1964-1965 SOIL FUMIGATION RESULTS ON VERTICILLIUM WILT CONTROL

Gene D. Easton[1/]

Introduction

Kunkel (1960, 1963) in Washington and Powelson (1960, 1962 and 1963) in Oregon reported significant yield increases 1, 2 and even 3 summers after Verticillium wilt soils were fumigated. Both of these workers conducted their experiments in soils which produced very low yields years prior to fumigation. These low yields were attributed to high infestation by the Verticillium wilt organism.

During the past three years, the cooperative research program of the Washington State Potato Commission and Washington State University on the control of Verticillium albo atrum R. and B. and Rhizoctonia solani Kuhn. has been greatly expanded. Research has been directed toward answering some of the following questions:

(1) Will fumigation increase yields on Verticillium wilt organism infested soil in Washington? (2) Does nitrogen fertilization in conjunction with soil fumigation affect wilt control? (3) Are fumigants applied in the fall as effective as those applied in the spring? (4) Does doubling the fumigation rates affect phytotoxicity, wilt control, and potato production?

History of Experimental Soils Prior to Fumigation

The field selected for the experiment near Prosser (infested soil, table 1) had raised potatoes for several years prior to fumigation in the spring of 1963 and was naturally infested with the Verticillium wilt organism. In 1963, Verticillium wilt was moderately severe in all of the control plots and the yield was only 268 cwt./A.

In 1963, soil near the Othello Research Farm (infested soil, table 1) was artificially infested with the Verticillium wilt organism. Infestation was accomplished by planting potato seed pieces which had been dipped in a suspension of the organism. Wilt symptoms the first season after inoculation (1963) were not too prominent but by 1964 symptoms were evident and some sclerotia (resting stage of the organism) were present in the stems. The yield in 1964 was 530 cwt./A. This artificially infested soil was fumigated in the spring of 1964.

The second field utilized for experiments near the Othello Research

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1/ Assistant Plant Pathologist, Department of Plant Pathology, Washington State University Irrigated Agriculture Research and Extension Center, Prosser, Washington.

Farm (virgin soil, table 1) was fumigated in the spring of 1964. This soil had never grown a crop of potatoes. From dry land, this soil had been planted to a grain nurse crop for 1 year and then to alfalfa for 3 years. Soil from a field to the west infested with the Verticillium wilt organism in 1963 was blown over this field in the spring of 1964 during time of fumigation. In the falls of 1964 and 1965, Verticillium wilt symptoms, but no sclerotia were seen on plants in the control plots. In 1964, Verticillium wilt was not severe in these plots and the yield was 515 cwt./A.

The soils in the two experiments at the Othello Research Farm used for experiments concerning fumigation and fertilization (tables 3, 4, 5 and 6) and fall versus spring fumigation (tables 7 and 8) were artificially inoculated with the Verticillium wilt organism in 1963. Wilt symptoms appeared later in the fall of that year and in 1964. The soil fumigants were applied in the fall of 1964 or the spring of 1965. In 1965, the Verticillium wilt disease in the control plots was moderate and the mean yield was 334 cwt./A.

Fields on farms at Toppenish (W. S. Parrish), Badger (Balcom and Moe) and Othello (P. J. Taggares), Washington were fumigated in the spring of 1965 (table 2). The fields at Toppenish and Othello had previously grown potatoes in 1964 and yields were low due to Verticillium wilt. The field at Badger had been in a sweet corn-potato rotation for several years. In 1964 the field was planted to sweet corn. Verticillium wilt was reported to have been present in the previous potato crop.

Results

Will fumigation increase production? --Some of the more effective fumigant combinations such as DD+ chloropicrin (30 + 2.5 gal./A.), M-2467 (propargyl bromide + Vidden D) at 30 gal./A., M-2467 + chloropicrin (30 + 2.5 gal./A.), Telone + chloropicrin (30 + 2.5 gal./A.) and Telone PBC (Telone + propargylbromide) + chloropicrin (30 gal./A.) significantly increased the total yield the first growing season but not the second season after spring fumigation of infested soil (table 1). Fumigants applied alone, such as DD, Telone and Vorlex at 30 gal./A., did not significantly increase the yeild in either year. Evidently, there was no residual effect from any of the fumigation treatments. In general, Verticillium wilt symptoms were delayed where the fumigation treatments significantly increased yield, but the organism was not eradicated since Verticillium microsclerotia were present in stems from treated plots.

