PEST CONTROL WITH ALTERNATIVE FUMIGANTS TO METHYL BROMDE FOR TOMATO

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Tomato *(Lycopersicon esculentum* Mill.) was grown during two seasons at three location to evaluate various chemicals and combination of chemicals as alternatives to methyl bromide (MBr) soil fumigant. Polyethylene-mulched tomato was grown with drip irrigation at two sites on Millhopper fine sands near Gainesville, FL (Horticultural Unit and Green Acres Research Farm) during the springs of 1994 and 1995, and near Bradenton FL with seep irrigation on an EauGallie fine sand in the spring and fall of 1994. Sites at the Horticultural Unit were heavily infested with purple and yellow nutsedges *(Cyperus rotundus* L. and *Cyperus esculentus* L. and moderately infested with the root-knot nematode, *Meloidogyne incognita* (Kofoid and White) Chitwood, and various soil fungi. The Green Acres site was heavily infested with *Meloidogyne arenaria* (Neal) Chitwood race 1, the peanut root-knot nematode. Sites at Bradenton were heavily infested with purple nutsedge, moderately to heavily infested with Fusarium wilt, *(Fusarium* oxysporum Schlecht. f. sp. *lycopersici* (Sacc.) Snyd. and Hans. race 3), and lightly infested with the rootknot nematode, M. *incognita.*

Treatments were arranged in randomized complete-block designs with six replications on single row plots with 0.9 m-wide bed tops. Black 0.038 mm thick polyethylene mulch (white mulch in the fall at Bradenton) was then applied over the bed top. Double-wall drip tubing (Chapin Twinwall, Watertown, NY),was placed 7.5 to 10 cm from the bed center under the mulch for application of water, fertilizer, and fumigants at Gainesville. At Bradenton, drip tubing was placed in appropriate plots to allow delivery of drip-applied fumigants. The crop was irrigated by subsurface irrigation. Soil fumigants were injected with three chisels per bed spaced 30 cm apart at a depth of 15 to 20 cm. Injected treatments were 98-2% MBr-chloropicrin (Pic) (450 $kg \cdot ha^{-1}$), 67-33% MBr-Pic (390 $kg \cdot ha^{-1}$), Pic (390 $kg \cdot ha^{-1}$) and 1,3-D + 17% Pic (327 $L \cdot ha^{-1}$). Pebulate (for nutsedge control) was applied on the bed surface and incorporated 15 to 20 cm deep with a roto-tiller before fumigant application. Dazomet (440 $kg \cdot ha^{-1}$ from a 92% formulation) and metain-sodiun (300 $L \cdot ha^{-1}$ from a 32% formulation) were applied on the bed surfaces and immediately incorporated. At the Horticultural Unit site, dazomet also was incorporated and then watered into the soil with 6 mm depth of water before mulch application. Metam-sodium (300 $L \cdot ha^{-1}$) and tetrathiocarbonate (1870 $L \cdot ha^{-1}$ plus 2 additional applications 187 $L \cdot ha^{-1}$) were applied through two drip tubes spaced 30cm apart per bed at Gainesville, and one drip tube at Bradenton. Tomato was transplanted into the treated soil three weeks after fumigant application in 1994 in early Apr., late in Mar. in 1995 at Gainesville, and on 7 Mar. 1994 and on 18 Oct. 1994 at Bradenton. Tomato roots were assessed for the presence of fungi in mid-June at Gainesville. At Bradenton, Fusarium wilt race 3 infected plants were enumerated weekly. After harvest, six plants per plot were collected for assessment of nematode galling of the root system at Gainesville and all plants per plot were assessed at Bradenton. Counts of nutsedge plants growing through the polyethylene mulch were made approximately 8 weeks after transplanting in an area of 0.1 m^2. Counts were made on the drip-tubing side of the plots at the Horticultural Unit. At Bradenton, nutsedge plants that emerged through the mulch film were counted in four randomly selected areas on each side of the plant row. Fruit were harvested twice at the mature green stage.

Marketable fruit yield Relative fruit yield with the two MBr treatments was designated to be 100% at each site (Table 1). At the Horticultural Unit site in 1994, relative yields with the Pic + pebulate and with the 1,3-D+ Pic + pebulate treatments were 86% and 85%, respectively, and in 1995 they were 1141/o and 102%, respectively. At Green Acres, relative yields with the two pebulate containing treatments in 1994 were 60% and 77%, respectively, and in 1995 were both 95%. At Bradenton, relative yields with these two treatments ranged from 101% to 119% during the spring and fall seasons, respectively. In contrast to the fair to excellent production obtained with the two pebulate-containing treatments at the Horticultural Unit in 1994, relative yields were 60% to 70% with Pic, 1,3- D + Pic, dazomet, and metam-sodium drip applied, 45% with soil applied metam-sodium, 47% with tetrathiocarbonate, and 40% with no treatment. Similarly, at Bradenton yields were reduced with alternative fumigants alone but where pebulate was combined with the fumigants

