 cm) with the chisels spaced 12 inches apart (30.4 cm) and then plowing 12 inches deep.

The broadcast method of fumigation covered the entire area in and between the 36 inch rows. Spring shanks on a front mounted tractor cultivator bar injected fumigant preplant in bands 9 inches (22.8 cm) deep and 9 inches apart. The soil was packed by a smooth roller immediately after fumigation.

Fumigation by the row method utilized a single straight shank with a 9 inch duckfoot tool. Two tubes mounted on the shank placed the fumigant at the outer under edge of the duckfoot tool to give 2 bands of fumigant preplant 9 inches deep and 9 inches apart (4.5 inches = 11.4 cm from the center of a 36 inch row). Two 8 inch (20.3 cm) covering discs mounted directly behind the shank covered the opening made by the shank in the soil.

Fumigants were applied preplant by the deep shank method in 1 band 18-20 inches deep (45.7-50.8 cm) by a single shank and covered as above.

Fumigants were applied by both the broadcast and row methods in 1968, 1969 and 1970. The deep shank method was included only in 1970.

Six fumigation treatments were used: (i) DD^(R) (1,3-dichloropropene, 1,2-dichloropropane, 3,3-dichloropropane, 2,3-dichloropropene and related C₃ chlorinated hydrocarbons) + Picfume^(R) (trichloromethane), (ii) Telone^(R) (1,3-dichloropropene and related hydrocarbons) + Picfume^(R), (iii) Telone C^(R) (Telone^(R) and Picfume^(R)), (iv) Terr-o-cide 30^(R) (ethylene dibromide and trichloromethane), (v) Terr-o-cide 30D^(R) (1,3-dichloropropene, 1,2-dichloropropane and related chlorinated hydrocarbons + trichloromethane), and (vi) Vorlex^(R) (chlorinated C₃ hydrocarbons and methyl isothiocyanate). Telone + Picfume and Telone C were applied in the 1968, 1969 and 1970 tests; Vorlex was in the 1968 and 1969 but not in the 1970 tests; Terr-o-cide 30 was used in the 1969 and 1970 tests; DD + Picfume and Terr-o-cide 30 D were applied in the 1970 test only. The rates of fumigants used were calculated based on the total area of a 36 inch row and not the portion of the row treated by the method of application. Dates of application were April 11-15, 1968; April 10-16, 1969; and April 1-14, 1970. The mean soil temperatures were measured by a continuously recording Friez Model No. 1100 soil thermograph. Mean temperatures for the 10 day period following fumigation in 1968, 1969, and 1970 at a 6 inch (15.24 cm) depth, were 49F (9.4C), 51F (10.6C) and 48F (8.89C), respectively. Soil moisture at the 2-8 inch (5.08-20.3 cm) depth from the soil surface during the fumigation periods for 1968, 1969 and 1970 was 12, 15 and 12%, respectively. Soil moisture during fumigation in 1970 at the 18-20 inch depth was 16%. A bar suction of 1 and 0.3 of the Shano siltloam soil is about 9 and 16% soil moisture by weight.

All treatments were randomly replicated 6 times in plots 12 ft wide = 3.66 m wide (4 - 36 inch = 0.3 m rows) by 20 ft = 6.1 m long.

The field was fertilized to correct deficiencies shown by standard soil tests. Fertilizer in the forms of ammonium nitrate, treble superphosphate, potassium chloride, and zinc were applied at rates of 400 lb N/a (448 kg N/hectare), 50 lb P/a (115 lb P₂O₅/a = 129 kg P₂O₅/hectare), 250 lb K/a (300 lb K₂O/a = 336 kg K₂O / hectare) and 10 lb Zn/a (11 kg Zn/hectare) was added to the field in 1968. The same rates of fertilizer were added to the field in 1969 and 1970, except that Zn was excluded. The P, K and Zn fertilizer were broadcast prior to plowing, and the N was banded at planting.

Russet Burbank potatoes were planted on May 9, 1968 (23 days after fumigation); May 14, 1969 (28 days after fumigation); and May 8, 1970 (24 days after fumigation). The seed pieces were planted 4-5 inches (10.1-12.7 cm) deep.

