RELATION OF NEMATODES, DISEASES AND FERTILITY TO TOMATO PRODUCTION ON OLD LAND.

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ABSTRACT

Methods of obtaining maximum results from use of broad-spectrum soil fumigants were evaluated on old agricultural sandy soils. Various formulations (EP 201, EP 230, Nemex, Vorlex) of chloropicrin, methyl isothiocyanate and D-D were effective as nematicide-fungicide-herbicide combinations. Use of 1.5 mil black polyethylene plastic film as a mulch enhanced control by all fumigants, particularly in areas where moisture was limiting. Where proper adjustment of nitrogen sources was made to mitigate the effect of initial depression of nitrification following soil fmuigation, yield increases made use of old land feasible.

INTRODUCTION

Nematodes, soil-borne disease organisms, weeds and deterioration of soil physical properties are problems encountered in producing high-yield quality tomato crops on old agricultural soils in Florida.

The conventional retreat to newly cleared land each year or two to escape soil pests and high salt content is becoming increasingly difficult and costly. Some effort has been made to rotate tomato with pangolagrass pasture to prevent the build-up of tomato pathogens such as root-knot nematodes (*Meloidogyne* spp,) (7), but crop rotations are of little use in soils infested with ecto-parasitic nematodes such af *Trichodorus christiei* (5). Southern blight, caused by *Pellicularia rolfsii,* (3), and the wilt disease organisms, *Fusarium oxysporum* f. *lycopersici* (race 2) and *Pseudomonas solanacearum* (2) are pathogens that are also not effectively controlled by crop rotation.

Broadcast soil fumigation has been too expensive on a field scale to be practical for wide row crops such as tomatoes. However, in-the-row soil fumigation (6), as practiced since 1949 on short-term crops for nematode control, has proved inadequate for the long-term trellised tomatoes grown for "pink harvest" and for crops grown in fields heavily infested with disease organisms.

Recently (4) plastic mulch has proved effective in control of weeds and conservation of moisture in vegetable crops. The development of methods for increasing yields through heavy applications of high analysis fertilizer introduced the practice of growing high value tomato crops under plastic mulch. With the benefits itemized by Geraldson (4) to be derived from utilizing the mulch throughout the growing season to help justify the cost of the film and the cost of its application and removal, plastic mulch has become an asset in improving the efficacy and feasibility of broad-spectrum soil fumigants on large acreage.

Prime interest of the research reported here was development of a coordinated program of land management which would insure profitable tomato yields from old agricultural land heavily infested with nematodes, soil-borne disease organisms and weeds. Since the cost of production was expected to be high on old land, as many factors as possible which might affect yields were included in the tests. Among these factors were broad-spectrum fumigants for control of soil-borne pests and fertilizer sources to assure unlimited balanced nutrition. Use of plastic mulch to minimize redistribution of pathogens from untreated to treated areas, to prevent weed growth and to restrict moisture fluctuations was also evaluated. The degree of disease control which was attained and the effect of fumigation on utilization of plant nutrients are published elsewhere.

This paper, therefore, will be concerned with the relation of nematode control to tomato yields in areas where soil-borne disease organisms and fertilizer imbalances may be correlated factors. Procedures are described to reduce the populations of abundant soil-borne pests in old land in order that uninhibited root systems might be free to supply sufficiently balanced nutrient to permit production of maximal yields.

