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MANAGEMENT OF FUSARIUM WILT, FUSARIUM CROWN ROT, VERTICILLIUM WILT (RACE 2), SOUTHERN BLIGHT, AND ROOT-KNOT OF TOMATO ON FINE SANDY SOILS

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Abstract. **Fumigants injected into low pH (5.5) EauGallie sandy soils fertilized with nitrate-nitrogen and covered with full bed polyethylene mulch reduced the incidence of fusarium wilt (*Fusarium oxysporum* Schlecht. f. sp. *lycopersici* (Sacc.) Snyd. & Hans.), fusarium crown rot (*Fusarium oxysporum* Schlecht. f. sp. *radicis-lycopersici* Jarvis and Shoemaker), verticillium wilt (*Vercillium albo-atrum* Reinke & Berth.), and southern blight (*Sclerotium rolfsii* Sacc.) of tomato (*Lycopersicon esculentum* Mill. cv. 'Sunny') and increased yields compared to that from nonfumigated,low pH plots. Raising the soil pH to 7.5 with hydrated lime in conjunction with the use of nitrate-nitrogen and mulch also greatly alleviated the severity of fusarium wilt, fusarium crown rot, and southern blight, and increased yields. The high soil pH encouraged development of verticillium wilt and root-knot (*Meloidogyne incognita* [Kofoid & White] Chitwood). However, the injection of fumigants into these high pH soils controlled verticillium wilt and root-knot, resulting in maximum fruit production. Inoculation experiments demonstrated that the verticillium wilt in this field experiment probably was caused by race 2 which is a pathogenic form new to Florida and different from the common race 1.**

Fusarium crown rot of tomato caused by *Fusarium oxysporum* f. sp. *radicis-lycopersici,* in recent years has become increasingly common in the Hillsborough-Manatee and Immokalee-Naples fresh market tomato production areas. The disease in the past 2 years has been found in numerous fields in both areas, affecting up to 50% of the plants in some locations. The disease also has been discovered on container-grown seedlings in the greenhouse (communication from C. Mellinger).

Since broad-spectrum soil fumigants give excellent control of fusarium wilt of tomato caused by the morphologically identical fungus *F. oxysporum* f. sp. *lycopersici* (4,8) and since tomato wilt is inhibited by an increase in soil pH (4,8), a field experiment was conducted to determine the effect of soil pH and broad-spectrum soil fumigants on the development of fusarium crown rot. However, several other soil-borne diseases developed in addition to crown rot. Verticillium wilt, caused by *Verticillium albo-atrum,* was one of these diseases, even though a resistant cultivar, 'Sunny' was used. Therefore, inoculation experiments were carried out in a growth room to determine whether a new pathogenic race of *V. albo-atrum* were involved.

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Materials and Methods

Roots and stems of crown rot and root-knot diseased tomato plants were removed from a commercial field, scattered over the experimental site, an EauGallie fine sand, and incorporated into the soil to infect the experimental area. Low and high soil pH plots were established by using sulfur or hydrated lime. On 11 Apr. 1985 the low pH plots ranged from 5.2-6.1 and the high pH plots ranged from 7.3-7.5.

Pure cultures of *F. oxysporum* f. sp. *radicis-lycopersici* were grown on sterile vermiculite saturated with a nutrient-dextrose medium. Field beds were formed and a furrow was made in the center of each. Then the *Fusarium*-infested vermiculite was put into the furrow, the furrow closed, and the bed reshaped and pressed.

Fumigants and rates evaluated included MB/C 33 (67% methyl bromide-33% chloropicrin mixture) at 350 lb./acre; MS/DD (80% chlorinated C_3 hydrocarbons, 20% methyl isothiocyanate) at 25 gal/acre; metam-sodium (32.7% sodium N-methyldithiocarbamate, 67.3% inert ingredients) at 50 gal/acre; and MB/C 2 (98% methyl bromide-2.0% chloropicrin mixture) at 2 rates, 300 and 400 lb./acre. All fumigants were injected 25 Feb. 1985 6 inches deep into the raised beds with 3 chisels spaced 8 inches apart. All plots were covered immediately after fumigation with 1.5 mil black polyethylene mulch. Container-grown 'Sunny' tomato plants were set into the field 2 weeks later on 11 Mar. 1985. Standard fungicides and insecticides were applied weekly for disease and insect control. All plants were staked and tied.

A split plot design with 4 replications was used. Whole plots were soil pH variables and subplots were soil fumigation variables. All data were statistically analyzed.

