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SOIL FUMIGANT, MULCH TYPE, AND HERBICIDE TREATMENTS AFFECT PEPPER YIELD AND VIGOR, AND CONTROL OF NUTSEDGE AND ROOT-KNOT NEMATODE

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Abstract. **Purple nutsedge (*Cyperus rotundus* L.) and root-knot nematodes (*Meloidogyne* spp.) are serious pests in vegetable production in Florida. Soil fumigation with methyl bromide in plasticulture systems has traditionally provided excellent control of these pests. This trial was conducted to evaluate alternative soil fumigants, methods of application, and other cultural practices as possible replacements to methyl bromide due to the reduced availability and increased cost of methyl bromide. Plots were established in a Lakeland fine sand at the UF/IFAS North Florida Research and Education Center—Suwannee Valley, near Live Oak, Florida. in the fall of 2003. Five soil fumigant treatments, two plastic mulches, and two herbicide treatments were used in the study. Pepper (*Capsicum annuum*) yield and vigor was affected by soil fumigation and mulch treatment. Purple nutsedge populations were affected by soil fumigation, mulch type, and herbicide treatment. Root-knot nematode populations were affected by soil fumigation treatment, but not mulch type or herbicide treatment.**

Florida vegetable growers using plastic mulch have depended upon an effective soil fumigant, usually methyl bromide for successful production (Olson, 2001; Overman and Jones, 1984; Overman and Martin, 1978). Growers now are seeking fumigant alternatives to methyl bromide due to the increased costs and reduced availability resulting from the legislated phase-out of methyl bromide. Much of the research on alternatives has included treatments of 1,3-dichloropropene (1,3-D) + chloropicrin (pic) (Gilreath et al., 1994; Gilreath et al., 1997, Gilreath et al., 1999; Hochmuth et al., 2003; Jones et al., 1995; Locascio et al., 1997; Locascio et al., 1999; McSorley and McGovern, 1996; Stall, 1994; Stall and Gilreath, 1996). Purple nutsedge (*Cyperus rotundus*) is a common weed pest to vegetable growers in Florida and is very difficult to control. Methyl bromide has provided excellent control in standard plasticulture systems. Recent research evaluating 1,3-D + pic in conjunction with virtually impermeable film (VIF) has shown promising results for controlling nutsedge (Hochmuth et al., 2002; Hochmuth et al., 2003; Nelson et al., 2000; Want et al., 1997). This study was conducted to evaluate the effectiveness of various soil fumigants, including 1,3-D + pic, and mulches in control of purple nutsedge (*C. rotundus*), root knot nematodes (*Meloidogyne* spp.) in a crop of bell pepper (*Capsicum annuum*).

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Table 1. Soil fumigant treatments and descriptions.

Treatment	Description
Untreated	No soil fumigant applied.
Prebed	Telone C-35® (61.1% 1,3-dichloropropene plus 34.7% chloropicrin) Dow AgroSciences LLC, Indianapolis Ind., applied at a rate of 35 gal per treated acre in prebed with fumigation chisels 8 inches deep with mulch application equipment.
Yetter	Telone C-35 (61.1% 1,3-dichloropropene plus 34.7% chloropicrin) Dow AgroSciences LLC, applied at a rate of 35 gal per treated acre in the prebed using a Yetter fumigation rig (Mirusso Fumigation, Boynton Beach Fla.) via three chisels per bed, 12 inches apart and 14 inches deep. The Telone C-35 Yetter treatment was followed by an application of chloropicrin (100%) 150 lb per treated acre applied in the prebed using the mulch application equipment.
Inline	InLine® (60.8% 1,3- dichloropropene plus 33.3% chloropicrin) Dow AgroSciences LLC, applied via two drip irrigation tapes per bed placed one-third of the way in from the shoulder. InLine rate was 35 gal per treated acre based on the 32-inch-wide beds as the treated area.
Methyl bromide	Methyl bromide (75%) plus chloropicrin (25%) Hendrix and Dail, Tifton, Ga., was applied to the prebed with the mulch application equipment. Methyl bromide rate was 400 lb per treated acre.