The yield of potatoes grown on spring fumigated virgin soil, not artificially infested with the organism, was not statistically increased the first or second growing season after application (table 1). Verticillium wilt symptoms, probably due to wind contamination of the soil, were not severe in 1964. In 1964, at Pasco, Washington, (unpublished

data) yields were also not increased on fumigated soils. In this experiment Verticillium wilt symptoms were just beginning to appear when the crop was harvested.

The same rates of fumigants were applied to commercial fields at Othello, Badger and Toppenish, Washington (table 2). Although Verticillium wilt was present at all locations, a significant yield response occurred only at Badger and only to Telone (30 gal./A.).

The greatest increases from fumigation are expected to occur when (1) the Verticillium wilt infestation is very high, (2) the potatoes are planted early and harvested late, and (3) the highest cultural standards are maintained, such as adequate fertilization, irrigation, insect control and weed control. Evidently, any factor which delays or shortens normal growth also lessens the yield response from fumigation.

Do nitrogen fertilization and fumigation interact to affect production? -- In 1964 and 1965, the addition of 50 to 300 lbs. N per acre, banded at planting to Verticillium wilt infested soil, with or without fumigation, significantly increased the yield and the number of tubers, compared to controls not receiving nitrogen (tables 3A and 3B, 4A and 4B, 5A and 5B, and 6A and 6B). In both years nitrogen treatments were supplemented with phosphorus, potassium and zinc to nulify any deficiencies of these elements. No deficiency symptoms other than those due to nitrogen were noted in any of the plants in the experiment.

Fumigation with Telone + chloropicrin significantly increased the yield and number of tubers even more compared to nonfumigated treatments where only nitrogen was applied (tables 3B, 4B, 5B and 6B). Fumigation with Telone alone did not increase the total yield or total number of tubers (tables 3A, 4A, 5A and 6A).

Are fumigants applied in the fall as effective as those applied in the spring? -- Fumigants enter the ground as liquids through chisels to depths of 9 to 10 inches. Most of the fumigants are volatile above 50°F and change to a gas which moves through the soil. Nematodes and soil-borne disease organisms may be killed by these volatile fumigants. If the soil becomes too cold in the fall, the fumigants might remain as liquids, be leached by moisture and become ineffective. Early fall fumigation is generally impossible because of harvesting the existing crops. Crop residues which have not broken down also may reduce the effectiveness of fumigants applied in the fall.

Fumigation done 3 to 4 weeks before planting possibly would be the most effective. In a cold early spring with soil temperatures below 50°F., however, fumigation should be delayed. Planting too soon after fumigation in the spring may cause phytotoxicity.

Rates of fumigants were applied on October 22, 1964 and again on

April 22, 1965. Planting was delayed 29 days after the time of spring fumigation. No stunting or abnormal growth (other than Verticillium wilt symptoms) was observed in any plot throughout the growing season. Statistical tests of paired spring or fall fumigation treatments indicated that differences between time of applications were due to chance alone and were not significant (table 7). Evidently, almost 1 month's delay of planting after fumigation in the spring reduced all phytotoxic effect.

There was a difference in yield between individual fumigation treatments (table 7). Telone + chloropicrin (20 + 5 gal.), Vidden D + chloropicrin (20 + 5 gal./A.) and Vorlex (45 gal./A.) applications produced significantly higher total yields than the control.

Does doubling the fumigation rates affect phytotoxicity, wilt control and potato production? -- Doubled rates of fumigants were applied in the fall and spring to determine what effect there would be on phytotoxicity and production. Planting was delayed until 29 days after the spring fumigations. No plant stunting or abnormal growth (other than Verticillium wilt symptoms) was observed. Statistical tests of paired spring or fall fumigation treatments indicated that differences between time of applications were due to chance alone and were not significant. (table 8).

There was a difference in yield between individual fumigation treatments (table8). Telone + chloropicrin (40 + 10 gal./A.), Vidden D + chloropicrin (40 + 10 gal./A.), Telone PBC (90 gal./A.) and Vorlex (90 gal./A.) produced significantly higher total yields than the control.

