Control of Fusarium Wilt of Tomato with Lime and Soil Fumigants

John Paul Jones and A. J. Overman

Plant Pathologist and Associate Nematologist, respectively, Agricultural Research and Education Center, Bradenton, Florida 33505.

Florida Agricultural Experiment Stations Journal Series Paper No. 3886.

Accepted for publication 1 July 1971.

ABSTRACT

Adjusting the soil pH from 6.0 to 7.0 or 7.5 reduced the incidence of Fusarium wilt of tomato caused by *Fusarium oxysporum* f. sp. *lycopersici* race 2, and increased total tomato fruit yields. The incidence of wilt was less, and yields were greater at a soil pH of 7.5 than at 7.0. Both Vorlex (methylisothiocyanate + D-D) and a 3:2 mixture of chloropicrin and D-D (mixture of 1,3-dichloropropene, 1,2-dichloropropane, and related hydrocarbons) at 35 gal/acre (327 liters/hectare) and 60 gal/acre 561 liters/hectare), respectively, gave excellent wilt control and yield responses. The chloropicrin + D-D mixture was phytotoxic and delayed maturity, especially at pH 6.0, although yields were markedly increased.

Increasing the soil pH to 7.0 or 7.5 increased yields as much as either fumigant at pH 6.0. However, the combination of fumigation plus increased pH increased yields as much as 72%, as compared to unfumigated, unlimed plots at pH 6.0. Phytopathology 61:1415-1417.

Several workers (2, 3, 6, 11, 12) have demonstrated control of Fusarium wilt of tomato (*Lycopersicon esculentum* Mill.), incited by *Fusarium oxysporum* (Schlecht.) f. sp. *lycopersici* (Sacc.) Snyd. & Hans. races 1 and 2, by elevating the soil pH. Broad-spectrum soil fumigants also have been proven to control Fusarium wilt (1, 4).

The test reported herein was designed to determine the effect and interaction of three soil pH levels and two soil fumigants upon the development of Fusarium wilt of tomato.

MATERIALS AND METHODS.–A split plot design was used; whole plots were soil pH levels, and subplots were fumigants. Each whole plot consisted of three 50-foot rows each containing 33 staked tomato plants of the Florida Agricultural Experiment Station breeding line 2153-D5-D1-1-BGBk. This line, being developed for mechanical harvest, is highly productive and has a concentrated early fruit set.

The soil type was Leon fine sand with a cation exchange capacity of 3.5 meq/100 g, an organic matter content of 2.5% and contains 2.5% clay and silt and 95.0% sand. The field had been artificially infested with *F. oxysporum* f. sp. *lycopersici* race 2, 2 years previously (6), and was planted to tomatoes each season thereafter.

Using the methods described by Jones & Woltz (6), we established whole plots of pH 6.0, 7.0, and 7.5. Hydrated lime [$Ca(OH)_2$] was used to adjust to pH 7.0 and 7.5, and elemental sulfur was used to adjust to pH 6.0. Gypsum ($CaSO_4$) was added to the pH 6.0 and 7.0 plots to adjust the soil calcium levels to that of the pH 7.5 plots.

One row of each whole plot was fumigated with 35 gal/acre (327 liters/hectare) of Vorlex (methylisothiocyanate 20% + D-D 80%), one row with 60 gal/acre (561 liters/hectare) of a 3:2 chloropicrin + D-D (mixture of 1,3-dichloropropene, 1,2-dichloropropane, and related hydrocarbons) mixture, and one row was not fumigated. All plots were covered immediately after fumigation with 1.5 ml black, polyethylene plastic film, and were set with tomato seedlings 2 weeks later (27 February). Soil temperature at the time of fumigation was 11 C at a 10.2-cm depth. Both fumigants were injected 15.2 cm into the soil with three chisels set on 20.3-cm centers. In general, the fumigation and fertility practices were those described by Jones et al. (4).

All stakes used in both fumigated and nonfumigated plots were steamed 4 hr at 93.5 C to eradicate *F. oxysporum* f. sp. *lycopersici* race 2 (6).

Soil pH determinations were made 13 February, 25 March, and 19 May, using the glass electrode method (9). The calcium content of the soil and of recently matured leaves was determined 19 May using standard flame photometer procedures (10).

The conversion of ammonium-N to nitrate-N was measured 25 March and 16 May as an estimate of the time microbial activity resumed in the fumigated soil. Soil samples were taken from fumigated and nonfumigated plots, amended in the laboratory with ammonium sulfate (2.8 mg/100 g soil), and calcium carbonate (0.2 g/100 g soil), and incubated 27 days at room temperature after the soil water content had been adjusted to the approximate field capacity. Nitrate-nitrogen was determined, using the brucine method (8).

All plots were harvested 7 times from 15 May through 9 June.

