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Effects of Application Strategies of Fumigant and Nonfumigant Nematicides on Cantaloupe Grown in Deep Sand Soils in Florida[1]

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Abstract: A 2-year study was conducted in which three treatment tactics of oxamyl (at planting application, application every 2 weeks, and rescue applications, as determined by crop symptoms) were compared to fumigant treatments with methyl bromide, 1,3-dichloropropene (1,3-D), and 1,3-D plus chloropicrin for management of *Meloidogyne* spp. In 2002, treatments that included 1,3-D produced higher yields as determined both by number and weight of marketable fruit. All treatment tactics relying solely on oxamyl, at planting, scheduled treatments, and rescue, were not different from untreated controls for both marketable yield and number of fruit. Gall ratings in 2002 were lowest for 1,3-D at the 112-liters/ha rate, followed by 1,3-D at 84 liters/ha with and without oxamyl. All treatments of oxamyl, except when combined with 1,3-D, had gall ratings not different from untreated plots. In 2004, treatments of methyl bromide and 1,3-D plus chloropicrin had the highest total number of both marketable fruit and highest marketable yields. All treatment strategies relying solely on oxamyl had yields equivalent to the untreated controls. Mean root-gall ratings were lowest for methyl bromide plus chloropicrin and 1,3-D plus chloropicrin treatments. Root-gall ratings for all treatment tactics relying solely on oxamyl were not different from untreated controls.

Key words: 1,3-dichloropropene, cantaloupe, chloropicrin, *Cucumis melo,* fumigation, gall rating, management, *Meloidogyne,* methyl bromide, nonfumigant, oxamyl, rescue, root-knot nematode.

Cantaloupe, *Cucumis melo* var. *reticulatus,* is produced on nearly 13,400 ha in the United States (Anonymous, 2004). This figure represents a 13% increase over the previous year. Values for cantaloupe differ from state to state, depending on availability and time of year. In 1997, cantaloupe was produced on ca. 460 ha in Florida with yields ranging from 2,700 kg/ha to 5,520 kg/ha (Mossler and Nesheim, 2001). Gross returns for Florida-grown cantaloupe may be as high as $7,500/ha (Mossler and Nesheim, 2001).

Root-knot nematodes, *Meloidogyne* spp., are serious pathogens of many horticultural crops including cantaloupe. Parasitism and reproduction of *M. incognita* on cantaloupe have been reported to be severe (Heald et al., 1988); however, there are few data on the effectiveness of fumigants vs. nonfumigants for managing root-knot disease on cantaloupe. Applications of both fumigant and nonfumigant nematicides have been shown to increase the marketable yield of snap bean (Rhoades, 1983), broccoli and squash (Rhoades, 1987), and pepper (Acosta et al., 1987).

The phaseout of methyl bromide creates a need for effective and reliable alternative strategies to manage nematodes and other soilborne pathogens in high-value vegetable crops. In Florida, cantaloupe is planted both as a primary and second crop following other high-value crops, such as strawberry. Our objectives were to determine whether oxamyl can be used on a crop to salvage a profitable harvest after the crop has shown symptoms of damage from root-knot nematodes and to determine whether scheduled applications of drip-irrigation-applied oxamyl are sufficient to increase yields as compared to fumigant treatments of methyl bromide, 1,3-D, and 1,3-D plus chloropicrin.

Materials and Methods

Experiments were conducted at the Plant Science Research and Education Unit, University of Florida, in Citra, Florida. Field dimensions were 13.7 m wide by 182.9 m long. The site used in 2002 was inoculated in summer 1999 with *M. arenaria* race 1 reared on *Lycopersicon esculentum* cv. Rutgers, and the site used in 2004 was inoculated with *M. javanica* in 2001. However, both sites were likely infested with mixed populations of *Meloidogyne* spp. Endemic populations of *Trichodorus* spp. and *Criconemoides* spp. also were present at the time of each experiment. Root-knot nematodes were maintained at high levels by planting okra, *Hibiscus esculentum* cv. Clemson Spineless across the field where experiments were conducted. Soils in the field were classified as a mixture of Arredondo and Sparr fine sand with 95% sand, 3% silt, 2% clay, 1.5% OM and pH 6.5.