EXPERIMENTAL METHODS

Two field areas were chosen for evaluating

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soil fumigants based on their history of soil pest problems. Both areas were Broward fine sand irrigated through seep ditches. The past history of Field A included 4 years of tomato, preceded by 5 years of Bahia grass (*Paspalum notatum*) and 1 year of tomato. The predominant plant parasitic nematode present during the past six years was the stubby-root nematode (*T. christiei*). During the summer months a moderate population of the sheath nematode (*Hemicycliophora parvana*) was supported by the re-established Bahia grass, but seldom more than 15 individuals per 150 ml. of soil were found in the root zone of the tomato crop. The soil pH averaged 6.5, organic matter content 2.5 percent and moisture equivalent 4.0 percent. Field B had been in vegetable production for over 40 years. The nematode population included heavy populations of sting (*Belonolaimus longicaudatus*) stubby-root (*T. christiei*), stunt (*Tylenchorhynchus capitatus*) and awl (*Dolichodorus heterocephalus*) nematodes. Moderate populations of sheath, rootknot (*Meloidogyne* spp. larvae), spiral (*Helicotylenchus erythrinae*) and lance (*Hoplolaimus galeatus*) nematodes were also present. Soil pH averaged 6.9, organic matter content 3.1 percent and the moisture equivalent 4.7 percent.

Preparation of the fields for all tests included thorough disking to encourage rotting of plant debris and maintenance of soil moisture adequate for seed germination for at least 2 weeks prior to fumigation. It is assumed that such moisture relations may render weed seed and microororganisms more vulnerable to toxic chemical vapors by germinating spores and sclerotia and hatching nematode eggs. Moisture content at time of fumigation was at field capacity except in test 3. Superphosphate and minor elements

Table 1. Fumigants evaluated and their chemical name.

Fumigants	Chemical names
AA	Allyl alcohol (2-propen-1-ol)
D-D	mixture of 1,3-dichloropropene,1,2-dichloropropane, and related hydrocarbons
EDB	1,2-dibromoethane
EP 201	chloropicrin (15%) + methyl isothiocyanate (17%) + D-D (68%)
EP 230	chloropicrin (15%) + methyl isothiocyanate (15%)
MC-2	methyl bromide (98%) + chloropicrin (2%)
Nemex	chloropicrin (50%) + D-D (50%)
Phorate	O,O-diethyl S-(ethylthio) methyl phosphorodithioate
SMDC	sodium N-methyldithiocarbamate
Telone-PBC	1,3-dichloropropene (80%) + chloropicrin (15%) + propargyl bromide (5%)
TMCB	tetramethylchlorobutene
Vorlex	methyl isothiocyanate (20%) + D-D (80%)
Zinophos	O,O-diethyl O-(2-pyrazinyl) phosphorothioate

were broadcast over the beds before fumigants and banded fertilizer were applied.

All fumigants except allyl alcohol (AA) and methyl bromide (MC-2) (Table 1) were injected 6 inches deep with 3 chisels on 8-inch centers. Beds were compacted with a heavy bed press to a height of 8 inches and barred-off to a width of 32 inches immediately following the injections. High analysis fertilizer was banded 12 inches from each side of the plant row. Where plastic mulch was used for the crop, a 4-foot strip of 1.5 mil black polyethylene film was stretched and sealed over the beds immediately after fumigating and fertilizing. Tomato seedlings from MC-2-treated soil in raised benches were planted through the plastic 2 weeks later.

AA was applied as a surface drench in ¼ acre-inch of water following injection with EDB and the application of fertilizer. Where phorate and zinophos were combined with AA, the emulsible formulation was included in the drench. All drenches were applied 3-5 days before plantings. Plots reserved for MC-2 were pressed, barred-off and *fertilized* before the gas was released beneath a conventional sealed plastic tent constructed to cover the full 32-inch width of the bed. The tent was removed after 5 days, and the plots either were or were not mulched with plastic as the experimental design dictated.

Granular chlordane was distributed over the bed surface for control of soil-borne insects. Recommended practices for foliar pesticides were followed throughout the crop seasons.

Soil samples were collected in the root zone of the tomato plants periodically during the crop season for laboratory assay of nematode populations.

Test 1. A preliminary test on Field A involved the use of 30 gallons per acre of 5 fumigants (Vorlex, Nemex, EP 201, EP 230 and TMCB) with and without plastic mulch. The source of nitrogen in the fertilizer was ammonium nitrate + potassium nitrate. Fusarium wilt (race 1) and southern blight were active in the field. Wilt-susceptible Rutgers were employed as test plants.

