SOIL FUMIGANTS FOR TOMATO PRODUCTION ON ROCKDALE SOILS

R. McSorley
Department of Entomology and Nematology
IFAS, University of Florida
Gainesville, FL 32611
R. T. McMillan, Jr., and J. L. Parrado
IFAS, University of Florida
Tropical Research and Education Center
18905 S.W. 280 St.
Homestead, FL 33031

Additional index words. nematodes, weeds, diseases.

Abstract. **Soil fumigants were evaluated for their activity against plant-parasitic nematodes; weeds; root diseases caused by *Fusarium* spp., *Pythium* spp., *Rhizoctonia solani* Kuehn, and *Verticillium albo-atrum* Reinke & Berth; and for their effects on tomato (*Lycopersicon esculentum* Mill.) yields in 3 field tests conducted on Rockdale soils in Dade County, Florida from 1983-1985. In most cases, fumigants containing methyl isothiocyanate and/or chlorinated C_3 hydrocarbons performed as well as methyl bromide-chloropicrin combinations in suppressing pest populations and enhancing yield. Performances of metam-sodium and dazomet were usually intermediate between those of the previously mentioned soil fumigants and unfumigated control plots. In one test however, metam-sodium, as well as chloropicrin and oxamyl failed to suppress pest populations below those of untreated plots.**

Use of broad-spectrum soil fumigants beneath polyethylene mulch has been a useful control measure for nematodes, soilborne organisms, and weeds in tomato (*Lycopersicon esculentum*) production for over 20 years (12). Previous research has demonstrated the efficacy of a variety of these materials against numerous nematodes and disease problems in Florida (9,10,13) and Georgia (5). The most frequently used fumigants have been mixtures of methyl bromide and chloropicrin (14). Currently, the Florida tomato industry is heavily dependent on methyl bromide-containing fumigants. However, there is a need to re-examine the efficacy of other broad-spectrum materials so that tomato producers could have a choice of effective fumigants, should regulatory action eventually threaten the status of one or more specific products.

Recently, several fumigants containing methyl isothiocyanate and/or chlorinated C_3 hydrocarbons, were shown to be comparable to methyl bromide-chloropicrin mixtures in controlling nematode and *Fusarium* problems on sandy soils in southwestern Florida (11). Fumigants containing 67% methyl bromide have also been effective in controlling root-knot nematodes (*Meloidogyne* spp.) and soilborne diseases and enhancing tomato yield on calcareous soils in southeastern Florida (15). There are important differences in the plant-parasitic nematodes typically found in sandy soils and those found in the calcareous Rockdale soils in the southeastern part of the state. The root-knot nematode (*Meloidogyne incognita* (Kofoid & White) Chitwood) is a serious pest of tomatoes on both soil types. However, on sandy soils, the sting nematode (*Belonolaimus longicaudatus* Rau), awl nematode (*Dolichodorus heterocephalus* Cobb), and stubby-root nematode (*Paratrichodorus christiei* [Allen]Siddiqi) can affect tomato plants, but these species are rare or unknown on Rockdale soils. On Rockdale soils the reniform nematode (*Rotylenchulus reniformis* Linford & Oliveira) is very common and is known to damage tomatoes (16). The present studies were conducted in order to assess the efficacy of fumigant and nematicide alternatives to methyl bromide on Rockdale soils in Dade County.

Materials and Methods

Three separate experiments were conducted during the course of this study. All tests were carried out in Rockdale fine sandy loam soil (2), with pH = 7.3 to 7.8, at the IFAS Tropical Research and Education Center in Homestead, Florida.

Test 1. The site in which this test was conducted had previously been planted to snap bean (*Phaseolus vulgaris* L.) in the late summer of 1983. Materials evaluated in this test included: MB/C, formulated as Dowfume MC-33 (67% methyl bromide [MB], 33% chloropicrin [C]), at a rate of 225 lb./bedded acre; MS/DD/C, formulated as Volrex 201 (34% chlorinated C_3 hydrocarbons [DD], 17% methyl isothiocyanate [MS], 15% chloropicrin [C], 34% inert ingredients), injected into beds at a rate of 25 gal/bedded acre; metam-sodium formulated as Vapam (32.7% sodium N-methyldithiocarbamate, 67.3% inert ingredients), drenched over the surface of the beds at 100 gal in 3,000 gal of H_2O/bedded acre; dazomet, formulated as Mylone 99 G (99% dazomet [tetrahydro-3,5-dimethyl-2H-1,3,5-thiadizine-2-thione]), 1% inert ingredients), spread over the bed surface at 530 lb./treated acre with a fertilizer spreader (Gandy) and incorporated into the beds by rototilling. The fumigants, MB/C and MS/DD/C, were injected into beds at a 6-inch depth from 3 chisels spaced 12 inches apart, on 5 Dec. 1983 and the beds covered immediately with a 1½ mil opaque gray-on-black polyethylene mulch. One of the dazomet treatments (dazomet + plastic seal) was also covered with polyethylene mulch, but the other dazomet treatment (dazomet + water seal), the metam-sodium treatment, and an untreated check were left uncovered and received 2 hrs of overhead irrigation immediately after treatment application, at approximately one inch an hour. The plot design was a randomized complete block, with 6 treatments and 4 replications. Each individual plot consisted of a bed 50 ft long and 42 inches wide, bedded rows on 6-ft centers. Prior to fumigation, 2000 lb./acre of fertilizer (N-P-K = 8-16-16) was incorporated into each bed. 'Flora-Dade' tomatoes were seeded in containerized flats (Speedling) with a peat-vermiculite mix (50% v/v) on 18 Nov. and transplanted as a single row of plants into the field on 16 Dec., at a distance of 12 inches between plants in rows. Plants were irrigated