Readings for Verticillium wilt were taken from 21-24 plants in a 20 ft row in each plot. The dates of readings were September 9, 1968; September 8, 1969 and September 23, 1970. The plots were harvested on October 7, 1968; October 8, 1969 and October 12, 1970.

RESULTS

Fumigation methods did not significantly differ in their effects on numbers of plants with Verticillium wilt, percent U. S. No. 1 tubers, and yields at either the 12.5 gal/a (116.9 liters/hectare) rate in 1968 and 1969; or at the 12.5, 25 (233.8 liters/hectare), 37.5 (350.7 liters/hectare) and 50 (467.6 liters/hectare) gal/a rates in 1970 (Table 1).

Plots fumigated with Vorlex had statistically more Verticillium wilted plants in 1968 and 1969 than Telone + Picfume, but not more than either Telone C or Terr-o-cide 30 (Table 1). None of the fumigants affected Verticillium wilt in 1970 (Table 1). All of the fumigants were equal in their effects on the percent of U. S. No. 1 tubers and yields.

Plots fumigated with 25 gal/a in 1968, 25 and 37.5 gal/a in 1969 and 25.0, 37.5 and 50 gal/a in 1970 had significantly less Verticillium wilt than plots not fumigated (Table 1). Only the rates of 37.5 gal/a in 1969 and 50 gal/a in 1970 increased percent of U. S. No. 1 tubers significantly more than the not fumigated treatment. Yields from plots fumigated with 12.5 and 25.0 gal/a in 1968; 18.75 (175.4 liters/hectare), 25.0 and 37.5 gal/a in 1969; and 12.5, 25.0, 37.5 and 50 gal/a in 1970 were significant compared to the not fumigated plots. The 25 gal/a rate produced significantly more yield than the 12.5 gal/a rate in 1968 and 1969, but not in 1970. Yields from plots treated with rates above 25 gal/a were not significantly different in 1969 and 1970.

DISCUSSION

The data show that applying fumigants at lower rates (below 12.5 - 25.0 gal/a) in localized areas by either row or deep shank methods did not control V. albo-atrum (Table 1). Evidently, these methods did not conserve fumigant by retaining it in a concentrated zone of protection against root infection by V. albo-atrum. No doubt the fumigant moved spherically from the point of injection throughout our soil and was not retained in any special zone whether placed 9 inches or 18-20 inches in depth.

Disadvantages to the row and deep shank methods of fumigation are the necessity of pre-plant premarking the field for application and difficulty in the later planting of potatoes in the treated areas. The deep shank method also required additional tractor power.

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Table 1. Effect of fumigants, rate of fumigants, and method of fumigation on Verticillium wilt control and yield in 1968, 1969 and 1970^{1/}.

1968

A. Effect of methods of application at 12.5 gal/a^{2/}

	<u>Broadcast</u>	<u>Row</u>
Vert. wilt ^{3/} (plants)	20 a ^{4/}	18 a
% U. S. No. 1	53 a	57 a
cwt/a	552 a	544 a

B. Effect of fumigants

	<u>Telone + Picfume (4:1 ratio)</u>	<u>Telone C</u>	<u>Vorlex</u>
Vert. wilt ^{3/} (plants)	16 b	19 ab	20 a
% U. S. No. 1	58 a	55 a	55 a
cwt/a	566 a	566 a	537 a

C. Effect of rates of fumigants (gal/a)

	<u>0</u>	<u>6.25</u>	<u>12.5</u>	<u>25.0</u>
Vert. wilt ^{3/} (plants)	22 a	23 a	19 a	13 b
% U. S. No. 1	57 a	56 a	55 a	58 a
cwt/a	493 c	523 bc	552 b	617 a

(Table continued)

Table 1 (continued)

1969A. Effect of methods of application at 12.5 gal/a ^{2/}

	<u>Broadcast</u>	<u>Row</u>
Vert. wilt ^{3/}	17 a	17 a
% U.S. No. 1	76 a	75 a
cwt/a	486 a	486 a