Materials and Methods

Plots were established in the fall of 2003 on a Lakeland fine sand at the North Florida Research and Education Center—Suwannee Valley near Live Oak, Fla. The soil was prepared by rototilling to a depth of 8 inches. Beds were formed on 5-ft centers oriented north and south and were fertilized with 600 lb/acre of 13-1.7-10.8 (N-P-K) as they were formed. The remaining fertilizer was applied weekly via drip irrigation resulting in a total nitrogen rate of 180 lb/acre. Plots were arranged in a split-split plot design with four replications. Main plots were soil fumigants, subplots mulch types, and the subsubplots herbicide treatments.

Soil fumigation treatments are described in Table 1. All herbicides, mulches, and fumigants, except inline fumigation, were applied on 5 Aug. 2003. Inline fumigation was applied on 6 Aug. 2003. As mulch was applied to the beds, the herbicide treatment was applied to the tops of the pressed beds by using a spray boom attached to the back of the press pan. The herbicide spray was applied to the soil just ahead of the back mulch roller. The herbicide treatments were either herbicide or no herbicide. The herbicide treatment was clomazone (Command; FMC Corp., Philadelphia, Pa.) 1 qt/acre plus metalochlor (Dual Magnum; Syngenta Crop Protection, Greensboro, N.C.) 1 pt/acre + napropamide (Devrinol; Stauffer Chemical Co., Westport, Conn.) 1.5 lb ai/acre.

Mulch treatments were either virtually impermeable mulch (VIF) (Hytibarrier, Klerk's, Richburg, S.C.) or high density polyethylene (HDPE) (Sonoco, Hartsville, S.C.). Both mulches were white-on-black with the white side applied up.

All plots had drip irrigation tape applied to the bed as the mulch treatments were applied. The inline fumigation plots had two drip tapes per bed applied one-third of the bed width in from each shoulder. The drip tape used on the inline plots was Eurodrip (San Diego, Calif.) tape with a delivery of 17 gal/h per 100 ft of tape. All other fumigation treatments used one row of Netafim (Fresno, Calif.) drip tape per bed applied in the bed center. The Netafim tape delivered 36 gal/h per 100 ft of tape. Both drip tapes had emitters at 12-inch spacings. This drip irrigation plan was used to approximate equal water volumes per linear foot of bed during the growing season.

The inline fumigation treatment was made using nitrogen gas as the propellant and metering devices from Dow AgroSciences. Treatment was applied over a run time of 240 min at 1300 ppm of 1,3-D plus pic.

'Brigadier' pepper transplants were planted on 5 Sept. 2003 in two rows per bed with 12 inches between plants in

Table 2. Soil air 1,3-D traces found in samples taken in bed center and shoulder areas.

		1,3-D gas trace levels (ppm)											
		1 DAT		5 DAT		8 DAT		12 DAT		15 DAT		19 DAT	
Mulch type	Fumigation treatment	Center	Shoulder	Center	Shoulder	Center	Shoulder	Center	Shoulder	Center	Shoulder	Center	Shoulder
HDPE	Prebed	100 b[z]	35 c	13 bc	6	0 b	0	0	0	0	0	0	0
HDPE	Yetter	138 b	88 a	45 ab	29	0 b	0	0	0	0	0	0	0
HDPE	InLine	338 a	56 b	81 a	25	13 a	0	0	0	0	0	0	0
HDPE	Methyl bromide	0 c	0 d	0 c	0	0 b	0	0	0	0	0	0	0
HDPE	Untreated	0 c	0 d	0 c	0	0 b	0	0	0	0	0	0	0
					NS		NS	NS	NS	NS	NS	NS	NS
VIF	Prebed	400 b	128 b	288 a	313 a	50 b	56 a	34 b	34 b	0 b	0 b	0	0
VIF	Yetter	338 c	263 a	344 a	300 a	88 a	63 a	50 a	46 a	11 a	5 a	0	0
VIF	InLine	500 a	94 b	294 a	200 b	69 ab	25 b	13 c	0 c	0 b	0 b	0	0
VIF	Methyl bromide	0 d	0 c	0 b	0 c	0 c	0 c	0 d	0 c	0 b	0 b	0	0
VIF	Untreated	0 d	0 c	0 b	0 c	0 c	0 c	0 d	0 c	0 b	0 b	0	0
												NS	NS

[z]Interaction is significant and mean separation within mulch types by Duncan's Multiple Range Test at the 5% level. Means in the same column (for each mulch type separately) followed by different letters are significantly different ($p \leq 0.05$).