Florida Agricultural Experiment Stations Journal Series No. 6830.
No endorsements or registrations implied herein.
The authors wish to thank the Florida Tomato Exchange, NOR-AM Agricultural Products, Inc., and Hopkins Agricultural Chemical Co. for financial assistance, and J. S. Reynolds, W. H. Dankers, and M. S. Little for technical assistance.

twice per week with overhead sprinklers, and were sprayed on an as-needed basis to control insects and foliar diseases. Herbicides were not applied to the plots, other than the test materials.

A soil sample for analysis of plant-parasitic nematodes was collected from each bed on 4 Jan. 1984 and again on 22 Mar. Each sample consisted of soil collected with a hand trowel to a depth of 4-6 inches from the root zones of 15 plants per plot. In the laboratory, each sample was passed through a 0.16-inch sieve to remove rock, and the nematodes were extracted from a 0.2-pint subsample by a modification (8) of Jenkin's (6) sieving and centrifugation method.

Plots were harvested on 26 Mar. by removing, grading, and weighing all fruit from 10 adjacent plants per plot (10 ft of row). The root systems of these 10 plants were also removed and rated for galling from root-knot nematodes and for necrosis due to *Fusarium* spp., *Pythium* spp., and *R. solani.* Root galling was rated on a 0-5 scale, where 0 = 0 galls per root system, 1 = 1-2 galls, 2 = 3-10 galls, 3 = 11-30 galls, 4 = 31-100 galls, and 5 = more than 100 galls per root system (17). Browning from root diseases was rated on the Horsfall-Barratt (4) 1-12 scale, where 1 = 0% or root surface covered by disease 2 = 0-3%, 3 = 3-6%, 4 = 6-12%, 5 = 12-25%, 6 = 25-50%, 7 = 50-75%, 8 = 75-88%, 9 = 88-94%, 10 = 94-97%, 11 = 97-100%, and 12 = 100% of root surface covered by disease.

Kerr's (7) basal medium was used to estimate soil fungal populations. A soil sample for analysis of soil-borne fungi was collected from each treatment bed 10 days after fumigation. Soil preparation and sample dilution was after that of Averre (1). Colony counts from 4 replications were made after 24 hrs. Data were analyzed by an analysis of variance, followed by mean separation using the Waller-Duncan test (3).

Weed populations in the plots were assessed by counting a 2.0-m-long section of row on 18 Jan. and by weighing the weed growth from a 2.0-m section on 26 Mar.

Test 2. The site for this test had been previously planted to okra [*Hibiscus esculentus* (L.) Moench.] during the summer of 1984. Materials evaluated in this test were: MB/C, formulated as Terr-O-Gas (67% methyl bromide, 33% chloropicrin), at a rate of 225 lb./bedded acre; MS/DD/C at 25 gal/bedded acre, MS/DD, formulated as Vorlex (80% chlorinated C_3 hydrocarbons, 20% methyl isothiocyanate) at 25 gal/bedded acre; and MS, formulated as Trapex 40 (40% methyl isothiocyanate, 60% inert ingredients) at 25 gal/bedded acre. All 4 of the chemicals were injected into beds at a 6-inch depth from 4 chisels spaced 8 inches apart. Also evaluated was metam-sodium, applied at 50 gal/treated acre in a 16-inch band, equivalent to 19 gal/bedded acre. Treatments were applied on 1 Nov. 1984 and all beds, including untreated controls, were covered with polyethylene mulch immediately after treatment. The plot design was a randomized complete block with 6 treatments and 4 replications. A soil sample for analysis of soil-borne fungi was collected from each treatment bed before and after fumigation, 16 Nov. and 23 Feb. Handling of soil samples and colony counts was after that in Test 1. Other cultural features were similar to Test 1, except that bed length was 25 ft and a 15-in spacing between plants was used. 'Flora-Dade' tomatoes were transplanted into the beds on 9 Nov. 1984.

