will require excellent management and attention to detail adjustment and operation. By use of precision seeding equipment and good seed a uniform seedling stand can be obtained. This will improve the ability of the machine to harvest the plants and improve the efficiency of the transplanter operators to handle the plants without producing skips. In addition, improved techniques of irrigation after transplanting and improved watering of the seedlings after harvest need to be developed to minimize seedlings exposure to damaging stress.

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EFFICACY OF ONE STREAM VERSUS THREE OF A SOIL FUMIGANT FOR PRODUCTION OF TOMATO[1]

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Abstract. **In a tomato production system which included a full-bed mulch, 'Walter' tomato yielded as well with a single stream application of the soil fumigants MBC (Dowfume MC-33) methyl bromide 66% + chloropicrin 33%, or DD-MENCS (Vorlex) methylisothiocyanate 20% + 1,3-dichloropropane-1,2-dichloropropene 80%, as with 3 streams of either fumigant spaced 8 inches (27 cm) apart. MBC also increased marketable yield of 'Tropic' tomato, regardless of type of application. Incidence of root-knot nematodes, Verticillium wilt and Fusarium wilt were reduced on susceptible cultivars by either method of treatment.**

The high value of Florida's tomato (*Lycopersicon esculentum* Mill.) crop is the result of a crop management program which includes soil treatment with a broad-spectrum soil fumigant under a full-bed mulch (i.e., 75-80 cm wide raised bed covered the entire width with 0.0025 cm thick polyethylene plastic film). Although single stream fumigation resulted in an increase in yield (1, 7), it has been the practice, especially with the development of Fusarium wilt, incited by *Fusarium oxysporum* Schl. f. sp. *lycopersici* (Sacc.) Snyder & Hansen race 2, in Florida to use multiple streams of a fumigant for the high yields expected of tomato under the full-bed mulch culture. With placement of fertilizer on the shoulders of the bed (2), it was thought that plant roots must be protected from root-rotting pathogens (*Rhizoctonia solani* Kuhn and *Pythium* spp.) and the vascular pathogens which can greatly reduce yields. It was further conjectured that this protection must be adequate to permit the absorption of nutrients by a healthy, expanding root system. Consequently, fumigants were and are currently applied with 3-5 chisels 8-12 inches (20-27 cm) apart and 6-8 inches (15-20 cm) deep to protect the tomato crop from soil-borne pathogens, nematodes, and weeds (5).

Two factors developing simultaneously in Florida's tomato industry suggested the possibility that this stringent fumigation practice might be relaxed: 1) the commercial success of the tomato cultivar 'Walter' which is resistant to Fusarium wilt race 1 and 2; and susceptible, but somewhat tolerant (3) to Verticillium wilt (*Verticillium albo-atrum* Reinke and Bert.), and 2) the introduction of containerized seedling transplants (produced in sterile media) to the planting procedure.

To test the premise that an alternate, more economical, pest management program combining a reduced zone of fumigated soil, plant resistance, and hardened 5-week old transplants could effectively maintain high yields of the 'Walter' tomato, 3 field experiments were carried out on Myakka fine sand.

Materials and Methods

In 2 expt [Fall 1976 and Spring 1977 (A)], both MBC (Dowfume MC-33) (methyl bromide 66% + chloropicrin 33%) and DD-MENCS (Vorlex) (methyl isothiocyanate 20% + 1,3-dichloropropane-1,2-dichloropropene 80%) were injected with 1 and with 3 chisels, 8 inches (20 cm) apart, in a 30-inch (75 cm) wide bed prepared in the standard manner (1). With MBC, 350 lb/acre (392 kg/ha) and with DD-MENCS 35 gals/acre (327 l/ha) were applied through each chisel. Thus 1/3 of the amount of chemical was applied with 1 chisel as with 3 chisels. In the third experiment [Spring 1977 (B)] only MBC was applied within blocks of the field held at 3 pH levels: 5.5, 6.5, and 7.5. Two weeks after fumigant application in all expt, containerized 'Walter' seedlings were transplanted into 4 replicates of treated and nontreated plots. The third expt [Spring 1977 (B)] was of split plot design in which transplants of both 'Walter' (susceptible to Verticillium wilt) and 'Tropic' (susceptible to Fusarium wilt race 2) were used.

All data were submitted to statistical analyses.

Results

Yield. All treatments in the 3 expt increased yields over the control except DD-MENCS in the fall 1976 (Table 1). MBC was better than DD-MENCS in all comparisons. Although plant mass in plots treated with 1 stream of DD-MENCS was obviously poorer than with 3 streams, there were no differences in total marketable yield between 1 and 3 streams of either fumigant, except that, in the fall expt, 1 stream of MBC was better than 3 streams. However, there was a difference in quality of the yield from 1 vs. 3 streams of DD-MENCS in that combined weight of extra large fruit (size 5 x 5 and 5 x 6) was 22% less with 1 than 3 streams.