Test 2. Field B. was chosen as the experimental site in which EP 201 (35 gallons per acre) and EDB + AA (6 + 25 gallons per acre) were evaluated. All plots were mulched with plastic. Fusarium wilt (race 2) to which the commercial varieties planted were susceptible was active in the portion of the field used for test 2.

Test 3. Ten fumigation treatments with and without plastic mulch were evaluated on Field A when the soil temperature at a 4-inch depth was 60° F and the moisture content at 7.7 percent, one-half of field capacity. Nemex, Vorlex, VPM, EP 230, EP 201, and AA were applied at the rate of 30 gallons per acre. Phorate and zinophos were combined with the AA at the rate of 5 and 4 gallons per acre, respectively. Telone-PBC was tested at 2 rates, 20 and 28 gallons per acre. MC-2 was used at 3 pounds per 100 square feet. One ton of 17-0-24-2 (urea + KNO_3 + $Ca(NO_3)_2$ + $MgSO_4$) was supplied in one application under the plastic. A similar quantity was applied to the non-plastic plots but at weekly intervals (about half the total N came from urea). Commercial varities resistant to Fusarium wilt (race 1) were planted. The southern blight fungus was active in the soil.

Test 4. Two rates of EP 201 were evaluated under plastic with the high nitrate-nitrogen analysis fertilizer in Field B. Temperature of the soil was 78°F at a 4-inch depth. Commercial varieties susceptible to Fusarium wilt (race 2) were set. Phoma stem canker and Fusarium wilt (race 2) were active in the field.

Results and Discussion

Test 1. Under plastic mulch all fumigants controlled the stubby-root nematode for 11 weeks (Table 2). Control without the mulch was effective with Vorlex and Nemex, but populations of the nematode in EP 230 and TMCB-treated soil had attained the magnitude of those in the non-fumigated soil by the eleventh week.

Test 2. Populations of sting, lance, sheath, awl and stunt nematodes (Table 3) were reduced for 21 weeks by EP 201 and EDB + AA. Stubby-root nematodes were controlled for 10 weeks

Table 2. Effectiveness of fumigants with (+) and without (-) plastic for the control of the stubby-root nematode (*Trichodorus christiei*).

		Number of weeks following treatment					
		3		7		11	
	Rate[a]	+	-	+	-	+	-
Control		131[b]	76	19	132	536	660
Vorlex	30	2	0	3	7	104	168
Nemex	30	42	34	4	30	252	155
EP 201	30	2	6	2	9	276	485
EP 230	30	43	30	10	16	273	700
TMCB	30	37	68	0	32	245	680
L.S.D.	.05	39		45		110	

[a]gallons per acre
[b]Number per 150 ml. soil extracted by the Christie-Perry method (1).

following fumigation. There was a decided reduction of all nematodes except sting in the control and EDB + AA-treated plots in the 21st week. This may be correlated with the inroads made on the host plant by Fusarium wilt (race 2).

Test 3. Nematode control by all chemicals applied under the plastic held for 2 months (Table 4). Without plastic control of stubby-root and sting nematodes in plots treated with SMDC did not last into the second month. Stubby-root nematodes appeared in EP 230 and Nemex-treated but un-mulched soil also during the second month. Sting nematodes remained at low levels through the third month in all plots except those treated with phorate. Nemex, Vorlex, EP 230 EP 201, Telone-PBC and MC-2 were most effective in reducing populations of the stunt nematode. Indices of rootknot galling on plants dug after harvest 5 months after planting indicated that only MC-2 and Vorlex were successful in suppressing rootknot in non-mulched plots (Table 5). Use of plastic did not increase the degree of control by these two materials; however, SMDC, EP 230 and Telone-PBC were more successful in protecting the plant roots with than without plastic.