B. Effect of fumigants.

	<u>Telone + Picfume (4:1 ratio)</u>	<u>Telone C</u>	<u>Terr-o-cide 30</u>	<u>Vorlex</u>
Vert. wilt ^{3/} (plants)	12 b	14 ab	14 ab	16 a
% U. S. No. 1	79 a	78 a	75 a	74 a
cwt/a	573 a	522 a	493 a	529 a

C. Effect of rates of fumigants (gal/a)

	<u>0</u>	<u>6.25</u>	<u>12.5</u>	<u>18.75</u>	<u>25.0</u>	<u>37.5</u>
Vert. wilt ^{3/} (plants)	18 ab	19 a	17 ab	14 bc	11 c	6 d
% U. S. No. 1	76 ab	73 b	75 ab	76 ab	78 ab	80 a
cwt/a	436 d	436 d	486 cd	530 bc	595 ab	653 a

(Table continued)

Table 1 (continued)

1970A. Effect of methods of application at 12.5, 25, 37.5 and 50 gal/a^{2/}.

	<u>Broadcast</u>	<u>Row</u>	<u>Deep Shank</u>
Vert. wilt ^{3/} (plants)	13 b	18 a	16 ab
% U.S. No. 1	43 a	39 a	44 a
cwt/a	523 a	494 a	494 a

B. Effect of fumigants

	<u>DD + Picfume (4:1 ratio)</u>	<u>Telone + Picfume (4:1 ratio)</u>	<u>Telone C</u>	<u>Terr-o-cide 30</u>	<u>Terr-o-cide 30D</u>
Vert. wilt ^{3/} (plants)	15 a	15 a	17 a	15 a	15 a
% U. S. No. 1	42 a	42 a	41 a	42 a	44 a
cwt/a	508 a	530 a	501 a	494 a	508 a

C. Effect of rates of fumigants (gal/a)

	<u>0</u>	<u>12.5</u>	<u>25.0</u>	<u>37.5</u>	<u>50.0</u>
Vert. wilt ^{3/} (plants)	21 c	20 c	16 b	13 ab	12 a
% U. S. No. 1	33 c	36 bc	41 a-c	45 ab	47 a
cwt/a	385 b	465 a	523 a	523 a	515 a

^{1/}Statistical summary of data in Tables 1, 2 and 3 of Appendix.^{2/}Broadcast = injection 9 inches deep and 9 inches apart; row = injection in 2 bands 9 inches deep and 4.5 inches from center of a 36 inch wide row.^{3/}Readings taken on September 9, 1968, September 8, 1969, and September 23, 1970 of about 20 plants of a 20-ft. row in each plot.^{4/}Means followed by the same letter of the alphabet are not significantly different at the 5% level according to Duncan's Multiple Range and Individual Degrees of Freedom Tests.

APPENDIX

Table 1. Effect of fumigants, rate of fumigants, and method of fumigation on Verticillium wilt control and potato production in 1968.

Fumigants	Gal/a ^{1/}	Methods of fumigation ^{2/}					
		Broadcast			Row		
		Vert wilt ^{3/} (plants)	% U.S.No. 1	cwt/a	Vert wilt ^{3/} (plants)	% U.S.No. 1	cwt/a
Telone + Picfume (4:1)	25.0	9 e ^{4/}	59 a	631 a	--	--	--
	12.5	19 b-d	57 a	559 b	17 cd	64 a	566 b
	6.25	-- ^{5/}	--	--	21 a-c	52 a	515 b-d
Telone C	25.0	15 d	56 a	646 a	--	--	--
	12.5	21 a-c	53 a	537 bc	19 b-d	53 a	544 bc
	6.25	--	--	--	22 ab	56 a	529 b-d
Vorlex	25.0	15 d	57 a	566 b	--	--	--
	12.5	20 a-c	50 a	551 bc	19 b-d	54 a	529 b-d
	6.25	--	--	--	24 a	60 a	515 b-d
Not fumigated	None	22 ab	57 a	493 d	22 ab	57 a	493 d

^{1/} All rates calculated on a broadcast basis.