except metam-sodium in spring 1994, yields were equal to that with MBr-Pic containing treatments.
Nematode control Root-knot nematode galling indices were significantly lower with MBr 98-2, MBr 67-33, and 1,3-D + Pic alone and + pebulate than with no fumigant treatment at the Horticultural Unit site (Table 1). Galling indices were intermediate with dazomet + pebulate, and with metam-sodium + pebulate, but were significantly lower than with no fim3igant treatment. Pic and Pic + pebulate provided no control of nematodes. At Green Acres in both seasons, root-knot nematode galling indices were reduced most consistently with MBr treatments. Nematode control was provided with 1,3-D + Pic alone and + pebulate was poor in 1994 and was excellent in 1995. Nematode control was poor with Pic, Pic + pebulate, dazomet, metam Na, and tetrathiocarbonate. At Bradenton, nematode counts were low even with the nonfumigated treatments and root galling indices were not significantly affected by treatments

Soil fungi control. Three predominant pathogenic fungi, *Rhizoctonia solani* Kuhn, *Macrophomina phaseolina* Tassi (Goidanich), and *Fusarium solani* (Mart) Sacc. (emend Snyd. and Hans.), were recovered from tomato roots at the two Gainesville sites. At Gainesville, the total number of colonies of these three fungi isolated from roots were significantly lower with MBr 98-2 and MBr 67-33 in all studies and five of six treatments with Pic alone and Pic + pebulate, and four of seven treatments withl, 3-D + Pic and 1,3-D + Pic + pebulate as compared with the non-fumigated treatments (Table 2). Dazomet, metam Na, and tetrathiocarbonate treatments did not significantly reduce the number of fungal colonies recovered. Where Pic was used alone or in combination with 1,3-D, total fungal counts were reduced as compared with the non-fumigated treatment in nine of the thirteen treatments. Pic is generally regarded as being more fungicidal than MBr, but in these studies, treatments with MBr (98-2 and 67-33) provided higher consistency for reducing fungal infections when compared to treatments with Pic without MBr (2% Pic). At Bradenton (plots were infested with *Fusarium* wilt race 3), use of all fumigants resulted in significant reductions in the percentage of plants infected as compared to the no fumigant treatment.

Nutsedge control. At the Horticultural Unit during the 1994, the nutsedge counts with no treatment was high (30 per 0.1 m^2,Table 2). Nutsedge counts were low per 0.1 m^2 area (number in parenthesis) with MBr 98-2 (7), MBr 67-33 (9), Pic + pebulate (11), and with 1,3-D + Pic + pebulate (15). Counts were higher with Pic (22) and 1,3-D + Pic (34). Nutsedge control was not provided with the other treatments. During the 1995 season, nutsedge counts averaged 3/0.1 m^2 with the two MBr treatments, 4.5/0.1 m^2 with the pebulate-containing treatments, and 16/0.1 m^2 with no treatment During the spring 1994 study at Bradenton, the combination of 1,3-D + Pic + pebulate and metam-sodium + pebulate provided nutsedge control as good as either MBr 98-2 or MBr 67-33 (Table 2). Nutsedge control with the other treatments was poor. In the fall 1994 study, the combination of pebulate with each of the alternative fumigants provided nutsedge control equal to that obtained with the MBr treatments.

Data from these studies indicate that-multiple pests adversely affect tomato production and that the initial level of these pests influences the degree of control obtained by the fumigants. Although no one pesticide provided the broad-spectrum and consistent control provided by MBr, a combination of chemicals did provide similar control in some studies. Pest control and fruit yields were lower with dazomet, metam Na, and tetrathiocarbonate treatments than with the MBr treatments. Where high populations of nutsedge were present, pebulate provided partial control of this weed and when combined with 1,3-D + Pic or Pic, resulted in sufficient tomato plant growth to obtain a 85% to 100% relative yield to that produced with MBr. In studies where nematodes and fungi populations were high and not adequately controlled, relative yields with Pic + pebulate and with 1,3-D + Pic + pebulate were as low as 60% of that produced with the MBr treatments. With the high cost to produce tomato, this level of yield would not be adequate for long term sustainable production. For these alternative fumigants to be acceptable, factors that influence the inconsistent control of nematodes and soil fungi at some sites must be determined.

Table 1. Marketable fruit yield of tomato and nematode control rating as influenced by fumigants at the locations during 1994 and 1995 seasons