Southern blight was controlled in all plastic-covered plots, including the non-fumigated checks. MC-2, Telone-PBC and EP 201 gave 75 percent control in non-mulched plots; control by other materials ranged from 66 to 35 percent, with 50 percent of the plants in non-fumigated plots being severely infected.

Neither nematode nor disease control, however, was reflected in fruit yields (Table 5). The fumigants most effective in reducing the levels of pathogens in the soil also depressed nitrification. Nitrification under the plastic in soil treated with Nemex, EP 230, EP 201, MC-2 and the high rate of Telone-PBC was reduced for 2 months. Only the Telone-PBC resulted in such drastic curtailment without plastic. SMDC,

Table 3. The effect of fumigants on populations of *T. christiei* (Tr), *B. longicaudatus* (B), *H. galeatus* (Hg), *H. parvana* (Hp), *D. heterocephalus* (D) and *T. capitatus* (Tc) and prevalence of Fusarium wilt (race 2) symptoms on tomato plants.

		Nematodes						Marketable yield	Fusarium infected plants	
	Weeks	Tr	B	Hg	Hp	D	Tc	bu/acre	Early[b]	Late[c]
Control	2	23[a]	2	20	42	164	454			
	6	15	64	23	34	50	181			
	10	131	104	42	25	38	246			
	14	530	548	5	23	1561	1160			
	21	105	412	2	17	567	606	929	3.0	19.0
EP 201	2	2			1	6	23			
35 ga	6	6	1		1	4	7			
	10	13	3		1	3	16			
	14	548	101		7	209	223			
	21	542	154	2	5	468	536	1114	1.2	2.8
EDB + AA	2	11			4	17	44			
6 + 25 ga	6	7	2	2	7	7	13			
	10	17	5	5	9	5	28			
	14	913	48	4		722	293			
	21	536	93	3	2	354	129	1064	1.1	7.7
L.S.D.	.05	128	95		24	203	165	75.8	0.79	

[a]Number per 150 ml. soil extracted by the Christie-Perry method (1).
[b]Numerical index where 1 = no disease and 5 = severe disease.
[c]Per cent of plants infected.

phorate + AA and zinophos + AA did not affect nitrification nor were they among the best materials tested for control of nematodes and fungi. this is a clear illustration of the fact that the entire soil community of microorganisms should be considered when using broad-spectrum fumigants to improve crops on old agricultural land. It should be stressed that the soil contains beneficial organisms necessary in the release of nitrogen from organic compounds. The ammonifying and nitrifying bacteria are important in conversion of organic nitrogen to ammonia and on to the nitrate-nitrogen form which is utilized by crop plants. Where fertilizer practices include high ammonia components and are not adjusted to compensate for the depression of nitrification prevalent for a period after fumigation, yields may not show an increase as a result of control of pathogenic nematodes and disease organisms.

Test 4. Excellent control of the 4 nematode species present was achieved by both rates of EP 201 (Table 6). Fusarium wilt (race 2) and Phoma stem canker were also dractically reduced by fumigation. In this test where nitrogen

Table 4. Response of nematodes and nitrifying organisms to fumigants applied with (+) and without (-) plastic.