^{2/} Broadcast = injection 9 inches deep and 9 inches apart; row = injection in 2 bands 9 inches deep and 4.5 inches from center of a 36 inch wide row.

^{3/} Readings taken on September 9, 1968 of about 24 plants from a 20-ft row in each plot.

^{4/} Means followed by the same letter in the alphabet are not significantly different at the 5% level according to Duncan's Multiple Range and Individual degrees of Freedom Tests.

^{5/} Not determined.

Table 2. Effect of fumigants, rate of fumigants, and method of fumigation on Verticillium wilt and potato production in 1969.

Fumigants	Gal/a ^{1/}	Method of fumigation ^{2/}					
		Broadcast			Row		
		Vert. wilt ^{3/} (plants)	U.S. No. 1 cwt/a	U.S. No. 1 cwt/a	Vert. wilt ^{3/} (plants)	% U.S. No. 1	cwt/a
Telone + Picfume (4:1)	37.5	2 h ^{4/}	78 b-f	719 a	--	--	--
	25.0	8 f-h	80 a-d	661 ab	--	--	--
	18.75	-- 5/	--	--	14 b-e	75 c-g	537 c-f
	12.5	15 a-e	80 a-d	537 c-f	17 a-c	79 a-e	515 d-h
	6.25	--	--	--	20 a	77 b-g	494 d-i
Telone C	37.5	5 g-h	85 a	632 a-c	--	--	--
	25.0	11 ef	82 ab	581 b-e	--	--	--
	18.75	--	--	--	14 b-e	75 c-g	523 c-g
	12.5	18 ab	79 a-e	501 d-i	18 ab	71 fg	472 e-i
	6.25	--	--	--	19 a	72 e-g	421 hi
Terr-o-cide 30	37.5	5 gh	81 a-c	675 ab	--	--	--
	25.0	13 c-e	74 d-g	574 b-e	--	--	--
	18.75	--	--	--	12 d-f	77 b-g	574 b-e
	12.5	19 a	72 e-g	428 g-i	16 a-d	74 d-g	508 d-h
	6.25	--	--	--	18 ab	70 g	436 f-i

(Table continued)

Table 2(continued)

Fumigants	Gal/a ^{1/}	Methods of fumigation ^{2/}					
		Broadcast			Row		
		Vert wilt ^{3/} (plants)	% U.S.No.1	cwt/a	Vert wilt ^{3/} (plants)	% U.S. No.1	cwt/a
Vorlex	37.5	11 ef	74 d-g	588 b-d	--	--	--
	25.0	15 a-e	77 b-g	559 b-e	--	--	--
	18.75	--	--	--	16 a-d	76 b-g	494 d-i
	12.5	17 a-c	71 fg	479 e-i	19 a	74 d-g	443 f-i
	6.25	--	--	--	19 a	71 fg	407 i
Not fumigated	none	19 a	76 b-g	436 f-i	19 a	76 b-g	436 f-i

^{1/} All rates calculated on a broadcast basis.

^{2/} Broadcast = injection 9 inches deep and 9 inches apart; row = injection in 2 bands 9 inches deep and 4.5 inches from center of a 36 inch wide row.

^{3/} Readings taken on September 8, 1969 of about 24 plants from a 20-ft row in each plot.

^{4/} Means followed by the same letter of the alphabet are not significantly different at the 5% level according to Duncan's Multiple Range and Individual Degrees of freedom Tests.

^{5/} Not determined.

Table 3. Effect of fumigants, rate of fumigants, and method of fumigation on Verticillium wilt and potato production in 1970.