A 10-ft section of row (8 plants) was harvested for mature fruit on 13 Feb. 1985 and again on 22 Feb. for all fruit. Soil samples for extraction of plant-parasitic nematodes were collected on 16 Nov., 8 Jan., and 22 Feb. Root systems of 6 plants from each plot were collected on 22 Feb. and rated separately for galling from root-knot nematodes using Taylor and Sasser's 0-5 scale (17), and for discoloration from soilborne diseases, using a 0-10 scale, where 0 = roots clean and free of browning, and 10 = roots completely brown. Weed populations were assessed on 21 Feb. by rating a 10-ft section of each bed for coverage by weeds, using Horsfall and Barratt's (4) 1-12 scale.

Test 3. This test was also conducted in a site previously planted to okra, but consisted of 9 treatments: MB/C, MS, MS/DD, MS/DD/C, and metam-sodium (Vapam) at the same rates and application methods as in Test 2; metam-sodium formulated as Busan 1020 (33% sodium N-methyldithiocarbamate, 67% inert ingredients) drenched onto the bed surface in a 16-inch band at 50 gal/treated acre or 19 gal/bedded acre; chloropicrin formulated as Soilex C-17 (17% chloropicrin, 83% penetrating solvents), injected through 4 chisels at 25 gal/bedded acre; and oxamyl formulated as Vydate L (24% oxamyl [methyl *N'N*-dimethyl-*N*-([methylcarbamoyl)oxy]-1-thiooxamimidate]), 76% inert ingredients), applied foliarly at 2.0 qt/acre in 100 gal water/acre on 3 occasions at 2-week intervals, beginning 2 Jan. 1985; and an untreated control. Eight treatments were applied on 30 Oct. and 1 Nov. 1984, and all beds, including controls, were covered with polyethylene mulch immediately after treatment. The chloropicrin treatment was applied on 5 Nov. The plot design was a randomized complete block, with 9 treatments and 4 replications. A soil sample for analysis of soil-borne fungi was collected from each treatment bed before and after fumigation, 29 Oct. and near the end of the experiment, 17 Apr. Handling of soil samples and colony counts were as in Test 1. Cultural conditions were identical to Test 2, except that bed length was 50 ft. 'Flora-Dade' tomatoes were seeded directly into all beds on 13 Nov. Despite overhead irrigation, a freeze on 21 Jan. severely damaged plants in these plots. Recovery was aided by weekly applications of foliar fertilizer (MIC-RO-PAC®, N-P-K = 11-8-5) at 1.5 qt/acre.

Tomatoes in 10-ft sections of row in each plot were harvested, graded, and weighed on 4 successive occasions: 28 Feb., 21 Mar., 4 Apr., and 16 Apr. Soil samples for extraction of plant-parasitic nematodes were collected on 4 Dec., 16 Jan., and 16 Apr. Root systems of 6 plants per plot were rated for galling from root-knot nematodes on 16 Apr., using Taylor and Sasser's 0-5 scale (17). Foliar damage from the 21 Jan. freeze was evaluated on 25 Jan. by rating damaged foliage on the Horsfall and Barratt (4) 1-12 scale. Weeds were evaluated on 14 Dec. by counting the weeds present in 3.3 ft of bed and rating the amount of a 3.3 ft section of bed covered by weeds, using the Horsfall and Barratt (4) 1-12 scale.

Results

Test 1. The reniform nematode (*R. reniformis*) and the root-knot nematode (*M. incognita*) were common in soil in these test plots. Although soil populations of root-knot nematodes were below detectable levels on 4 Jan., popula-

Table 1. Nematode, weed, and harvest data by treatment from tomato plots, 1983-84 (Test 1)[z].

Fumigant[y]	Nematodes/0.2 pt soil: Reniform 4 Jan.	Reniform 22 Mar.	Root-knot 22 Mar.	Root gall index[x]	Weeds/2.0 m of row—1/18: Santa Maria	yellow nutsedge	total weeds	Total fruit yields (kg)[w]
None	81 a	2259 a	311 a	2.45 a	94 a	48 a	216 a	23.2 a
Dazomet + plastic seal	6 b	89 bc	6 bc	0.90 abc	11 b	20 ab	58 b	25.4 a
Dazomet + water seal	4 b	22 bc	99 ab	1.65 abc	11 b	25 ab	72 b	24.8 a
MS/DD/C	1 b	5 c	0 c	0 c	8 b	14 b	70 b	26.5 a
Metam-sodium	6 b	119 b	144 a	1.70 abc	4 b	9 bc	42 bc	21.8 a
MB/C	1 b	6 c	1 c	0.02 bc	3 b	3 c	24 c	26.1 a

[z]All data are means of 4 replications; mean separation by the Waller-Duncan test, 5% level.
[y]Dazomet = 99% dazomet, 1% inert ingredients (Mylone 99G). MS/DD/C = 34% chlorinated C_3 hydrocarbons, 17% methyl isothiocyanate, 15% chloropicrin, 34% inert ingredients (Vorlex 201). Metam-sodium = 32.7% SMDC, 67.3% inert ingredients (Vapam). MB/C = 67% methyl bromide, 33% chloropicrin (Dowfume MC-33).
[x]Rating on a 0-5 scale, averaged over 10 plants/plot, Mar. 26.
[w]Yields per 3.05 m of row (10 plants), Mar. 26.