In the second spring experiment (B), the number of streams of MBC did not affect the yield of large sized fruit

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Table 1. Effect of number of streams of fumigant on yield of 'Walter' tomato in 3 seasons and 'Tropic' tomato in one season.

		Tomato yields (kg-cartons/ha)[z]			
		Fall 1976	Spring 1977 (A)	Spring 1977 (B)	
	Streams	Walter	Walter	Walter	Tropic
Control		3367 c[y]	2928 c	2343 b	3734 b
MBC	1	4246 a	5051 a	4539 a	5637 a
	3	3807 b	5344 a	5271 a	6223 a
DD-MENCS	1	3294 c	4173 b		
	3	3514 c	4173 b		

[z]$\frac{\text{Kg-cartons/ha}}{2.471}$ = 30-lb cartons/A

[y]Means followed by the same letter in each column do not differ significantly at the 5% level of probability according to Duncan's multiple range test.

of 'Walter' (Table 2). The yield of larger fruit from 'Tropic' was greater with 3 streams of MBC than with 1 stream. However, this difference was significant only in the third harvest.

There was a positive yield response of 'Tropic' to increased soil pH which was traced to differences in the third picking (control < 1 stream < 3 streams) of the larger fruit.

Wilt disease control: An average of 38,200 lb/A (43,000 kg/ha) of tomato fruit was produced in the fall and spring (A) seasons (Table 1) despite the fact that 66 and 42% of the plants wilted in the 2 crops (Table 3). The incidence of Verticillium wilt on 'Walter' in the first and third trials was decreased equally well by either fumigant up to the time of first harvest. After the first harvest, wilt increased in plots treated with DD-MENCS and in the spring 1977 (A) expt there were also differences between the number of streams, in favor of 1 stream over 3. Both applications were successful in controlling Fusarium wilt in the susceptible 'Tropic' tomato until the final harvest.

Nematode control: All treatments controlled root-knot nematodes, *Meloidogyne incognita* (Kofoid & White) Chitwood, in the 'Walter' tomato (Table 4). Despite the severity of root-knot nematodes on the previous tomato crop, there was a low incidence of root-knot galling on 'Tropic' and no differences occurred among treatments.

Table 4. Index[z] of root-knot nematode galling on 'Walter' and 'Tropic' tomato roots observed after harvest in fumigation experiments.

		Season			
		Fall 1976	Spring 1977 (A)	Spring 1977 (B)	
Treatment	Streams	W[y]	W	W	T
Control		3.44b[x]	4.2b	3.1b	0.8a
MBC	1	0 a	0.4a	0.9a	0.2a
	3	0 a	0.1a	0.6a	0.2a
DD-MENCS	1	0 a	0.8a		
	3	0.3 a	1.4a		

[z]Index: 0 = no galling; 5 = severe galling.
[y]W = Walter cv; T = Tropic cv.
[x]Means followed by the same letter in each column do not differ significantly at the 5% level of probability according to Duncan's multiple range test.

Discussion

Although the horticultural environment (pH range 6.5-7.5, nitrogen ratio 20% NH_4-N to 80% NO_3-N) established by Florida growers in tomato fields is conducive to control of Fusarium, it favors Verticillium wilt (Fig. 1). The latter disease is less debilitating than might be ex-

Table 2. Yield (kg-cartons/ha)[z] of extra large fruit (size 5 x 5 and 5 x 6) of 'Walter' and 'Tropic' tomato from soil treated with 1 and 3 streams of MBC in the Spring (B) test.

				Harvest no.					
		Total		1		2		3	
	Streams	W[y]	T	W	T	W	T	W	T
Control		805b[x]	3001c	586b	1098b	220b	1391b	73b	512c
MBC	1	2269a	5271b	1318a	1684a	805a	2343a	146ab	1245b
	3	3001a	6369a	1464a	1757a	1245a	2709a	293a	1903a

[z]$\frac{\text{Kg-cartons/ha}}{2.471}$ = 30-lb boxes/A

[y]W = Walter; T = Tropic

[x]Means followed by the same letter in each column do not differ significantly at the 5% level of probability according to Duncan's multiple range test.

Table 3. Percentage of 'Walter' and 'Tropic' tomato plants showing wilt symptoms prior to the first and after the last harvest, a 3-week period.