Table 3. Effect of soil fumigation, mulch, and herbicide treatments on total purple nutsedge (*Cyperus rotundus*) populations on three sampling dates.

Treatments	Purple nutsedge populations (no. per 100 linear feet of bed)		
	15 DAT	29 DAT	61 DAT
Fumigation			
Prebed	195 c[z]	460 b	1221 b
Yetter	0 d	9 c	48 c
InLine	479 b	1145 a	2205 a
Methyl bromide	27 d	67 c	20 c
Untreated	809 a	1080 a	851 b
Mulch Type			
HDPE	370 a	641 a	980 a
VIF	234 b	458 b	759 b
Herbicide			
Herbicide	212 b	376 b	601 b
No herbicide	397 a	738 a	1151 a

[z]The interaction between treatments was not significant; therefore, main effects are presented. Within source of variation, means in the same column followed by a different letter are significantly different by Duncan's Multiple Range Test at the 5% level.

each row. Each plot was 37.5 ft long. Standard insecticide and fungicide sprays were applied weekly during the entire growing season.

Beginning 1 d after the inline treatment (1 DAT), soil gas traces of 1,3-D were recorded in all plots. Concentrations of 1,3-D were determined by sampling the air in the soil 4 inches deep using a gas sample tub (Gas Tech, Kanagawa, Japan) sensitive to 1,3-D. Two samples per plot were taken, one in the bed center, and one taken 2 inches in from the west shoulder of each bed. Gas samples were taken on 1, 5, 8, 12, 15, and 19 DAT (0 DAT = 6 Aug. 2003).

Purple nutsedge counts were taken in each plot on 15, 29, and 61 DAT. Counts taken on 15 DAT were made on all 37.5 ft plots, but other counts were made on 5-ft subplots and final data are presented on a basis of number per 100 linear ft of bed top.

Pepper plant vigor ratings were recorded on 22 Sept. 2003 (47 DAT). Ratings were made on a scale of 1-5 to where, 1 = poor vigor and 5 = excellent vigor.

Mature green pepper fruit were harvested once on 10 Nov. 2003, just prior to the first frost of the fall of 2003. All fruit were graded using USDA standards for grades of bell pepper with Fancy, US No. 1, US No. 2, and cull categories. Fruit yield weights of each grade were recorded.

Soil samples for nematode assays were taken from each plot on 1 Dec. 2003 (87 DAT). Samples were assayed for root-knot nematode (*Meloidogyne* spp.) and reported as number per 100 cm^3 soil.

All data were analyzed by analysis of variance and mean separation was by Duncan's Multiple Range Test.

Results and Discussion

A significant interaction was found between fumigant and mulch treatments for 1,3-D gas levels found in the soil air (Table 2). The highest levels of 1,3-D were found in the bed center in the inline treatment on 1 DAT for both mulch types. Gas was found at higher levels under the VIF mulch than the HDPE mulch. Yetter fumigation treatment resulted in the longest period of detection of 1,3-D under VIF mulch, lasting until 15 DAT. No 1,3-D was detected 19 DAT for any treatment. As expected, no 1,3-D was detected for the methyl bromide and untreated control on any date with either plastic mulch.

No significant interaction was found between treatments for sedge populations. Therefore, main effects are presented. Fumigation treatment significantly affected sedge populations on all three collection dates (Table 3). Highest sedge populations on 21 Aug. were found in the untreated check followed by inline and prebed treatments. However, by 4 Sept., highest populations of sedge were found in both untreated and inline treatments, followed by prebed. By 6 Oct.,

Table 4. Effect of soil fumigation, mulch, and herbicide treatments on pepper yield and pepper grade.