Table 2. Effect of soil fumigation on fungal population of *Rhizoctonia solani* and *Verticillium albo-atrum* in tomato beds, 1983-84 (Test 1)[z].

Fumigant[y]	Total no. of fungal colonies/plate at 1:1,000 dilution	Percent colonies[x]: Rhizoctonia	Verticillium	Root disease rating[w]
None	330 a	15.0 a	20.0 a	1.6 a
Dazomet + plastic seal	40 b	0.0 c	0.4 c	1.6 a
Dazomet + water seal	39 b	0.1 c	0.7 c	1.8 a
MS/DD/C	49 b	6.7 b	5.9 b	1.6 a
Metam-sodium	38 b	0.0 c	0.0 c	1.9 a
MB/C	37 b	0.1 c	0.2 c	1.7 a

[z]All data are means of 4 replications; mean separation in columns by the Waller-Duncan test, 5% level.
[y]See Table 1 for key to fumigant ingredients.
[x]Number of colonies per gram of soil recovered from capsules buried in tomato treatment beds.
[w]Percentage of root system discolored rated on Horsfall and Barratt's 1-12 scale, 26 Mar.

Table 3. Nematode and fungal populations by sampling date and treatment for tomato plots, 1984-85 (Test 2).

Fumigant[z]	Nematodes/0.2 pt soil[y]: Reniform 16 Nov.	Reniform 8 Jan.	Reniform 22 Feb.	Root-knot[x] 8 Jan.	Root-knot 22 Feb.	Fungal propagules/gram of dry soil[y]: Pythium 16 Nov.	Pythium 23 Feb.	Fusarium 16 Nov.	Fusarium 23 Feb.	Rhizoctonia 16 Nov.	Rhizoctonia 23 Feb.
None	62 a	632 a	271 a	12 a	9 a	1210 a	989 a	5100 a	5210 a	13 a	17 a
Metam-sodium	21 a	30 b	71 b	0 b	6 a	1200 a	210 c	4010 a	122 d	13 a	0 c
MB/C	28 a	0 c	1 c	0 b	0 b	1300 a	70 e	4820 a	0 f	14 a	0 c
MS/DD	29 a	20 bc	1 c	0 b	0 b	1200 a	300 b	5020 a	1100 b	14 a	10 b
MS/DD/C	31 a	0 c	10 c	0 b	0 b	1220 a	112 d	6000 a	1.3 e	12 a	0 c
MS	28 a	0 c	0 c	0 b	0 b	1300 a	306 b	5200 a	613 c	14 a	11 b

[z]Metam-sodium = 32.7% SMDC, 67.3% inert ingredients (Vapam), MB/C = 67% methyl bromide, 33% chloropicrin (Terr-O-Gas 67). MS/DD = 80% chlorinated C_3 hydrocarbons, 20% methyl isothiocyanate (Vorlex). MS/DD/C = 34% chlorinated C_3 hydrocarbons, 17% methyl isothiocyanate, 15% chloropicrin, 34% inert ingredients (Vorlex 201), MS = 40% methyl isothiocyanate, 60% inert ingredients.
[y]All data are means of 4 replications; mean separation in columns by Waller-Duncan test, 5% level. All data were transformed by $\log_{10}(x+1)$ prior to analysis.
[x]Juveniles.

Table 4. Weed data and root ratings by treatment for tomato plots, Spring, 1985 (Test 2)[z].

Fumigant[y]	Root gall index[x]	Root disease index[w]	Weed control rating[v]: All weeds	Black medic	Carolina geranium	Yellow nutsedge
None	2.72 a	9.1 a	3.8 a	2.8 ab	3.0 a	2.0 a
Metam-sodium	2.95 a	4.6 b	4.8 a	4.0 a	2.2 a	2.0 a
MB/C	0 b	5.2 b	2.2 a	2.0 a	1.5 a	2.0 a
MS/DD	0.17 b	6.2 ab	2.8 a	2.2 b	2.2 a	1.8 a
MS/DD/C	0.21 b	7.0 ab	3.2 a	2.8 ab	2.2 a	2.0 a
MS	0.33 b	4.5 b	3.0 a	2.0 b	1.5 a	1.8 a

[z]All data are means of 4 replications; mean separation by Waller-Duncan test, 5% level.
[y]See Table 3 for key to fumigant ingredients.
[x]Rating on 0-5 scale for 6 plants/plot.
[w]Rating on 0-10 scale for 6 plants/plot.
[v]Horsfall-Barratt 1-12 scale of weed coverage on a 3.05-m-long section of bed.