Although the original purpose of the experiment was to determine the effect of soil pH and fumigants on the control of fusarium crown rot, several other diseases, such as Fusarium wilt (race 2), southern blight, verticillium wilt, and root-knot developed. The wilt diseases were evaluated weekly and the percentages of diseased plants were determined for each disease. However, only the data for 28 May 1985 are presented. After the fruit were harvested for the third time on 5 June, all plants were dug and the roots and crowns were washed and examined for crown rot, southern blight, and root-knot.

Because verticillium wilt symptoms, or at least verticillium wilt-like symptoms, developed on the 'Sunny' cultivar which is resistant to *V. albo-atrum* race 1, petiole sections were excised from leaves having typical symptoms, surface

Table 1. Effect of soil pH and soil fumigants on the percentage of 'Sunny' to tomato plants with fusarium wilt, fusarium crown rot, and southern blight.

Fumigant	Amount/acre	Fusarium wilt at soil pH		Fusarium crown rot at soil pH		Southern blight at soil pH	
		5.5	7.5	5.5	7.5	5.5	7.5
		Percent					
None	–	74	8	82	39	31	7
MB/C 33	350 lb.	3	18	7	17	0	0
MB/C 2	300 lb.	21	10	22	4	7	0
MB/C 2	400 lb.	30	14	31	13	14	0
Metam-sodium	50 gal	86	22	76	25	26	6
MS/DD	25 gal	21	24	20	17	4	1
LSD .05		15	16	20	20	15	15

sterilized in 10% clorox, and plated on potato dextrose agar (PDA) plates. Pure colonies of *V. albo-atrum* were obtained consistently. One of these isolates and a known race 1 *Verticillium* isolate, were raised in pure culture on PDA plates and used to root-dip inoculate 2-week old tomato seedlings of race 1 verticillium wilt resistant and susceptible cultivars. Inocula were prepared by comminuting in tap water separate plates of the unknown isolate and of the known race 1 with a Waring blender. The spore concentrations were adjusted to approximately 60 million spores/ml of inoculum. The test seedlings were root dip inoculated, dibbled into containerized flats filled with a peat:vermiculite mix, and incubated in 26°C growth rooms receiving 800 ft. candles illumination 6 hr/day.

Results and Discussion

The incidence of fusarium wilt was decreased greatly by raising the soil pH (Table 1). Nearly 75% of the plants in nonfumigated, low pH soil had fusarium wilt symptoms compared to 8% in nonfumigated high pH soil. At pH 5.5, MB/C 33 gave excellent control of fusarium wilt, whereas MB/C 2 at both rates and Vorlex gave good control (Table 1). Disease occurrence at pH 7.5 was not severe enough to separate the fumigants in this experiment, although in prior experiments Overman and Jones (6) obtained excellent results with MB/C 33, MB/C 2, and MS/DD at 7.0-7.5.

Fusarium crown rot reacted similarly to fusarium wilt in that an increase in soil pH decreased the incidence of disease from 82% to 39% in nonfumigated soil. At pH 5.5, MB/C 33 gave excellent control, whereas MB/C 2 at both rates and MS/DD gave good control. At the higher pH of 7.5, MB/C 33, MB/C 2, MD/DD, and metam-sodium all reduced the incidence of disease (Table 1).

These results, together with those of Overman and Jones (6), demonstrate that fusarium crown rot can be controlled by a combination of high soil pH and fumigation in Florida. Perhaps covering the fumigated soil with plastic mulch and using well water for transplanting may have prevented the recontamination problem possibly encountered by others (7,8).

Southern blight also was controlled by an increase in *soil* pH to 7.5 (Table 1). Only 7% of the plants in nonfumigated pH 7.5 soil had southern blight symptoms compared to 31% in nonfumigated 5.5pH soil. MB/C 33, MB/C 2 (at both rates), and MS/DD greatly reduced the incidence of southern blight in the pH 5.5 plots (Table 1). Very little disease developed at pH 7.5, and at this pH MB/C 33 and MB/C 2 completely eliminated the disease.

Table 2. Effect of soil pH and soil fumigants on the percentage of 'Sunny' tomato plants with root-knot and verticillium wilt.

Fumigant	Amount/acre	Root-knot at soil pH		Verticillium wilt at soil pH	
		5.5	7.5	5.5	7.5
		Percent			
None	–	46	93	17	90
MB/CC 33	350 lb.	0	3	6	14
MB/C 2	300 lb.	1	0	7	6
MB/C 2	400 lb.	4	0	4	8
Metam-sodium	50 lb.	32	87	7	71
MS/DD	25 lb.	28	17	22	58
LSD/ .05		10	10	16	16

Table 3. Effect of soil pH and soil fumigants on total yields (lb./80 linear ft.) of 'Sunny' tomato.

