Table 3. Relationships of soil pH and level of ammonia-nitrogen to watermelon Fusarium wilt incidence, 1974.

Soil treatment[y]	Soil pH (5/3)	Seedling wilt (%)[z]		Wilt after thinning (%)[z]		Yield (tons/acre)	
		Garr.[x]	CG	Garr.	CG	Garr.	CG
pH 5.2-6.0, 25% NH_4-N	5.6	2	1	9	1	21.8	29.6
pH 5.2-6.0, no NH_4-N	6.0	10	6	16	3	16.4	27.8
pH 7.0-7.3, 25% NH_4-N	6.8	16	6	26	3	16.8	26.5
pH 7.0-7.3, no NH_4-N	7.2	8	3	35	0	12.3	29.8

[z]Wilt data given as percentage of plants that died of Fusarium wilt. Thinning was done 5 weeks after planting.
[y]The pH 5.2-6.0 and 25% NH_4-N treatment represents the normal cultural practice. Hydrated lime was used to raise the soil pH to 7.0-7.3 in mid-February, 2 weeks prior to planting.
[x]Garr. = 'Garrisonian' and CG = 'Charleston Gray'.

and lower yields, but this was never statistically significant. This trend to increased seedling wilt incidence may have resulted indirectly from the stunting. We have observed that 'Calhoun Gray' is most likely to wilt when it is a very small seedling, and the high pH stunting may have prolonged its period of greatest susceptibility.

At first glance, our results seem inconsistent with those reported by others on watermelons (1, 4). However, our experiments were conducted on moderately to heavily *Fusarium* infested 'old' watermelon land; whereas, the work of Jones et. al (4) showed that high pH and 25% ammonia-nitrogen reduced the incidence of watermelon wilt for a year or two after Fusarium infestation. This was relative to the incidence of watermelon wilt at a low pH 4.0 and 80% ammonia-nitrogen. Based on these results (1, 4) we would certainly recommend a soil pH of 6.0-6.5 and 25% NH_4-N as a good standard cultural practice for watermelon growers. However, our results show conclusively that growers should not expect to control Fusarium wilt of watermelon on 'old' land by manipulating soil pH and nitrogen source.

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EFFICACY OF SOIL FUMIGANTS APPLIED VIA A DRIP IRRIGATION SYSTEM[1,2]

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Additional index words. root-knot nematodes, methyl bromide, SMDC, DBCP, okra, tomato.

Abstract. **Drip irrigation systems were evaluated as vehicles for distribution of soil fumigants into mulched beds prior to planting. Okra yields were increased following application of DBCP (1,2-dibromo-3-chloropropane) (27 kg/ha) or MBC-33 (methyl bromide 67% + chloropicrin 33%) (392 kg/ha) through a bi-wall linear irrigation system for control of pests in sandy soil. MBC-33 was successfully distributed the full length of a 90 m-bed through the bi-wall tube located on the bed surface under a full-bed, plastic mulch; however, rapid loss of the gas occurred when the fumigant was introduced into a micropore irrigation tape and only 9 m of the plant bed was adequately fumigated. Methyl bromide (488 kg/ha), introduced into the irrigation water applied through a bi-wall tube buried 10 cm in the full-mulched bed, increased yield of tomato 20% and significantly reduced the incidence of root-knot nematodes attacking the crop. Application of methyl bromide through similarly buried micropore tape was ineffective.**

A rapid increase in human population density, especially along the seaboard areas of Florida, has resulted in an increased utilization of water. The inability of the Florida aquifers to provide people, industry and agriculture with unlimited water has prompted changes in the conventional management of agricultural waters.

Water conservation has become a prime goal of Florida agriculture. Monitoring of wells, recycling of tail water, and closed systems of irrigation have received increasing attention by commercial growers as well as researchers in the past 4 years. The ultimate in water conservation may be the drip

[1]This research was supported, in part, by the IFAS Center for Environmental Programs and Natural Resources, University of Florida.
[2]Florida Agricultural Experiment Stations Journal Series No. 256.

irrigation concept, wherein an amount of water is programmed to provide a constant level of moisture near field capacity in the rhizosphere of the crop plant. This can be achieved in row crops by distributing water to the plants through networks of tubes designed to deliver water linearly or from point sources spaced 10 to 90 cm apart along the tube length. This type of irrigation system not only permits precise water control but offers a concise method for applying nutrients (1, 4) and pesticides (3, 5) in the arena of the plant rhizosphere.

Utilization of the irrigation network for application of chemicals during the crop season offers the possibility of using the system to distribute multi-purpose soil fumigants prior to planting.

This paper is an evaluation of the efficacy of several soil fumigants which are routinely applied as linear injections at a depth of about 15 cm below the soil surface in a full-mulch bed culture (2) but which, in this work, were injected by way of the irrigation system.