tions of both nematode species increased to high levels by harvest, particularly in the untreated control plots (Table 1). Soil populations were reduced by the various treatments, particularly by MS/DD/C or MB/C. Galling from root-knot nematodes was significantly lower than in untreated control plots when either of these 2 fumigants were used (Table 1). The most common weed species present in this test were Santa Maria (*Parthenium hysterophorus* L.) and yellow nutsedge (*Cyperus esculentus* L.). Populations of Santa Maria and total weed populations were reduced by all treatments, and yellow nutsedge by all treatments except dazomet (Table 1). Other weed species present in lower numbers included Virginia pepperweed (*Lepidium virginicum* L.), sowthistle (*Sonchus oleraceus* L.), black medic (*Medicago* spp.), and Carolina geranium (*Geranium carolinianum* L.) Fruit yields were not significantly affected by fumigation, despite the levels of weed and nematode control achieved (Table 1). Although incidence of disease on the tomato root systems was low and unaffected by treatment, the treatments used were all effective in reducing soil populations of *R. solani* and *V. albo-atrum* below levels found in untreated plots (Table 2).

Test 2. Reniform and root-knot nematodes occurred in these plots, and were reduced to very low levels by 4 of the soil fumigants (Table 3). Activity of metam-sodium was intermediate, however. Other plant-parasitic nematodes found in this site included the spiral nematode (*Helicotylenchus dihystera* [Cobb] Sher), the stunt nematode (*Quinisulcius acutus* [Allen] Siddiqi), and the ring nematode (*Criconemella onoensis* [Luc] Luc & Raski), but these occurred at only very low levels (5/0.2 pint soil) and were not affected by treatment. Galling from root-knot nematodes was significantly reduced by 4 of the fumigants compared to unfumigated controls, but not by metam-sodium (Table 4). Root browning from soilborne diseases was reduced compared to untreated levels by metam-sodium, MB/C, or MS (Table 4). All chemicals used were effective in reducing soil populations of *Pythium* spp., *Fusarium* spp., and *R. solani* below levels found in untreated plots (Table 3).

The most common weeds found in this site were black medic, Carolina geranium, and yellow nutsedge. Of these, only black medic was significantly affected by treatment. The metam-sodium treatment was associated with higher black medic populations than several other treatments. No treatments provided significant control of weeds compared to the unfumigated treatment (Table 4). Other weed species occasionally found in the plots included Mexican pricklepoppy (*Argemone mexicana* L.), common ragweed (*Ambrosia artemistifolia* L.), and black nightshade (*Solanum nigrum* L.).

Total yields of marketable fruit and all fruit were improved with MB/C, MS/DD, MS/DD/C, or MS, compared to unfumigated plots (Table 5). Yields of metam-sodium-treated plots were intermediate, and not significantly better than those from the unfumigated plots. Several significant differences within fruit grades were also apparent (Table 5).

Test 3. Reniform and root-knot nematodes were also common in this site, and MB/C was most consistent in reducing soil populations of both species (Table 6). Compared to unfumigated plots, MB/C, MS, MS/DD/C, and MS/DD were each effective in reducing galling from root-knot nematodes to very low levels (Table 6). Plots treated with metam-sodium consistently had significantly higher levels of galling than the untreated plots. Chloropicrin and oxamyl were ineffective in reducing root galling.

Table 5. Yield data by fruit size and treatment for tomato plots, Spring, 1985 (Test 2). Data combined for two harvest dates (13 and 22 Feb.).

Fumigant[z]	Marketable yield (kg) per 3.05 m of row by fruit size[y]						Culls[x]	Total fruit weight
	5x6	6x6	6x7	7x7	7x8	Total		
None	0.6 ab	3.5 a	4.0 a	1.1 a	10.1 a	19.3 a	0.2 a	19.5 a
Metam-sodium	1.6 bc	4.0 a	5.9 b	1.6 a	10.2 a	23.3 ab	0.4 a	23.7 ab
MB/C	2.4 c	5.3 a	6.1 b	2.0 a	11.3 ab	27.1 b	0.5 a	27.6 b
MS/DD	0.4 a	4.1 a	7.1 b	1.9 a	12.9 b	26.4 b	0.3 a	26.7 b
MS/DD/C	1.3 ab	4.2 a	5.6 ab	1.9 a	11.8 ab	24.8 b	0.5 a	25.3 b
MS	1.5 bc	4.9 a	6.3 b	1.5 a	13.0 b	27.2 b	0.5 a	27.7 b

[z]See Table 3 for key to fumigant ingredients.
[y]Means of 4 replications; mean separation in columns by Waller-Duncan test, 5% level.
[x]Fruit damaged by insects and other causes.

Table 6. Nematode counts by sampling date and treatment for tomato plots, 1984-85 (Test 3).