Doubling the rates of fumigants (table 8) did not in general increase total yield above the single rates (table 7).

Summary

1. In general, yield was increased about 100 cwt./A. by spring application of the more effective fumigants used in these experiments the first growing season after fumigation but not the second season. Verticillium wilt symptoms were delayed by fumigation.

2. Fumigation of soils which had never raised potatoes did not give a yield response.

3. Yields, in general, were not increased when Verticillium wilt infested, commercial fields were fumigated. Factors such as poor weed control, late planting, early frost or low incidence of the wilt organism may explain the poor response from fumigation.

4. The application of nitrogen (ammonium nitrate) to Verticillium wilt infested soil, with and without fumigation, significantly increased yield and the total number of tubers, compared to controls receiving

no nitrogen. Fumigation with Telone + chloropicrin increased the yield and the number of tubers even greater than nonfumigated treatments where only nitrogen was applied, while fumigation with Telone alone did not increase yield.

5. There was no phytotoxicity or differences in total yield between fall and spring fumigation of Verticillium wilt infested soil when planting was delayed 29 days after fumigation in the spring.

6. Doubling the rates of fumigants applied to Verticillium wilt infested soil did not cause phytotoxicity or reduce yield compared to the nonfumigated control and single rate of each fumigant.

Conclusion

Washington State University does not yet recommend the use of any fumigant for control of Verticillium wilt. Research will be continued to determine if promising fumigants are sufficiently effective, economical, and safe for use in potato production.

Table 1. Effect on total yield of potatoes one and two growing seasons after spring fumigation of Verticillium wilt infested soil and virgin soil.

Fumigants	Gal./A.	Yield (cwt./A.) Prosser (Infested Soil) 1963	Prosser (Infested Soil) 1964	Othello (Infested Soil) 1964	Othello (Infested Soil) 1965	Othello (Virgin Soil) 1964	Othello (Virgin Soil) 1965
DD	30	318	268	569	392	-	-
DD + chloropicrin	30 + 2.5	375*	261	-	-	-	-
" "	20 + 5	-	-	600	457	-	-
M-2467 (Propargyl bromide + Vidden D)	30	360*	303	607*	428	-	-
M-2467 + chloropicrin	30 + 2.5	379*	296	-	-	-	-
Telone PBC (Telone + chloropicrin + Propargyl bromide)	30	-	-	623*	421	-	-
Telone	30	234	213	530	378	576	450
Telone + chloropicrin	30 + 2.5	410*	310	-	-	-	-
" "	20 + 5	-	-	515	385	607	407
Vorlex	30	318	289	584	414	600	428
Control	none	268	234	530	392	515	349

*Values significantly greater than the control.

Table 2. The effect of spring fumigation of Verticillium wilt infested commercial fields at 3 locations in Washington

Fumigant	Gal per acre	Toppenish Mean Vert. wilt (22-25 total plants)	Toppenish Mean tuber wt. (cwt. /A.)	Badger Mean Vert. wilt (22-25 total plants)	Badger Mean tuber wt. (cwt. /A.)	Othello Mean Vert. wilt (22-25 total plants)	Othello Mean tuber wt. (cwt. /A.)
Telone	30	5*	400	5*	523*	5	315
Telone	45	5*	384	3*	449	2	307
Telone + chloropicrin	20 + 2.5	3*	346	3*	482	3	338
Vidden D	30	6*	407	4*	506	4	346
Vidden D	45	7*	392	5*	474	4	346
Vidden D + chloropicrin	20 + 2.5	5*	407	3*	449	5	323
Control	none	11	338	10	457	2	307

*Values significantly different from the control.

Table 3. The effect of soil fumigation and nitrogen on yield (cwt./A.) at Othello, Washington in 1964.
(Verticillium wilt infested soil)

Lbs. N per acre	Mean Total Weight (cwt./A.) No fumigation	Telone (45 gal./A.)	Means
A. Control versus Telone fumigation			
0	178	223	200
100	400	415	407*
200	392	492	442*
300	469	461	465*
Means	359	397	
B. Control versus Telone and chloropicrin fumigation		(20 + 3 gal./A.)	
0	178	208	193
100	400	492	446*
200	392	530	461*
300	469	561	515*
Means	359	447*	

*Values significantly higher than control (no ammonium nitrate).