The incidence of Fusarium wilt was estimated every 2nd week (27 April-2 June) by examining the plants for internal and external symptoms. Internal vascular browning was detected by examining leaf petiole scars.

All plants were sprayed twice weekly with an alternating program of premixed maneb + zinc and zineb for foliage disease control and for minor element nutrition of the plant. In addition, zinc sulfate, iron sulfate, and manganese sulfate were applied weekly at the rate of 0.25 lb./100 gal (0.299 g/liter) water. Insecticides were applied as needed.

All plants were evaluated for growth and vigor 24 days after planting (23 March), using a 1 to 5 scale where 1 represented very poor growth; and 5, excellent growth.

PHYTOPATHOLOGY for November (61:1319-1414) was issued 8 November 1971

TABLE 1. Effect of soil fumigation and soil pH on nitrification

Fumigant	Rate	ppm NO_3-N/sampling date and soil pH					
		25 March			16 May		
		6.0	7.0	7.5	6.0	7.0	7.5
	gal/acre[c]	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*
Vorlex[a]	35	27	84	115	275	425	380
Chloropicrin + D-D[b]	60	20	40	54	52	200	236
Control		195	170	215	259	360	472

[a] Methylisothiocyanate 20% + D-D 80%.
[b] A 3:2 mixture.
[c] Gal/acre = 9.35 liters/hectare.

TABLE 2. Effect of soil pH and fumigants on the incidence of Fusarium wilt of Fla 2153 tomato plants

Fumigant	Soil pH			Soil pH			Soil pH		
	6.0	7.0	7.5	6.0	7.0	7.5	6.0	7.0	7.5
	% wilt (5/4)			*% wilt (5/18)*			*% wilt (6/2)*		
Vorlex[a]	1.5	0.0	0.7	11.2	7.5	1.5	9.7	15.0	3.7
Chloropicrin + D-D[b]	0.0	0.0	0.0	0.7	4.5	1.5	2.2	6.7	3.7
Control	34.0	9.7	5.2	57.5	37.5	18.0	82.0	60.0	40.7
LSD (.05) fumigants within pH	15.6			22.9			19.1		
LSD (.05) pH within fumigants	13.0			21.0			18.7		

[a] Vorlex (methylisothiocyanate 20% + D-D 80%), 35 gal/acre (327 liters/hectare) rate.
[b] A 3:2 mixture, 60 gal/acre (561 liters/hectare) rate.

RESULTS.—By controlled use of hydrated lime and elemental sulfur, we established plots 13 February with initial pH values of 6.0, 7.0, and 7.5. On 25 March, the average pH values were 6.0, 7.1, and 7.3; by 19 May they had decreased to 6.0, 6.6, and 7.0.

The calcium content of the leaf tissue at pH 6.0, 7.0, and 7.5 was 0.47, 0.82, and 0.65%, respectively. The soil calcium at pH 6.0, 7.0, and 7.5 was 438, 538, and 726 μg/ml, respectively.

Nitrification initially (25 March) was greatly decreased by both fumigant treatments (Table 1). Nitrification increased as the soil pH increased. By 16 May, nitrification had resumed in the Vorlex-treated plots regardless of soil pH, but remained strongly repressed in the chloropicrin + D-D-treated plots at pH 6.0. At pH 7.0 or 7.5, the nitrifying bacteria apparently had recovered to some extent in the chloropicrin + D-D-treated plots, but were still relatively inactive compared to nonfumigated plots.

Raising the soil pH to 7.0 or 7.5 with hydrated lime reduced the incidence of Fusarium wilt of tomato incited by race 2 (Table 2). A pH of 7.5 gave better disease control than pH 7.0 despite the fact that the plant calcium content was greater at pH 7.0 than at pH 7.5. This is consistent with the hypothesis advanced by Jones & Woltz (5) that control of race 2 by hydrated lime is associated with the soil pH rather than the calcium content of the plant.

Poor growth of some plants was noticed soon after transplanting. The poor growth was associated with the use of the chloropicrin + D-D mixture, especially at pH 6.0. Phytotoxicity was considerably less at pH 7.0 or 7.5.

The phytotoxicity of chloropicrin + D-D at pH 6.0 also was reflected by the yields, in that Vorlex at pH 6.0 increased yields 78 bu/acre (5,241 kg/hectare) more than chloropicrin + D-D, whereas at pH 7.0 and 7.5, the chloropicrin + D-D plots outyielded the Vorlex plots by 28 (1,882 kg/hectare) and 45 (3,024 kg/hectare) bu/acre, respectively (Table 3). Moreover, fruit yields were considerably delayed at pH 6.0 by the chloropicrin + D-D mixture. For instance, at pH 6.0, 61, 74, and 88% of the total fruit yield had been harvested by 1 June from the chloropicrin + D-D, Vorlex, and nonfumigated plots, respectively.