Fumigant[z]	Nematodes per 0.2 pt soil[y]						
	Reniform			Root knot[w]	Stunt	Root gall index[x]	
	4 Dec.	16 Jan.	16 Apr.	16 Apr.	4 Dec.	21 Jan.	16 Apr.
MB/C	0 a	0 a	1 a	0 a	0 a	0.08 a	0.12 a
MS	2 ab	0 a	85 bc	48 bc	0 a	0.30 a	0.00 a
MS/DD	45 cd	1 a	46 b	6 a	0 a	0.18 a	0.90 a
MS/DD/C	8 abc	12 bc	146 bc	25 b	0 a	0.82 ab	1.25 a
Metam-sodium (Vapam)	1 a	14 bc	246 bc	600 d	1 a	2.95 d	4.82 d
Metam-sodium (Busan)	22 bcd	5 ab	334 bc	459 d	0 a	2.85 d	4.70 cd
Chloropicrin	99 d	36 c	591 c	84 c	1 a	2.68 d	3.28 bc
Oxamyl	88 cd	15 bc	234 bc	175 cd	5 a	2.30 cd	4.15 bcd
None	59 cd	25 bc	521 c	220 cd	1 a	1.62 bc	3.15 b

[z]MB/C = 67% methyl bromide, 33% chloropicrin (Terr-O-Gas 67). MS = 40% methyl isothiocyanate, 60% inert ingredients. MS/DD = 80% chlorinated C_3 hydrocarbons, 20% methyl isothiocyanate (Vorlex). MS/DD/C = 34% chlorinated C_3 hydrocarbons, 17% methyl isothiocyanate. 15% chloropicrin, 34% inert ingredients (Vorlex 201). Metam-sodium (Vapam) = 32.7% SMDC, 67.3% inert ingredients (Vapam). Metam-sodium (Busan) = 33% SMDC, 67% inert ingredients (Busan 1020). Chloropicrin = 17% chloropicrin, , 83% penetrating solvents (Soilex C-17). Oxamyl = 24% oxamyl, 76% inert ingredients (Vydate L).
[y]Data are means of 4 replications; mean separations in columns by Waller-Duncan test, 5% level. All data were transformed by $\log_{10}(x+1)$ prior to analysis.
[x]Rating on 0-5 scale for 6 plants/plot.
[w]Juveniles.

Significant control of weeds was not achieved in this test, although treatment with metam-sodium resulted in significantly higher nutsedge populations and bed coverage by weed species than in untreated plots.

Defoliation resulting from freeze damage was severe, but showed no significant differences associated with fumigation treatments at P = 0.05 (Table 7). Because of the severe freeze damage, yields were erratic and showed no significant differences associated with treatments (Table 8).

MB/C, MS/DD, MS/DD/C, MS, and metam-sodium (Vapam) provided significant control pf *Pythium* spp., *Fusarium* spp., and *R. solani*. Metam-sodium (Busan) was slightly effective in reducing the population of all 3 fungi. Chloropicrin was more effective for *Pythium* spp. but ineffective for *Fusarium* spp. and *R. solani*. Oxamyl was not effective for any of the 3 fungi (Table 9).

Table 7. Weed populations by treatment for tomato plots, 14 Dec. 1985 (Test 3).

Fumigant[z]	Freeze damage[x]	Weed coverage[w]	Weed populations/ 1.0 m of row[y]: Yellow nutsedge	Oxalis	Ragweed
MB/C	6.7 a	2.2 a	6.0 a	0.0 a	1.8 a
MS	6.7 a	2.8 a	11.5 ab	3.2 a	0.4 a
MS/DD	6.7 a	3.2 ab	11.2 ab	4.8 a	0.5 a
MS/DD/C	8.0 a	2.8 a	11.0 ab	5.0 a	0.2 a
Metam-sodium (Vapam)	7.4 a	4.5 b	31.2 c	27.0 a	1.2 a
Metam-sodium (Busan)	7.2 a	4.5 b	38.5 c	11.5 a	1.5 a
Chloropicrin	8.8 a	3.5 ab	15.2 ab	8.8 a	1.2 a
Oxamyl	7.8 a	2.5 a	18.5 b	0.8 a	2.0 a
None	8.3 a	3.0 a	7.0 ab	12.0 a	0.5 a

[z]See Table 6 for key to fumigant ingredients.
[y]All data are means of 4 replications; mean separation in columns by Waller-Duncan test, 5% level.
[x]Defoliation from freeze damage rated on Horsfall-Barrett 1-12 scale, Jan. 25, 1985.
[w]Percentage of bed covered by all weeds rated on Horsfall-Barratt 1-12 scale.

Discussion

Several of the fumigants evaluated here could be potential alternatives to methyl bromide-chloropicrin mixtures. These include MS/DD, MS/DD/C, and MS. In Test 2, in which significant yield differences were observed, these materials enhanced yield as much as MB/C did. Metam-sodium was less effective, and intermediate in its influence, as observed elsewhere (5). MS/DD, MS/DD/C, MS, and methyl bromide-chloropicrin mixtures were similar in their ability to reduce nematodes, fungal populations, and root galling. MB/C was still somewhat more effective than other compounds in lowering soil pest populations in Test 3. Dazomet was intermediate in its nematicidal activity (Test 1), but metam-sodium, chloropicrin and oxamyl provided little in nematode control (Test 3), and

Table 8. Yield data by fruit size and treatment for tomato plots, Spring 1985 (Test 3).