Fumigant	Amount/acre	Yield (lb.) Soil pH 5.5	Yield (lb.) Soil pH 7.5	Total
None	–	283	439	722
MB/C 33	350 lb.	643	675	1318
MB/C 2	300 lb.	610	745	1355
MB/C 2	400 lb.	539	665	1204
Metam-sodium	50 gal	305	506	811
MS/DD	25 gal	583	547	1130
LSD .05		95	95	220

Table 4. The effect of *Verticillium albo-atrum* isolates on subsequent development of verticillium wilt on growth room plants.

Cultivar	Reaction to race 1	Disease (%) R1[z]	Disease (%) R2[z]
	Expt. 1		
Tropic	resistant	0	100
Sunny (1)	resistant	9	100
Sunny (2)	resistant	19	95
Walter	susceptible	81	100
	Expt. 2		
Hayslip	resistant	31	98
Tropic	resistant	5	95
Duke	resistant	q0	93
Sunny	resistant	17	86
Walter	susceptible	85	93
Tempo	susceptible	93	83
Florida MH-1	susceptible	97	96
	Expt. 3		
Walter	susceptible	97	77
Tropic	resistant	19	83
IRAT (France)	?	100	35
11-VI (NCS)	?	5	57
8-VI (NCS)	?	0	33

[z]R1 = known race 1 isolate, R2 = unknown isolate.

Fusarium wilt, fusarium crown rot, and southern blight were similar in that an increase in soil pH inhibited disease development. Root-knot was the opposite, a high soil pH encouraged disease development (Table 2). Over 90% of the plants at pH 7.5 developed root-knot, whereas only 46% were diseased at pH 5.5 in nonfumigated soil (Table 2). At pH 5.5, MB/C 33 and MB/C 2 gave excellent control, whereas MS/DD and metam-sodium gave marginal results. MS/DD, however, used at the standard rate of 35 gal/acre gives excellent control of root-knot in low pH soils (6). At pH 7.5, MB/C 33, MB/C 2, and MS/DD gave excellent root-knot control.

An increase in soil pH from 5.5 to 7.5 greatly increased the incidence of verticillium wilt in nonfumigated soil)Table 2). Only 17% of the plants at pH 5.5 were diseased compared to 90% at pH 7.5. There was too little disease at pH 5.5 to properly evaluate the fumigants; however, at pH 7.5, MB/C 33 and MB/C 2 gave excellent control (Table 2). MS/DD at the 35 gal/acre rate in the past was as efficacious as MB/C 33 or MB/C 2 (3).

Total yields were increased greatly in nonfumigated soil by raising the soil pH to 7.5 (Table 3). MB/C 33, MB/C 2, and MS/DD at pH 5.5 greatly increased total yields. At pH 7.5, MB/C 33 and MB/C 2 greatly increased yields. MS/DD provided marginal results at this pH. However, total yields collectively (pH 5.5 yields + pH 7.5 yields) were increased statistically and significantly by MS/DD, MB/C 33, and MB/C 2.

In the first verticillium inoculation experiment, 'Tropic' seedlings were not diseased by race 1, whereas 100% were diseased by the new isolate (Table 4). Two sources of 'Sunny' (one from J. Oxford and one from the Asgrow Seed Company) also proved to be resistant to race 1, but susceptible to the new isolate. 'Walter' was equally susceptible to both isolates. It appeared that a new pathogenic race was involved which was different from race 1.

In the second inoculation experiment, all race 1-resistant cultivars ('Hayslip', 'Tropic', 'Duke', and 'Sunny') were resistant to the known race 1 isolate, and all were susceptible to the new isolate (Table 4). All race 1-susceptible cultivars were equally susceptible to the race 1 isolate and to the new isolate. This experiment verified that a pathogenic form different from race 1 was involved.

Two race 2-resistant breeding lines were obtained from North Carolina State University and one from France to determine their reactions to race 1 and to the new isolate. 'Walter' proved to be susceptible to both isolates, whereas 'Tropic' was resistant to race 1, but susceptible to the new race (Table 4). The cultivar from France seemed to be susceptible to race 1, resistant to the new race. The North Carolina cultivars were resistant to race 1, and perhaps resistant to the new isolate. Further inoculation experiments are needed to clarify this tolerance or resistance.

These inoculation experiments demonstrated conclusively that a *Verticillium albo-atrum* race new to Florida and distinct from race 1 was involved in the field fumigation experiment. It is probable that this new form is similar to race 2 previously reported in Ohio (1), California (2), and North Carolina (5).

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