Table 4. The effect of soil fumigation and nitrogen on number of tubers at Othello, Washington in 1964. (Verticillium wilt infested soil)

Lbs. N per acre	Mean Total Number of Tubers		
	No fumigation	Telone (45 gal./A.)	Means
A. Control versus Telone fumigation			
0	106	101	103
100	165	153	159*
200	151	172	161*
300	138	167	152*
Means	140	148	
B. Control versus Telone and chloropicrin fumigation		Telone + chloropicrin (20 + 3 gal./A.)	
0	106	103	104
100	165	193	179*
200	151	196	173*
300	138	176	157*
Means	140	167*	

*Values significantly higher than control (no ammonium nitrate).

Table 5. The effect of soil fumigation and nitrogen on yield (cwt. /A.) at Othello, Washington in 1965. (Verticillium wilt infested soil)

Lbs. N per acre	Mean Total Weight (cwt. /A.) No fumigation	Telone (30 gal. /A.)	Means
A. Control versus Telone fumigation			
0	94	109	102
50	210	203	207*
150	334	399	367*
Means	212	237	

*Values significantly higher than control (no ammonium nitrate).

B. Control versus Telone and chloropicrin fumigation		Telone & chloropicrin (20 & 5 gal. /A.)	
0	94	174	134
50	210	261	236*
150	334	421	378*
Means	212	285*	

*Values significantly higher than controls (no ammonium nitrate and no fumigation).

Table 6. The effect of soil fumigation and nitrogen on number of tubers at Othello, Washington in 1965. (Verticillium wilt infested soil).

Lbs. N per acre	Mean Total Number of Tubers		
	No fumigation	Telone (30 gal./A.)	Means
A. Control versus Telone fumigation			
0	52	60	56
50	107	99	103*
150	120	140	130*
Means	93	100	

*Values significantly higher than the control (no ammonium nitrate).

B. Control versus Telone and chloropicrin fumigation		Telone & chloropicrin (20 & 5 gal./A.)	
0	52	91	72
50	107	115	111*
150	120	148	134*
Means	93	118*	

*Values significantly higher than controls (no ammonium nitrate and no fumigation).

Table 7. The effect of fall versus spring fumigation of infested soil on Verticillium wilt and yield at Othello, Washington.

Fumigants	Gal. per acre	Time of fumigation	Mean% Vert. wilt (plants) Sept. 1	Mean yield, 1/ cwt./A.
Telone	45	Spring	12	421
"	45	Fall	14	348
Telone & chloropicrin	20 & 5	Spring	5 2/	443 2/
" "	20 & 5	Fall	7	407
Telone PBC	45	Spring	11	407
" "	45	Fall	11	413
Vidden D	45	Spring	19	298
"	45	Fall	16	356
Vidden D & chloropicrin	20 & 5	Spring	11	428 2/
" "	20 & 5	Fall	11	370
Vorlex	45	Spring	9	413
"	45	Fall	11	428 2/
Control	none	--	15	334

1/ Statistical tests of yields indicated that differences between fall and spring application were due to chance alone and were not significant.

2/ Values significantly different from the control.

Table 8. The effect of doubling the rates of fumigants applied in fall and spring to infested soil on Verticillium wilt and yield at Othello, Washington

Fumigants	Gal. per acre	Time of fumi-gation	Mean% Vert. wilt (plants) Sept. 1	Mean yield,[1] cwt./A.
Telone	90	Spring	15	378
"	90	Fall	11	421
Telone & chloropicrin	40 & 10	Spring	6[2]	443[2]
" "	40 & 10	Fall	10	407
Telone PBC	90	Spring	4[2]	457[2]
" "	90	Fall	9	356
Vidden D	90	Spring	16	356
"	90	Fall	15	328
Vidden D & chloropicrin	40 & 10	Spring	4[2]	450[2]
" "	40 & 10	Fall	7	413
Vorlex	90	Spring	4[2]	436[2]
"	90	Fall	11	399
Control	none	--	15	334

1/ Statistical tests of yields indicated that differences between fall and spring application were due to chance alone and were not significant.

2/ Values significantly different from the control.