Fumigant[z]	Marketable yield (kg) per 3.05 m of row by fruit size[y]: 5x6	6x6	6x7	7x7	7x8	Culls[x]	Total fruit Weight
MB/C	0.71 a	2.06 a	4.10 a	1.15 a	4.75 a	0.62 a	13.39 a
MS	0.77 a	1.40 a	2.66 abc	1.22 a	3.59 a	0.40 a	10.04 a
MS/DD	0.96 a	2.25 a	3.47 ab	0.62 a	3.12 a	0.76 a	11.18 a
MS/DD/C	0.44 a	1.00 a	1.91 abc	0.65 a	3.11 a	0.31 a	7.42 a
Metam-sodium (Vapam)	0.42 a	1.26 a	3.52 ab	1.19 a	4.90 a	0.51 a	11.40 a
Metam-sodium (Busan)	0.19 a	0.35 a	2.11 abc	0.66 a	3.23 a	0.27 a	6.81 a
Chloropicrin	0.21 a	0.28 a	0.26 c	0.33 a	0.99 a	0.02 a	2.09 a
Oxamyl	0.51 a	0.39 a	0.98 bc	0.35 a	2.66 a	0.30 a	4.83 a
None	0.51 a	1.66 a	2.22 abc	0.83 a	3.93 a	0.37 a	9.53 a

[z]See Table 6 for key to fumigant ingredients.
[y]Means of 4 replications; mean separation in columns by Waller-Duncan test, 5% level.
[x]Fruit damaged by insects and other causes.

Table 9. Fungi populations by sampling date and treatment for tomato plots, 1984-1985 (Test 3).

Fumigant[z]	Propagules per gram of dry soil[y]: Pythium spp. 29 Oct.	Pythium spp. 17 Apr.	Fusarium spp. 29 Oct.	Fusarium spp. 17 Apr.	Rhizoctonia solani 29 Oct.	Rhizoctonia solani 17 Apr.
MB/C	1400 a	0 c	9,880 a	0 c	20.6 a	0 d
MS	1390 a	0.4 b	11,000 a	0 c	18.9 a	0.6 c
MS/DD	1380 a	0.5 c	11,620 a	0 c	19.7 a	0 d
MS/DD/C	1370 a	0.5 b	10,810 a	0 c	19.9 a	0 d
Metam-sodium (Vapam)	1300 a	0.2 b	10,000 a	0 c	19.9 a	0 d
Metam-sodium (Busan)	1450 a	978 a	9,800 a	9,990 b	20.1 a	8.9 b
Chloropicrin	1310 a	999 a	10,560 a	10,760 b	17.8 a	19.2 a
Oxamyl	1300 a	1010 a	10,490 a	12,500 a	20.4 a	19.9 a
None	1380 a	1010 a	10,790 a	12,690 a	20.8 a	22.0 a

[z]See Table 6 for key to fumigant ingredients.
[y]All data means of 4 replications; mean separation by Waller-Duncan test, 5% level.

often did not reduce populations below levels found in unfumigated control plots.

MS/DD, MS/DD/C, and MS all achieved significant control of root diseases as indicated by browning indices, but MS was most similar to the methyl bromide-chloropicrin mixtures in obtaining maximum disease reductions. Results with metam-sodium were similar.

Some weed control was achieved in Test 1, with MB/C being most effective and MS/DD/C and metam-sodium similar in their activity. Generally, however, weed control was erratic in these tests and so it is difficult to generalize about weed control with the broad-spectrum fumigants studied. Metam-sodium, formulated as Busan or Vapam, actually enhanced yellow nutsedge populations in Test 3.

MS/DD, MS/DD/C, and MS are as effective as methyl bromide-chloropicrin mixtures on sandy soils in Florida (11), and their results on Rockdale soils are also encouraging. Some of the alternative fumigants performed nearly as well as methyl bromide-chloropicrin mixtures in most instances, and it is possible that future research and trials will further reveal their efficacy. Refinement of application technique and registration by the Environmental Protection Agency of several of the products tested could provide growers with alternative nematicides and fungicides to be integrated into crop management systems for commercial tomato production along with genetic and cultural methods for managing pest populations.