Treatments were applied on single raised beds 23 cm tall, 91 cm wide, 12 m long and spaced on 1.8-m centers. In 2002, treatments of 1,3-dichloropropene (1,3-D) were applied broadcast on the flat soil surface with six chisels spaced 30 cm apart and 7 days later raised beds were formed using a Kennco powerbedder (Kennco Mfg., Ruskin, FL). In 2004, fumigant treatments were applied to raised beds with three chisels spaced 30 cm apart.

All oxamyl (formulation contained 0.19 kg a.i./liter) treatments were applied via drip irrigation at 4.7 liters/ha in 30 liters of water. Prior to oxamyl injection, ca. 20 liters of water per replicate was applied and after injection the drip lines were purged with an additional 10 liters of water. Rescue treatments with oxamyl (4.7 liters/ha) were initiated when aboveground symptoms of stunting, chlorosis, and incipient wilting were first observed. Treatments were arranged in a randomized complete block design with four replicates.

Immediately before bed formation a 6-17-16 (N-P_2O_5-K_2O) fertilizer mix was banded over the treatment area at 842 kg/ha. The raised beds were covered

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with a black, low-density polyethylene mulch (1.25 mil thickness), and a single drip tube (8 mil, 30-cm emitter spacing) with a flow of 1.9 liters/minute/30.5 m of row (Roberts Irrigation Products, San Marcos, CA) was inserted into the bed centers under the mulch using a Kennco mini-combo unit (Kennco Mfg., Ruskin, FL.). Seed of cantaloupe cv. Athena (Syngenta Seeds-Rogers Brand Vegetable Seeds, Boise, ID) was planted on 45-cm spacing down the center of each polyethylene-mulched bed on 25 March 2002 and 15 March 2004. Remaining N and K_2O were applied as ammonium nitrate and muriate of potash, respectively, in 8 weekly applications divided equally to deliver a total of 168 kg/ha N and 168 kg/ha K_2O for the crop. Fungal pathogens were managed using chlorothalonil and azoxystrobin, and insect pests were managed using methomyl.

Spring 2002: Six treatments were evaluated: (i) 1,3-D (Telone II, Dow AgroSciences, Indianapolis, IN) at 84 liters/ha, (ii) 1,3-D applied at 112 liters/ha, (iii) 1,3-D applied at 84 liters/ha plus oxamyl (Vydate L, Dupont, Wilmington, DE) applied 2 and 4 weeks after planting, (iv) oxamyl applied 2 and 4 weeks after planting, (v) oxamyl applied at the time of first visible symptoms of root-knot nematode damage and again 2 weeks later (rescue treatment), and (vi)a nontreated control.

Spring 2004: Eight treatments were evaluated: (i) 67% methyl bromide-33% chloropicrin (MB+C) at 392 kg/ha, (ii) 65% 1,3-D-35% chloropicrin (Telone C35, Dow AgroSciences, Indianapolis, IN) at 327.2 liters/ha, (iii) oxamyl applied at planting and again 2 weeks later, (iv) oxamyl applied at planting and 2 and 4 weeks later, (v) oxamyl applied at first visible symptoms of root-knot nematode damage, (vi) oxamyl applied at first visible symptoms of damage and 2 weeks later, (vii) oxamyl applied at first visible symptoms of damage and 2 and 4 weeks later, and (viii) a nontreated control.

Treatment evaluations: In both years fruit was harvested at maturity and a total number of fruit and marketable yield, as determined by the weight of fruit per treatment, was compared among treatments. After the final harvest, six plant root systems per treatment, chosen arbitrarily, were dug and rated for galling based on a 0-to-100 scale where 0 = no visible galls and 100 = 100% of the root system galled (Barker et al., 1986). In 2004, after the final harvest, 10 cores of soil (ca. 500 cm^3) per plot were collected around cantaloupe roots with a 2.5-cm-diam., 27-cm-long cone-shaped sampling tube. The soil from each plot was composited and nematodes were extracted from 100 cm^3 of soil by the centrifugal-flotation method (Jenkins, 1964). Plant-parasitic nematodes were counted using an inverted microscope at 10× magnification. All data were subjected to analysis of variance (ANOVA) and means separation by least significance difference test (LSD Test) (SAS Institute, Cary, NC).