		Nematodes												Nitrif.	
		+						-						+	-
Treatment	Ga	Tr[a]	B	He	Hg	Tc	D	Tr	B	He	Hg	Tc	D	ppm NO_3-N	
		1 month after fumigation													
Control		94[b]	15	33	61	644	22	22	13	49	76	1087		1164	1027
Nemex	30													176	192
Vorlex	30				7	19								511	492
SMDC	30	7	1	1	7	377		12		51	16	349		1103	1330
EP 230	30					4						12		402	957
EP 201	30	1				97				8		75		222	434
phorate + AA	5 + 30	14		55	30	198			3	11	41	197	35	845	1053
zinophos + AA	4 + 30	4		2	14	476		29	7	191	40	570		1073	1061
Telone-PBC	20	18						43	39	98	30	749		682	857
Telone-PBC	28													79	369
MC-2	3#/100 ft^2													123	54
L.S.D. .05		35			12	208				41	26	84		413	205
		2 months after fumigation													
Control		121	61	28	61	724	10	63	12	121	59	649		1110	1183
Nemex	30	155	2			6		54	1		3	5		693	893
Vorlex	30	4	2		10	7		29			1	7		885	700
SMDC	30	47	3	17	11	155	1	88	16	58	21	191		1240	1010
EP 230	30	47				31		44	1	1		26		660	920
EP 201	30	67						4	1		6	1		373	818
phorate + AA	5 + 30	14	8	8	59	118	10	31	27	53	59	606	12	1005	1094
zinophos + AA	4 + 30		9	23	37	40	3	17	37	46	92	188		1195	1041
Telone-PBC	20	72			1	10		15		9	14	158		909	1223
Telone-PBC	28	15						8						344	332
MC-2	3#/100 ft^2							6						270	601
L.S.D. .05		43	25	14	17	52		30		33	45	117		399	476
		3 months after fumigation													
Control		106	44	27	13	253	24	75	72	166	7	201	24	1386	1241
Nemex	30	160			3	2	10	270				25		1471	1036
Vorlex	30	105			1	22	11	134	2	16	1	10		1853	1083
SMDC	30	94	15	2	17	138	6	209	10	8	5	48	8	1391	1101
EP 230	30	278						109				23		1895	1278
EP 201	30	136	58	109		29	16	297	2	2		53	5	1083	1068
phorate + AA	5 + 30	2	62	39	16	59			52	28	11	83	46	1893	1145
zinophos + AA	4 + 30	3	15	21		28	13			10		13		1945	1459
Telone-PBC	20	165		37		26		240		19		102		1613	1181
Telone-PBC	28	100				6		315	5	2		13		1196	951
MC-2	3#/100 ft^2	31				1		69			1	22		1528	1115
L.S.D. .05		69	20	35		74		121	32	35		16			

[a]Tr = _T._ _christiei_, B = _B._ _longicaudatus_, He = _H._ _erythrinae_, Hg = _H._ _galeatus_, Tc = _T._ _capitatus_, D = _D._ _heterocephalus_.
[b]Number 150 ml soil extracted by the Christie-Perry method (1).

Table 5. Comparison of tomato yields with severity of rootknot infection in fumigated soil with (+) and without(-) plastic.

Treatment	Ga	Rootknot index[a] +	Rootknot index[a] -	Yield bu/A +	Yield bu/A -
Control		3.8	3.7	924	988
Nemex	30	3.0	3.6	450	900
Vorlex	30	2.4	2.5	623	1004
SMDC	30	2.2	3.3	818	893
EP 230	30	2.5	2.9	600	947
EP 201	30	2.9	2.8	594	1024
phorate + AA	5 + 30	3.5	3.9	693	1010
zinophos + AA	4 + 30	3.1	3.8	790	950
Telone-PBC	20	2.4	3.8	663	1050
Telone-PBC	28	1.5	2.8	577	942
MC-2	3#/100 ft^2	1.8	1.4	481	1118

[a]Numerical rating of galling on plant roots 5 months after planting: 0 = none, 4 = severe infestation of *M. incognita acrita*.

was applied as NH_4NO_3 and KNO_3, no problem resulted from the retarded nitrification, and increased yields of tomato fruit were correlated with nematode and disease control. Yields from non-fumigated soil and areas fumigated with 35 and 50 gallons per acre of EP 201 were 287, 752 and 692 bushels per acre, respectively.

The results of these tests show that the combination of fumigants, plastic mulch and high analysis fertilizers can contribute greatly to successful cropping of old land to tomato if the entire width of the bed beneath the plastic is fumigated and nitrogen in the fertilizer is used mostly in the nitrate form. The plastic apparently does not seal the chemical vapors into the soil. On sandy soils the planting time is not delayed by using plastic over the fumigant. Increased control as a result of mulching immediately after application of the material probably can be traced largely to retention of moisture through-out the soil profile. Since the soil surface does not tend to dry, premature escape of the fumigant is prevented.