		Marketable yield (% of MBr-Pic 67-33)[z]						Nematode gall index[w]				
		Gainesville				Bradenton		Gainesville				Brad.
		Hort. Unit		Green Acres		Spring	FALL	Hort. Unit		Green Acres		Spring
Treatment	Rate/ha	1994	1995	1994	1995	1994	1994	1994	1995	1994	1995	1994
Untreated		41 f	48 e	58 de	57 e	4 d	54 b	4.5 ay	5.3 a	8.9 ab	8.9 a	2.8 ab
MBr-Pic 98-2%	450 kg	103 a	105 ab	105 a	105 a	100 a	---	1.0 b	0.2 c	4.1 e	1.1 c	0.2 b
MBr-Pic 67-33%	390 kg	100 a	100 abc	100 a	100 a	100 a	100 a	1.2 b	0.4 c	3.6 e	1.4 c	0.2 b
Chloropicrin (Pic)	390 kg	63 cde	---	76 bc	---	53 b	---	4.3 a	---	8.5 ab	---	0.2 b
Pic + pebulate[y]	390 + 4.5 kg	88 ab	117 a	61 cde	97 ab	---	119 a	3.5 a	0.9 C	8.7 ab	5.8 b	--
1,3-D+ 17% Pic (C- 17)	327 L	70 bc	---	74 cd		55 b	---	1.2 b	---	6.3 cd		0.2 b
1,3-D. 17% Pic + peb.	327 L + 4.5 kg	87 ab	105 ab	79 b	97 ab	101 a	107 a	1.0 b	0.5 c	6.6 cd	2.6 c	0.8 b
Dazomet	440 kg	66 cd	---	55 e	---	54 b	---	3.2 ab	---	7.4 bc	---	2.0 ab
Dazomet + 6 mm irr.	440 kg	63 cde	---	---	---	---	---	3.9 a	---	---	---	--
Dazomet + pebulate	440 + 4.5 kg	--- [x]	86 cd	---	90 abc	---	96 a	---	2.1 bc	---	3.5 c	--
Metam Na	300 L	46 ef	---	66 cde	...	19 cd	---	3.2 ab	---	9.0 ab	---	4.4 a
Metam Na + pebulate	300 L + 4.5 kg	---	79 d	---	76 cd	48 bc	101 a	---	3.9 b	---	7.9 b	2.2 ab
Metam Na (drip)	300 L	66 cd	---	65 cde	---	47 bc	---	3.8 a	---	4.9 de	---	2.8 ab
Tetrathiocarbonate (drip)	1870 L	48 ef	---	52 e	---	7 d	---	4.2 a	---	9.7 a	---	3.4 ab

[z]Marketable fruit included size categories with mean weight of extra-large 205 , large 150 g, and medium 115 g,
[y]Pic applied at 375 kg in 1995 at Green Acres.
[x]Treatment not applied.
[w]Root-knot gall indices 0- 10 with 0 = no galls, ----- 10 = 100% of root system galled.
Mean separation within columns by Duncan's multiple-range test, P = 0.05

Table 2. Total fungi infecting tomato roots and nutsedge control as influenced by fumigants at three locations during 1994 and 1995 seasons.

		Gainesville (total fungal colonies/plant sample)[z]				Bradenton (*Fusarium* wilt, % plants infected)[y]		Nutsedge (no. per 0.1 m^2)			
		Hort.Unit		Green Acres		Spring	Fall	Gainesville		Bradenton	
								Hort.Unit	Spring	Fall	
Treatment	Rate/ha	1994	1995	1994	1995	1994	1994	1994	1995	1994	1994
Untreated		11.3 e	14.3 a	8.0 a	15.5 a	40 a	23 a	30 abc	16 a'	53 ab	22 a
MBr-Pic 98-2%	450 kg	3.3 d	4.3 c	2.0 b	8.0 bc	0 c	---	7 e	2 c	8 d	--
MBr-Pic 67-33%	390 kg	4.8 cd	4.3 c	2.3 b	3.0 c	0 c	0 b	9 e	4 c	4 d	I b
Chloropicrin (Pic)	390 kg	4.3 cd	---	4.3 ab	---	4 c	---	22 bcd	---	60 ab	--
Pic + pebulate[x]	390 + 4.5 kg	4.5 cd	4.3 c	3.0 b	4.0 bc	---	0 b	I I e	2 c	---	6 b
1,3-D + 17% Pic	327 L	5.0 bcd	---	5.3 ab		8 bc	---	34 a	---	66 a	--
1,3-D +17% Pic + peb	327 L + 4.5 kg	2.8 d	3.8 c	4.0 ab	3.5 c	4 c	0 b	15 de	3 c	5 d	7 b
Dazomet	440 kg	10.0 ab	---	2.7 b	---	4 c	---	31 ab	---	37 c	--
Dazomet + 6 mm irr.	440 kg	10.3 a	---	---	---	---	---	25 abc	---	---	--
Dazomet + pebulate	440 + 4.5 kg	---[w]	8.7 abc	---	7.0 bc	---	0 b	---	3 c	---	6 b
Metam Na	300 L	11.3 a	---	4.0 ab	---	8 bc	---	32 a	---	56 ab	--
Metam Na + pebulate	300 L + 4.5 kg	---	6.8 c	---	3.3 c	4 bc	0 b	---	10b	7 d	5 b
Metam Na (drip)	300 L	6.5 abcd	---	3.3 b	---	20 b	---	22 cd	---	51 b	--
Tetrathiocarbonate (drip)	1870 L	8.8 abc	---	8.0 a	---	12 bc	---	33 a	---	54 ab	---

[z]Total fungi infecting tomato roots included *Rhizoctonia solani. Macrophomina phaseolina.* and *Fusarium spp.*
[y]Plants infected with *Fusarium oxysporum* f. sp. *Lycopersici*
[x]Pic applied at 375 kg in 1995 at Green Acres
[w]Treatment not applied.
Mean separation within columns by Duncan's multiple-range test, P= 0.05.