Literature Cited

1. Averre, C. W., III. 1966. Isolating *Pythium* and *Fusarium* from a limestone soil in subtropical Florida. Proc. Soil Crop Sci. Soc. Fla. 26:279-285.
2. Gallatin, M. H., J. K. Ballard, C. B. Evans, H. S. Galberry, J. J. Hinton, D. P. Powell, E. Truett, W. L. Watts, G. C. Wilson, Jr., and R. G. Leighty. 1958. Soil Survey (detailed-reconnaissance) of Dade County, Florida. U.S. Government Printing Office, Washington.
3. Helwig, J. G. and K. A. Council. 1979. SAS User's Guide, 1979 edition. SAS Institute Inc., Cary, NC.
4. Horsfall, J. G., and R. W. Barratt. 1945. An improved grading system for measuring plant diseases. Phytopathology 35:655-(abstr.).
5. Jaworski, C. A., S. C. Phatak, S. M. McCarter, A. W. Johnson, and N. C. Glaze. 1980. Evaluation of fall treatment with broad spectrum chemicals and nematicides for production of pepper, tomato, and cabbage transplants in southern Georgia. J. Amer. Soc. Hort. Sci. 105:756-759.
6. Jenkins, W. R. 1964. A rapid centrifugal-flotation technique for separating nematodes from soil. Plant Dis. Rptr. 48:692.
7. Kerr, A. 1962. The root rot *Fusarium* wilt complex of peas. Austral. J. Biol. Sci. 16:66-69.
8. McSorley, R. and J. L. Parrado. 1981. Effect of sieve size on nematode extraction efficiency. Nematropica 11:165-174.
9. Overman, A. J. and J. P. Jones, 1968. Effect of polyethylene mulch on yields of tomatoes infested with root-knot nematodes. Proc. Soil Crop Sci. Soc. Fla. 28:258-262.
10. Overman, A. J. and J. P. Jones. 1977. Efficacy of one stream versus three of a soil fumigant for production of tomato. Proc. Fla. State hort. Soc. 90:407-409.
11. Overman, A. J. and J. P. Jones. 1985. Soil fumigants for control of nematodes, fusarium wilt, and fusarium crown rot on tomato. Proc. Fla. State Hort. Soc. 97:194-197.
12. Overman, A. J., J. P. Jones, and C. M. Geraldson. 1965. Reaction of nematodes, diseases and fertility to tomato production on old land. Proc. Fla. State Hort. Soc. 78:136-142.
13. Overman, A. J., J. P. Jones, and C. M. Geraldson. 1970. Interaction of cultivars, nematodes, and fumigants on development of *Verticillium* wilt on tomatoes. Proc. Fla. State Hort. Soc. 83:203-208.
14. Overman, and F. G. Martin. 1978. A survey of soil and crop management practices in the Florida tomato industry. Proc. Fla. State Hort. Soc. 91:294-297.
15. Pohronezny, K. and R. McSorley. 1981. *Meloidogyne*-fungal complexes in tomato roots in calcareous soils. Nematol. Medit. 9:151-157.
16. Rebois, R. V., B. J. Eldridge, J. M. Good, and A. K. Stoner. 1973. Tomato resistance and susceptibility to the reniform nematode. Plant Dis. Rptr. 57:169-172.
17. Taylor, A. L. and J. N. Sasser. 1978. Biology, identification and control of root-knot nematodes (*Meloidogyne* species). North Carolina State University Graphics, Raleigh.

Proc. Fla. State Hort. Soc. 98:237-239. 1985.

WATER AND FERTILIZER TIMING FOR TRICKLE-IRRIGATED TOMATOES

S. J. LOCASCIO
Vegetable Crops Department
University of Florida, IFAS
Gainesville, FL 32611
S. M. OLSON AND F. M. RHOADS
North Florida Research and Education Center
University of Florida, IFAS
Quincy, FL 32351
C. D. STANLEY AND A. A. CSIZINSZKY
Gulf Coast Research and Education Center
University of Florida, IFAS
Bradenton, FL 34203

Additional index words. Drip irrigation, ET, *Lycopersicon esculentum*, water frequency.

Abstract. **Tomatoes (*Lycopersicon esculentum* Mill.) were grown in Gainesville on an Arrendondo fine sand, in Quincy on an Orangeburg loamy fine sand, and in Bradenton on an Eau Gallie fine sand to evaluate the effects of water quantity and timing of water and fertilizer application with trickle irrigation on fruit production. 'Sunny' tomatoes were grown on mulched beds with water quantities of 0.25, 0.5, and 1.0 pan applied in 1 or 3 applications/day. Fertilizers, applied at 200-100-300, 206-50-300, and 238-48-382 lb./acre N-P-K on the 3 soil sites, respectively, were applied 100% preplant or 40% N and K and 100% P applied preplant with 60% N and K applied with the trickle irrigation water. On the sandy soils at Gainesville and Bradenton, tomato fruit yields were greater with 0.5 than 0.25 or 1.0 pan water quantity. The number of daily water applications had no effect on total yield. Yields were greater with preplant than split fertilizer application. On the loamy soil at Quincy, fruit production was greater with the 1.0 than 0.5 pan water application with little difference in yield due to water application and fertilizer application timing. Tomato leaf N and K concentrations were generally lower with the 1.0 than 0.5 pan water quantity.**

Florida Agricultural Experiment Stations Journal Series No. 6875.