Results

2002. Treatments with 1,3-D at 112 liters/ha and 1,3-D at 84 liters/ha plus oxamyl both had the highest marketable fruit weights and number of fruits ($P \leq 0.05$) (Table 1). Treatments that included only oxamyl or 1,3-D at 84 liters/ha without oxamyl were not different from the nontreated control for either total marketable weights or total numbers of fruit (Table 1). Mean gall ratings were lowest for the 1,3-D treatment at 112 liters/ha, and all 1,3-D treatments had lower gall ratings than nontreated plots ($P \leq 0.05$) (Table 1).

2004. Methyl bromide and 1,3-D-chloropicrin treatments had the highest overall marketable yields and numbers of fruit (Table 2). All treatments with oxamyl at different timings and frequency had no effect on marketable yield (fruit weight and number) compared with the nontreated control (Table 2). Mean root gall ratings for both the methyl bromide and the 1,3-D-chloropicrin treatments were lower than all other treatments ($P \leq 0.05$) (Table 2). Numbers of *Trichodorus* spp. were lower in plots treated with methyl bromide than all other treatments ($P \leq 0.05$) (Table 2). The lowest numbers of *Criconemoides* spp. were observed in plots treated with methyl bromide or 1,3-D-chloro-

TABLE 1. Marketable numbers of fruit and yield and mean root gall ratings of cantaloupe as affected by fumigant and nonfumigant nematicides in 2002.

Treatment and broadcast rate/ha	Rate/12.2 m of row[a]	Application method	Timing	Number of marketable fruit	Yield (kg/ha)	Mean root gall rating[c]
Untreated				2,354 b	3,363 bc	37 a
1,3-D, 84 liters	31 ml/chisel	broadcast	preplant	2,780 ab	9,537 ab	22 b
1,3-D, 112 liters	42 ml/chisel	broadcast	preplant	3,228 a	11,546 a	9 c
1,3-D, 84 liters +	31 ml/chisel,	broadcast, drip	preplant	3,138 a	10,584 a	16 bc
Oxamyl[b] 4.7 liters	10.5 ml		2 and 4 weeks post plant			
Oxamyl 4.7 liters	10.5 ml	drip	at planting, 2 and 4 weeks post plant	2,309 b	7,815 bc	25 ab
Oxamyl 4.7 liters	10.5 ml	drip	at first sign of damage, and 2 weeks later	2,331 b	6,545 b	25 ab

Data are means of four replicates. Means with the same letter are not different ($P < 0.05$) according to least significant difference test (LSD).
[a] Rates were based on 1.8-m row spacing.
[b] Formulation contains 0.19 kg/liter a.i.
[c] Based on a 0-to-100 scale, where 0 = no galls, 10 = 10% of root system galled, . . . 100 = 100% of root system galled (Barker et al., 1986).

TABLE 2. Marketable numbers of fruit and yield, mean root gall ratings, and mean number of ectoparasitic nematodes and root-knot nematode second-stage juveniles (J2) extracted from 100 cm^3 soil taken from around cantaloupe roots treated with selected fumigant and nonfumigant nematicides in 2004.