Materials and Methods

In two field tests a drip irrigation system was substituted for the constant water table which routinely provides water in a full-bed mulch cropping system used for vegetable production on sandy soil (2). In both tests, two types of drip tubing were used: 1) a micropore non-woven polyethylene tubing (Viaflo(R))[3] which at .25 kg/cm² pressure delivers linearly 5.7 lpm water per 305 m of the tubing and 2) a double-chambered bi-wall polyethylene tube (Chapin(R))[4] which at .28 kg/cm² pressure delivers water through single emission ports spaced 60 cm apart at the rate of 9.8 lpm in a 305 m length.

The fields of Myakka fine sand chosen for these tests were naturally infested with root-knot nematodes *(Meloidogyne incognita acrita)*; the area of the first test also was infested with the stubby-root nematode *Trichodorus christiei*.

After planting both fields, openings were cut in the plastic mulch to assay the degree of weed control obtained across the bed following treatment. Irrigation in all plots was programmed for 20 minutes each hour throughout the 12 week crop. After final yields were harvested, soil samples were collected from the plots for estimation of nematode populations associated with the root systems of the okra and tomato crops. The roots were rated for severity of galling due to attack by root-knot nematodes using a scale of 0 = none, 5 = severe galling.

Test 1. Ninety-meter plots were selected as the experimental unit in the initial test in order to measure the efficacy of the soil fumigants at three distances from the point at which the chemical was injected into the tubing. Both the micropore and the bi-wall tubes were placed on the soil surface in the middle of a 75 cm-wide bed prior to banding 1344 kg/ha 18-0-25 fertilizer on the shoulders of the bed and sealing the bed under 1.25 mil black polyethylene mulch. Two weeks prior to seeding 'Clemson Spineless' okra in 2 rows 15 cm from the irrigation tubes, the following soil fumigants were injected into the upstream ends of the tubes: 1-2-dibromo-3-chloropropane (DBCP 12.1EC, 27 Kg a.i./ha) applied over a period of 28 hours into the irrigation water; methyl bromide 67%-chloropicrin 33% mixture (MBC-33, 392 kg/ha) applied over a 15 minute period into the micropore tube while the irrigation system was full of water and into the bi-wall tube both when the tube was full and empty of water; and sodium methyl dithiocarbamate (SMDC 32.7%, 77 l/ha) injected over a period of 5 hours into the irrigation water being applied through the micropore tube.

In each case the far end of the tube was temporarily opened to facilitate rapid movement of the fumigant the entire length of the plot.

Test 2. In the second test both types of irrigation tubes were buried along a line 10 cm below the surface and 25 cm from the middle of the 75 cm-wide bed. Prior to sealing the bed under 1.25 mil black polyethylene mulch, a single band of 18-0-25 fertilizer was placed on the bed surface on the opposite side of the bed from the tubing. Over a period of 20 minutes methyl bromide (MBr 975 kg/ha) was metered into the irrigation system 2 weeks before transplanting 1 row of 2.5 cm x 2.5 cm containerized transplants of 'MH-1' tomato on 45 cm spacing in the center of the bed. Non-fumigated plots using both types of irrigation were planted in a similar manner.

Results

Pre-plant application of MBC-33 through the bi-wall drip tube gave excellent control of the root-knot nematode on the okra crop subsequently grown in the treated plots (Table 1). However, populations of the stubby-root nematode were not altered. Significant increases in yield were obtained when the fumigant was injected into the system

[3]Manufactured by E. I. duPont de Nemours and Co., Wilmington, Del.

[4]Manufactured by Chapin Watermatics, Inc., Watertown, N.Y.

Table 1. Effect of pre-plant soil fumigants, injected into 90-meter lengths of micropore or bi-wall drip irrigation tubes on okra yields and nematodes associated with the crop at time of harvest.

Treatment	Root-knot index[z]			Trichodorus/ 150 ml soil			Yield No. okra pods		
	0-30′	150-180′	250-280′	0-30′	150-180′	250-280′	0-30′	150-180′	250-280′
Micropore									
Control	3.0c[x]	4.2d	4.7d	81b	42ab	72b	197c	300c	319c
DBCP (27)[y]	3.0c	1.0b	1.0b	83b	250d	263d	222c	538b	580b
MBC-33 (392)	0.0a	5.0d	5.0d	13a	185c	190c	1263a	579b	300c
SMDC (224)	4.3d	4.3d	4.3d	14a	89b	86b	177c	210c	290c
Bi-wall									
Control	2.5b	3.3c	3.3c	82a	61a	45a	300e	465cd	259e
DBCP (27)	1.5b	2.0b	0.0a	133ab	210b	390c	434d	356de	482cd
MBC-33 (392)									
—water	0.0a	0.0a	0.6a	27a	105ab	121ab	582bc	697b	638b
+water	0.0a	0.2a	0.0a	12a	34a	56a	883a	832a	960a

[z]Index: 0 = no root galling; 5 = severe root galling.