DISCUSSION.—The poor early growth and the late maturity of the plants in the chloropicrin + D-D-treated plots possibly was caused by residual chloropicrin which was toxic to the tomato seedlings. However, the poor growth and late maturity may have been induced by ammonia which accumulated because of the suppressed nitrification in the chloropicrin + D-D-treated plots. Martin & Chapman (7) have shown that ammonia is more rapidly lost by volatilization from soils of high pH than from more acid soils.

TABLE 3. Effect of soil pH and fumigation on total yield (bu/acre) of the tomato breedling line Fla 2153

Fumigant	Rate	Soil pH		
		6.0	7.0	7.5
	gal/acre[c]	*bu/acre*	*bu/acre*	*bu/acre*
Vorlex[a]	35	1091	1236	1323
Chloropicrin + D-D[b]	60	1013	1264	1368
Control		793	1068	1168

LSD (.05) between fumigant means at the same soil pH = 72.8.
LSD (.05) between pH means within fumigants = 70.8.

[a]Methylisothiocyanate 20% + D-D 80%.
[b]A 3:2 mixture.
[c]Gal/acre = 9.35 liters/hectare; bu/acre = 67.2 kg/hectare.

Yield differences due to soil pH or fumigation probably would have been greater had a medium- to late-maturing stake or trellis tomato variety been used. Breeding line 2153-D5-D1-1-BGBk, by virtue of its early concentrated set and yield, produced extremely well despite Fusarium wilt.

Soil fumigation with a wide spectrum fumigant, using the techniques described by Jones et al. (4), costs ca. $250.00 to $300.00/acre. The cost of liming virgin Leon fine sand to a pH 7.0 or 7.5 is ca. $30.00 to $50.00/acre. On the basis of Fusarium wilt control and yields secured in this test, it would be economically more feasible to raise the soil pH than to remain at pH 6.0 and fumigate. However, fumigation plus a pH of 7.5 increased yields 155 to 200 bu/acre (13,450 kg/hectare) over nonfumigated pH 7.5 plots. Two hundred or 155 bushels (10,423 kg/hectare) of tomato can return a sum considerably more than $250.00. Yet preliminary experiments and field observations indicate that under Florida conditions, Verticillium wilt is considerably enhanced by a soil pH of 7.5 and is difficult to control even by fumigation. Therefore, a pH of 7.0 would be preferred, as Verticillium wilt development possibly would be avoided. At pH 7.0, yields without fumigation were equal to fumigation at pH 6.0, and fumigating at pH 7.0 increased yields 168 (11,298 kg/hectare) to 196 bu/acre (13,181 kg/hectare) compared to nonfumigated pH 7.0 plots.

LITERATURE CITED

1. COX, R. S. 1963. Control of Fusarium wilt, root rot and weeds on trellis-grown tomatoes in south Florida. Fla. State Hort. Soc. Proc. 76:131-134.
2. EDGERTON, C. W., & C. C. MORELAND. 1920. Tomato wilt. La. Agr. Exp. Sta. Bull. 174:3-54.
3. FISHER, P. L. 1935. Physiological studies on the pathogenicity of Fusarium lycopersici Sacc. for the tomato plant. Md. Agr. Exp. Sta. Bull. 374:261-281.
4. JONES, J. P., A. J. OVERMAN, & C. M. GERALDSON. 1966. Effect of fumigants and plastic film on the control of several soil-borne pathogens of tomato. Phytopathology 56:929-932.
5. JONES, J. P., & S. S. WOLTZ. 1967. Fusarium wilt (race 2) of tomato: effect of lime and micronutrient soil amendments on disease development. Plant Dis. Reptr. 51:645-648.
6. JONES, J. P., & S. S. WOLTZ. 1968. Field control of Fusarium wilt (race 2) of tomato by liming and stake disinfestation. Fla. State Hort. Soc. Proc. 81:187-191.
7. MARTIN, J. P., & H. D. CHAPMAN. 1951. Volatilization of ammonia from surface-sterilized soils. Soil Sci. 71:25-34.
8. PEECH, M., & L. ENGLISH 1944. Rapid microchemical soil tests. Soil Sci. 57:167-195.
9. PIPER, C. S. 1947. Soil and plant analysis. Intersci. Publ. Inc. N.Y. 368 p.
10. SCHOLLENBERGER, C. J., & R. H. SIMON. 1945. Determination of exchange capacity and exchangeable bases in soil-ammonium acetate method. Soil Sci. 59:13-24.
11. SCOTT, I. T. 1924. The influence of hydrogen ion concentration on the growth of Fusarium lycopersici and on tomato wilt. Mo. Agr. Exp. Sta. Res. Bull. 64.
12. SHERWOOD, E. C. 1923. Hydrogen ion concentration as related to the Fusarium wilt of tomato seedlings. Amer. J. Bot. 10:537-553.