Treatment and broadcast rate/ha	Rate/12.2 m of row[a]	Application method	Timing	Number of marketable fruit	Yield (kg/ha)	Mean root gall rating[c]	*Trichodorus* spp.	*Criconemoides* spp.	J2
Untreated				2,101 b	3,602 b	88 a	8 c	43 c	61
67% methyl bromide 33% chloropicrin, 392 kg	86 ml/chisel	in-row	preplant	5,268 a	11,543 a	24 b	0.3 a	0 a	18
65% 1,3-D + 35% chloropicrin, 327.2 liters	121.6 ml/chisel	in-row	preplant	5,436 a	10,430 a	12 b	5 c	1 a	13
Oxamyl[b], 4.7 liters	10.5 ml	drip	4 days post planting and 2 weeks later	2,746 b	4,589 b	73 a	2 b	40 c	27
Oxamyl, 4.7 liters	10.5 ml	drip	4 days post planting, 2 and 4 weeks later	2,438 b	4,705 b	62 a	4 bc	16 b	17
Oxamyl, 4.7 liters	10.5 ml	drip	at first sign of damage	2,466 b	4,371 b	90 a	2 b	25 bc	26
Oxamyl, 4.7 liters	10.5 ml	drip	at first sign of damage, 2 weeks later	2,101 b	4,190 b	85 a	3 bc	17 b	19
Oxamyl, 4.7 liters	10.5 ml	drip	at first sign of damage, 2 and 4 weeks later	2,242 b	4,285 b	76 a	1 b	24 bc	64

Data are means of four replicates. Means with the same letter are not different ($P < 0.05$) according to least significant difference test (LSD).
[a] Rates were based on 1.8-m row spacing.
[b] Formulation contains 0.19 kg/liter a.i.
[c] Based on a 0-to-100 scale, where 0 = no galls, 10 = 10% of root system galled, . . . 100 = 100% of root system galled (Barker et al., 1986).

picrin ($P \leq 0.05$). The number of root-knot nematode juveniles recovered from soil was highly variable, and no treatment effects were detected (Table 2).

Discussion

Methyl bromide is used extensively as a soil fumigant and recognized to be the standard for controlling weeds, insects, and soilborne fungi (Noling and Becker, 1994; Thomas, 1996). Because of environmental concerns, the soil fumigant was phased out in 2005 (Riegel et al., 2001). However, its continued use is currently allowed under a Critical Use Exemption statute. This means cantaloupe can be double-cropped following high-value crops, which are always treated with methyl bromide, without a serious threat of suffering from severe root-knot disease (Aerts et al., 2001). Excellent nematode management can be achieved with 1,3-D; however, it has limited usage on cantaloupe (Aerts et al., 2001). All too frequently growers fail to use nematode management tactics and find themselves with a root-knot nematode disease problem about 4 to 6 weeks after planting. Application of the nonfumigant nematicide oxamyl applied through drip irrigation has been investigated and may represent an alternative management tactic to replace the nematicidal component vacated by the proposed loss of methyl bromide (Lembright, 1990; Westerdahl et al., 1993).

A minor crop such as cantaloupe would be unlikely to retain a labeled use for methyl bromide even if critical use exemptions are granted beyond 1 January 2007. Planted cantaloupe acreage has increased 13% from 2003 to 2004, placing a larger acreage at risk to damage from root-knot nematodes (Anonymous, 2004). In our studies we have shown the promise of two tactics, both using 1,3-D as a nematicide. In 2002, plots treated with 1,3-D at 112 liters/ha provided control of root-knot nematodes (<10% root galling) and produced marketable fruit yields that were better than the nontreated plots. In 2004, plots treated with a preplant formulation of 65% 1,3-D-35% chloropicrin provided equivalent nematode control compared to methyl bromide and produced equivalent marketable yields. All of our treatment tactics that were dependant solely on oxamyl failed to provide adequate nematode control or improve marketable yields. Yield in the nontreated plots in 2002 was ca. 70% of that treated with 1,3-D at 112 liters/ha. Yields in 2004 were lower than in 2002; however, treatment with 1,3-D plus chloropicrin more than doubled the yield over that in the nontreated plots. The addition of oxamyl as a post-plant treatment coupled with 1,3-D did not increase the yield over that of 1,3-D alone. The added expense of applying oxamyl for nematode control either preplant, every 2 weeks throughout the growing season, or at first indication of damage with subsequent applications would not be economically justified based on the results of these trials.

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