Table 6. Correlation of nematode control with yields from tomato grown with high nitrate-nitrogen fertilizer on mulched fumigated soil.

Treatment	Number of nematodes per 150 ml soil — Weeks after application: 2	6	10	15
	Trichodorus christiei			
Control	113[a]	281	23	33
EP 201 35 ga	0	21	1	0
50 ga	0	3	10	3
	Belonolaimus longicaudatus			
Control	64	50	52	47
EP 201 35 ga	4	3	2	8
50 ga	0	0	0	5
	Dolichodorus heterocephalus			
Control	348	190	2	12
EP 201 35 ga	4	5	0	0
50 ga	0	0	0	0
	Tylenchorhynchus capitatus			
Control	420	283	135	49
EP 201 35 ga	0	3	4	12
50 ga	0	2	12	10

[a]Extracted by the Christie-Perry method (1).

Leaching of fertilizer nutrients is virtually eliminated by the use of plastic mulch. This horticulturally favorable environment of uniform moisture and consistently available nutrients to which plant roots are exposed beneath plastic seems to buffer the damage caused by nematodes and root-pruning soil-borne pathogens on tomato. The plants tolerate higher concentrations of nematodes about the roots without showing severe stunting.

Maintenance of a high water table with this practice encourages the root system to remain close to the bed surface beneath the plastic and limits growth to that volume of soil which has been fumigated. This is particularly desirable on land infested with the tomato wilt disease organisms. Vagrant roots escaping into the untreated alleys would be vulnerable to infection, and most of the benefit to be derived from soil fumigation would be lost.

Another advantage of growing a crop under plastic mulch is derived from the fact that cultivation of weeds is not necessary. Not only is the cost of weeding reduced, but control of soil-borne pathogens is increased by the elimination of root pruning which inevitably accompanies cultivation.

Recontamination is held at a minimum in the volume of soil occupied by the plant roots. Non-fumigated soil is not introduced to the area protected by the mulch, and with all the fertilizer supplied in the initial preparation of the beds, no mechanical equipment comes in contact with the bed to spread pathogens. Although this practice is expensive ($300 to $400 per acre for fumigants, fertilizer and plastic film), with it high value crops such as tomato which may be expected to yield 1,000 to 1,500 bushels per acre of quality fruit can be consistently successful on old agricultural land.

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CRITERIA FOR GRADING FLORIDA SWEET CORN

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Abstract

Commercial grading practices were evaluated by measuring the physical characteristics of 4,645 packed and discarded ears. In the warm spring months, 92 percent of the fancy grade Iobelle sweet corn sampled in the Everglades area had ears at least 1 or 2 inches longer than the 6 inch minimum requirement. In the cool winter months, ears harvested in eastern Palm Beach and Broward counties were shorter and had poorer tip fill.

Sixty eight percent of the ears which were discarded as non-fancy culls had marketable lengths of 3 to 6 inches and could have been husked and trimmed to meet the requirements of the U.S. consumer standards. Longer ears had higher percentages of their length filled with

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Table 1. Cob length distribution for fancy grade and discarded ears of Iobelle sweet corn harvested in the East Coast and Everglades areas.

Harvest month	Number Ears	Cob length - inches 4	5	6	7	8	9	Ave. Cob length inches
		Percent of total number ears						
Fancy - East Coast								
Feb.	230			30	64	6		7.1
March	288		2	42	52	4		6.9
April	682			10	70	20		7.5
Fancy - Everglades								
April	634			6	70	24		7.5
May	310			2	25	69	4	8.1
Discards - East Coast								
Feb.	862	8	32	56	4			5.9
March	502	1	17	51	30	1		6.5
April	120		2	21	68	9		7.2
Discards - Everglades								
Feb.	757	5	22	60	13			6.1