		Fall 1976		Spring 1977 (A)		Spring 1977 (B)			
		Walter[z]		Walter[z]		Walter[z]		Tropic[y]	
	Streams	15[x]	18	8	11	5	8	5	8
Control		26b[w]	66c	20b	42b	63b	98a	39b	60b
MBC	1	0a	7a	5a	47b	16a	68a	6a	11a
	3	0a	10a	16b	45b	11a	52a	3a	3a
DD-MENCS	1	11a	29b	9a	19a				
	3	3a	17b	9a	33b				

[z]Verticillium wilt susceptible.
[y]Fusarium wilt susceptible.
[x]Weeks after planting.
[w]Means followed by the same letter in each column do not differ significantly at the 5% level of probability according to Duncan's multiple range test.

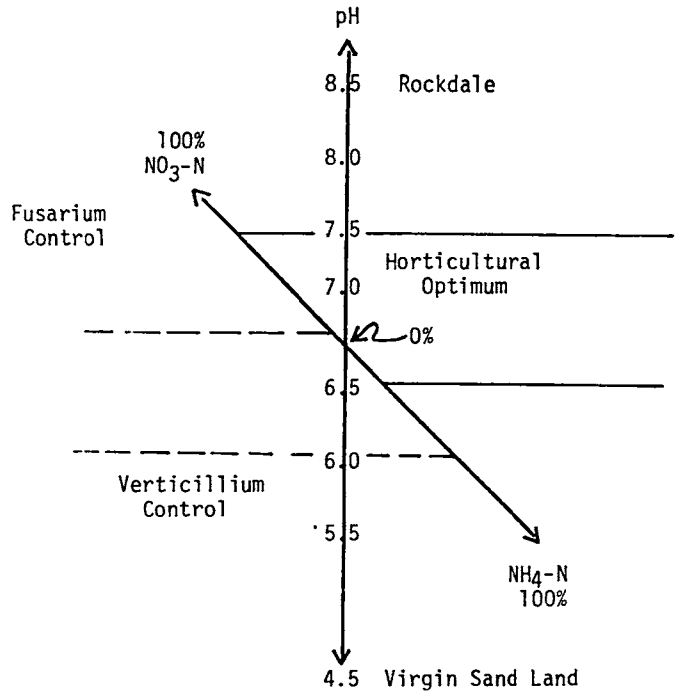

Fig. 1. Diagram of the relationship of the present day horticultural environment established for tomato crops by manipulation of pH and NO_3-N/NH_4-N ratios to biological control of Fusarium and Verticillium wilt organisms in the soil.

pected in soils with an adjusted pH of 6.5-7.5 and high NO_3-N levels because the 'Walter' tomato is somewhat tolerant of Verticillium wilt.

In soils infested with the Verticillium wilt organism, the protection afforded by this level of crop tolerance delays the effect of wilt on yield.

Other factors in the programmed crop management system also contribute to the protection of yield potential and thereby contribute to the success of a single stream compared to 3 streams.

One of these contributions is the full-bed mulch: by protecting the bed itself from undue handling or erosion due to cultivation associated with routine weed control and nutrient side-dressings, and from the extremes of temp and moisture changes, the plants develop undisturbed root systems which are exposed to minimal stress and thereby are better able to sustain some degree of attack by non-systemic root pathogens.

The use of containerized tomato transplants also contributes to the overall success of the single stream fumigation procedure. The fact that the plant is already 5-6 weeks old at transplanting means that the crop can succeed with a shorter period of protection in the field. The crop will be closer to maturity before the root system expands substantially into nontreated areas of the bed.

In the earlier development of soil fumigation for tomato in Florida (1, 4), a single stream of fumigant was effective because: 1) cultivars were protected by genetic resistance to the wilt organism active at the time, *F. oxysporum* f. sp. *lycopersici* race 1; 2) nutrient applications were placed in accordance with root-system expansion; and 3) Verticillium was not a general problem because tomato crops were grown only once or twice before the grower migrated to new land and possibly because of the low pH of the fields.

The modern systems approach to crop management designed to maximize yield was developed in the interim between the rise of Fusarium wilt incited by race 2 as an economic problem in the state (7) and the release of 'Walter' as a cultivar resistant to the disease.

Now that 'Walter' is grown by most growers in the state, it is feasible to consider refinement of the fumigation procedure. Reduction of the total amount of chemicals required to produce any crop is attractive for economic and environmental reasons; researchers and growers alike are therefore eager to integrate all cultural, genetic and chemical means available to combat soil pests effectively and economically. This research indicates some progress toward this goal.

Summary

Under Florida conditions reducing the fumigated zone and thus the total chemical applied in ground beds did not compromise the benefit derived with 'Walter' or 'Tropic' from either MBC or DD-MENCS.

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