Fumigants	Method of fumigation ^{2/}										
	Broadcast					Row					Deep Shank
	Gal/a ^{1/}	Vert wilt ^{3/} (plants)	U. S. No. 1	%	cwt/a	Vert wilt ^{3/} (plants)	U. S. No. 1	%	cwt/a	Vert wilt ^{3/} (plants)	U. S. No. 1
DD + Picfume (4:1)	50.0	10 a-c ^{4/}	51 a-d	515 b-h	14 a-c	44 b-h	522 b-h	10 a-c	51 a-d	508 b-i	
	37.5	6 c	43 b-i	551 a-e	15 a-c	47 b-f	493 c-j	14 a-c	46 b-g	493 c-j	
	25.0	15 a-c	43 b-i	551 a-e	20 a	33 i-l	486 c-k	17 a-c	41 c-j	537 b-f	
	12.5	20 a	35 g-l	529 b-g	20 a	34 h-l	428 j-l	20 a	37 f-k	450 h-l	
Telone + Picfume (4:1)	50.0	10 a-c	46 b-g	566 a-c	15 a-c	43 b-i	522 b-h	11 a-c	47 b-f	486 c-k	
	37.5	10 a-c	41 c-j	580 ab	13 a-c	44 b-h	559 a-d	16 a-c	53 ab	537 b-f	
	25.0	11 a-c	43 b-i	624 a	19 ab	39 e-k	493 c-j	17 a-c	45 b-g	515 b-h	
	12.5	19 ab	37 f-k	486 c-k	20 a	32 j-l	500 b-i	18 a-c	37 f-k	471 e-k	
Telone C	50.0	9 a-c	48 a-f	515 b-h	17 a-c	35 g-l	508 b-i	15 a-c	59 a	529 b-g	
	37.5	12 a-c	40 d-k	515 b-h	17 a-c	38 f-k	529 b-g	18 a-c	42 b-j	500 b-i	
	25.0	15 a-c	46 b-g	559 a-d	20 a	40 d-k	508 b-i	19 ab	39 e-k	508 b-i	
	12.5	21 a	31 j-l	421 k-l	20 a	31 j-l	450 h-l	20 a	39 e-k	457 g-k	

(Table continued)

Table 3 (continued)

Fumigants	Method of Fumigation ^{2/}												
	Broadcast					Row					Deep Shank		
	Gal/a ^{1/} (plants)	U.S.No. 1	%	Vert ₃ / wilt ₃ / (plants)	cwt/a	U.S.No. 1	%	Vert ₃ / wilt ₃ / (plants)	cwt/a	U.S.No. 1	%	U.S.No. 1	cwt/a
Terr-o-cide 30	50.0	10 a-c	45 b-g	471 e-k	16 a-c	46 b-g	500 b-i	2 c	35 g-1	486 c-k			
	37.5	10 a-c	43 b-i	522 b-h	18 a-c	41 c-j	471 e-k	6 c	52 a-c	508 b-i			
	25.0	10 a-c	40 d-k	551 a-e	20 a	38 f-k	471 e-k	18 a-c	45 b-g	457 g-k			
	12.5	20 a	42 b-j	522 b-h	21 a	37 f-k	457 g-k	19 ab	40 d-k	457 g-k			
Terr-o-cide 300	50.0	7 bc	51 a-d	544 a-f	16 a-c	48 a-f	544 a-f	11 a-c	50 a-c	522 b-h			
	37.5	11 a-c	50 a-e	551 a-e	13 a-c	45 b-g	515 b-h	14 a-c	50 a-e	529 b-g			
	25.0	13 a-c	46 b-g	537 b-f	18 a-c	38 f-k	479 d-k	15 a-c	47 b-f	515 b-h			
	12.5	20 a	38 f-k	435 i-l	20 a	34 h-1	486 c-k	19 ab	33 i-1	471 f-k			
Not fumigated ^{5/}	None	21 a	36 g-1	392 1	21 a	27 j-1	377 1	21 a	35 g-1	377 1			

^{1/}All rates calculated on a broadcast basis.

^{2/}Broadcast = injection 9 inches deep and 9 inches apart; row = injection in 2 bands 9 inches deep and 4.5 inches from center of a 36 inch wide row; and deep shank = injection with by one shank 18-20 inches deep in the center of a 36 inch wide row.

^{3/}Readings taken on September 23, 1970 of about 24 plants from a 20-ft row in each plot.

^{4/}Means followed by the same letter of the alphabet are not significantly different at the 5% level according to Duncan's Multiple Range and Individual Degrees of Freedom Tests.

^{5/}Method of fumigation applied but no fumigant injected.