Treatments	Pepper yield (lb/acre)					
	Total	Marketable	Fancy	US No. 1	US No. 2	Cull
Fumigation						
Prebed	11,880 a[zy]	11,574 a	8,741 a	2,152 b	681	306 a
Yetter	11,896 a	11,466 a	8,676 a	2,181 b	610	430 a
InLine	6,104 b	6,046 b	3,562 b	1,748 b	736	58 b
Methyl bromide	12,028 a	11,783 a	7,839 a	3,120 a	823	245 ab
Untreated	6,199 b	6,107 b	3,414 b	1,864 b	829	91 b
					NS	
Mulch Type						
HDPE	8,834 b	8,631 b	5,896	1,997 b	738	203
VIF	10,409 a	10,160 a	6.997	2,429 a	734	249
			NS		NS	NS
Herbicide						
Herbicide	9,744	9,512	6,698	2,141	673	232
No herbicide	9,493	9,273	6,181	2,289	802	220
	NS	NS	NS	NS	NS	NS

[z]The interaction between treatments was not significant; therefore, the data for each treatment are presented separately. Means in the same column (for each treatment separately) followed by a different letter are significantly different by Duncan's Multiple Range Test at the 5% level.
[y]Yields overall are low due to early harvest before killing frost.

the highest populations were found in the inline treatment, followed by untreated and prebed. The lowest populations of sedge were found in the Yetter, methyl bromide, and herbicide treatments on all three dates with no significant difference between those treatments on either date. Mulch treatments also affected sedge populations (Table 3). The highest sedge populations were found in HDPE treatments on all three dates.

Herbicide treatment also affected sedge populations (Table 3). Sedge populations were lower in the herbicide treatment on all three dates. Herbicide treatment reduced the sedge populations by about 50% from the no herbicide treatment on each date. But, herbicide treatment alone did not fully control nutsedge.

Pepper yield. No significant interaction was found between treatments for pepper yield. Therefore, main effects will be presented by each treatment separately. Fumigation treatments had a significant effect on pepper yield for most USDA grade categories. Highest total marketable yield (one harvest) was found for methyl bromide, prebed, and Yetter fumigation treatments. Marketable yields were greatly reduced in inline and untreated treatments. The same trend was found for Total yield and Fancy fruit yield.

Higher total marketable pepper yield was found in the VIF mulch treatment over HDPE (Table 4). This was likely due to reduced nutsedge competition in VIF mulch treatments.

No significant difference was found in any pepper yield category as a result of the Herbicide treatment when compared to No Herbicide (Table 4).

No significant interaction was found between treatments for plant vigor. Therefore, main effects will be presented separately by treatment. Lowest plant vigor was found in untreated and inline fumigation treatments (Table 5). All other fumigation treatments resulted in similar plant vigor. Mulch type and herbicide treatment did not affect plant vigor (Table 5).

No significant interaction was found between treatments for root-knot nematode populations. Therefore, the root-knot nematode data will be presented separately by treatment. All fumigation treatments reduced root-knot nematode populations when compared to the untreated treatment (Table 6). Yetter and methyl bromide treatments reduced populations to near zero. Root-knot nematode populations were not affected by mulch or herbicide treatments (Table 6).

Table 5. Effect of soil fumigation, mulch, and herbicide treatments on the vigor of pepper plants.

Treatment	Plant vigor rating (1-5)
Fumigation	
Prebed	4.6 a[z]
Yetter	4.6 a
InLine	3.1 b
Methyl bromide	4.4 a
Untreated	2.9 b
Mulch Type	
HDPE	3.8
VIF	4.1
	NS
Herbicide	
Herbicide	4.0
No herbicide	3.9
	NS

[z]The interaction between treatments was not significant; therefore, main effects are presented. Means in the same column (for each treatment separately) followed by a different letter are significantly different by Duncan's Multiple Range Test at the 5% level.

Table 6. Effect of soil fumigation, mulch, and herbicide treatment on root-knot nematode populations.

Treatment	Root-knot nematode population (no. per 100 cm^3 soil)
Fumigation	
Prebed	13 b[z]
Yetter	1 b
InLine	39 b
Methyl bromide	2 b
Untreated	299 a
Mulch Type	
HDPE	57
VIF	87
	NS
Herbicide	
Herbicide	65
No herbicide	76
	NS

[z]The interaction between treatments was not significant; therefore, the data for each treatment are presented separately. Means in the same column (for each treatment separately) followed by a different letter are significantly different by Duncan's Multiple Range Test at the 5% level.

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