[y]Kg a.i./ha.

[x]Means within each parameter followed by the same letter do not differ significantly (P = 0.05) according to Duncan's multiple range test.

Table 2. Effect of methyl bromide (975 kg/ha) applied through micropore and bi-wall irrigation systems on root-knot nematode (Meloidogyne sp.) populations[z] in 9 positions of the treated bed at maturity of the tomato crop.

Treatment	Depth cm	Position of Sample					
		Bi-wall			Micropore		
		F. band[y]	Plant	Tube	F. band	Plant	Tube
Control	10	8a[x]	13a	8a	0a	65ab	50ab
	20	37a	137c	137c	35a	94abc	113c
	30	144cd	128c	244d	167cd	169cd	235d
M. bromide	10	0a	0a	2a	0a	11a	29a
	20	0a	1a	10a	41a	83abc	73abc
	30	1a	0a	1a	73abc	214d	230d

[z]Number of nematodes per 150 ml. soil, mean of 4 replications.
[y]F. band = fertilizer band.
[x]Means followed by the same letter do not differ significantly (P = 0.05) according to Duncan's multiple range test.

while the irrigation was in operation. The fumigant performed equally well along the entire 90 m length of the tubing. MBC-33 distended the micropore tube only an approximate 9 m along the 90 m length. Nematode control and yield increase was evident only in that portion of the bed (Table 1). Conversely, DBCP performed erratically with either type of tube but seemed to significantly increase okra yields. SMDC applied through the micropore tube failed to control nematodes or improve okra yields.

In test 2, MBr controlled root-knot nematodes in the soil of the mulched tomato bed at a distance 50 cm laterally from and 20 cm below the bi-wall tube buried in the bed (Table 2). Populations of root-knot nematodes were not affected by injection of MBr into the buried micropore tube. Regardless of treatment, a greater marketable yield was produced in plots using the bi-wall system. The fumigant improved yield even further in the bi-wall system, but had no effect on yields from plots with the micropore system.

In both tests, weed control was excellent the full width of the beds treated with MBC-33, MBr, or SMDC.

Discussion

The feasibility of applying soil fumigants through drip irrigation systems may depend on the type of drip tubing used in the system and in the case of DBCP, the timing of application. Broad-spectrum fumigants are biocides and, therefore, must be applied prior to planting a crop. However, DBCP as a fumigant is relatively non-phytotoxic and can be applied to living plants. Previous work (3) indicated that application of DBCP over 9 weeks of the crop season was efficacious in controlling root-knot and improving tomato yields. Comparing previous results with the results of this work, it is evident that following a one-time application of DBCP with irrigation that develops a constant downward flow of water may dilute and leach the chemical and forestall proper benefit from the material as a nematicide.

Table 3. Total marketable yield of tomato cv 'MH-1' from beds treated 2 weeks before planting with methyl bromide applied through the irrigation system.

Treatment	Rate kg/ha	Marketable fruit kg/ha	Root-knot index[z]
Micropore			
Control	—	17,417c[y]	5.0b
M. bromide	975	17,697c	4.5b
Bi-wall			
Control	—	26,003b	5.0b
M. bromide	975	31,390a	0.2a

[z]Index of root-knot galling: 0 = none; 5 = severe.
[y]Means followed by the same letter in each parameter do not significantly differ (P = 0.05) according to Duncan's multiple range tset.

Failure with SMDC may have been due to the position of the micropore tube. Although the tube was covered by the mulch, the permeability of the 1.25 mil polyethylene to the fumigant vapors and the heat developed under the mulch when exposed to the sun may permit rapid dissipation of the fumigant to the atmosphere.

SMDC may perform better when applied into tubes which have been buried in the mulched beds. Since SMDC is water miscible, it would lend itself particularly well to drip irrigation systems if effective rates and placement can be devised.

The bi-wall system was an efficient vehicle for MBr or MBC-33, whether buried or laid on the surface of the bed under the mulch. In the same way that the carrier tube allows for equilibrium of the water flow along the length of the tube, so the bi-wall permits distribution of the fumigant the length of the line before release is facilitated through the outer chamber into the soil. In crop management systems with or without full-bed mulch it may be wise to bury the tube to deter leaching of soluble nutrients and to ease problems related to water quality and clogging of the emission ports. In either case, methyl bromide alone or with chloropicrin may be compatible with the system.

Summary

Methyl bromide at the rate of 975 kg/ha and methyl bromide 67%-chloropicrin 33% mixture at 392 kg/ha were successful injected into a bi-wall drip irrigation system to control root-knot nematodes in mulched ground beds 75 cm wide. Okra yields were increased by treatment with the methyl bromide-chloropicrin mixture and tomato yields were increased with methyl bromide. Treatment with DBCP and SMDC through the irrigation system prior to planting was not as successful in improving yield of either okra or tomato.

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