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EFFECTIVENESS OF BROADCAST APPLICATION OF TELONE C-35 AND TILLAM + DEVRINOL IN TOMATO

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Abstract. **Two experiments (Fall 2000 and Spring 2001) were conducted to determine the efficacy of broadcast applications of a mixture of 65% 1,3-dichloropropene (Telone II) and 35% chloropicrin (Telone C-35) with a tank mix of pebulate (Tillam) + napropamide (Devrinol) herbicides. These treatments were compared to in-bed applications of Telone C-35 as an alternative to methyl bromide for soil fumigation in fresh market tomato production on flatwoods soils in west central Florida. Treatments consisted of a nontreated control, Telone C-35 applied in-bed, Telone C-35 applied broadcast with a Yetter Avenger coulter applicator, alone or followed by additional chloropicrin applied in-bed, Telone II broadcast followed by additional chloropicrin in the bed, and methyl bromide in-bed. A tank mix of Tillam + Devrinol was applied broadcast and incorporated in the top 5 to 6 inches of the soil in both experiments prior to bed formation. Treatments were located on the same site each season to allow pest populations to build over time as a result of seasonal treatments. Staked tomatoes were grown on polyethylene mulched beds and data were collected for control of nutsedge, soilborne diseases and nematodes, and tomato fruit production. There was little nutsedge in the test site in the fall, but by spring the population had increased and treatment differences were observed. Although all Telone plots were treated with Tillam + Devrinol for nutsedge control, Telone C-35 in-bed was more efficacious than broadcast application, unless chloropicrin was applied to the bed. Soilborne disease (Southern blight and Fusarium wilt race 3) control varied somewhat between broadcast and in-bed application of Telone C-35. Fusarium wilt was more prevalent in the fall and was controlled by all fumigant treatments. There was no difference in wilt incidence in the spring. Southern blight was not a serious pest in the fall, but by spring it had become better established. While in-bed application of Telone C-35 provided blight control equal to methyl bromide in the spring, broadcast application did not, unless it was accompanied by additional chloropicrin in the bed. Telone controlled nematodes regardless of the method of application. Tomato yields followed the same trend as nutsedge and southern blight control; marketable fruit yields were not different among fumigant treatments in the fall, but in the spring yield was lower where Telone C-35 was applied broadcast without additional chloropicrin applied to the bed.**

Research and grower demonstration trials have established that the current most likely, registered soil fumigant alternative to methyl bromide is a combination of 1,3-dichloropropene (Telone II) and chloropicrin, commonly formulated as Telone C-35 with 65% and 35% of 1,3-dichloropropene and chloropicrin, respectively (Csinos et al., 2000; Gilreath et al., 1994; Jones et al., 1995; Locascio et al., 1997). Additionally, it has been shown that a herbicide must be used with Telone/chloropicrin formulations in order to provide weed control (Gilreath et al., 1994). Where nutsedge (*Cyperus* spp.) is a problem in tomato (*Lycopersicon esculentum* Mill.), growers have been advised to use Tillam (pebulate), either alone or in combination with other herbicides, such as Devrinol (napropamide), to broaden the spectrum of weed species controlled. Most data for Telone C-35 were generated with in-bed applications and it was not until about 2 years ago that emphasis shifted from in-bed to broadcast application as a possible means of mitigating the onerous label restrictions, which required all workers in the field at the time of application to use maximum personal protective equipment (PPE).

An effective dosage of a fumigant is a combination of a specific concentration of fumigant for a given duration of exposure. Outgassing or the gaseous loss of fumigant from the soil can limit efficacy by either reducing the concentration in the soil around the pest or shortening the exposure duration or both. Soil moisture and temperature change rapidly in the first 2 inches of field soil in response to changes in the atmosphere. These changes greatly influence the retention of soil fumigants. As soil temperature increases or moisture decreases, soil fumigants volatilize more rapidly. Although no odor is noted at the time of broadcast application of Telone C-35, the rapid volatilization of fumigant is likely once the fumigant reaches the upper few inches of the soil profile. Nematodes are known to move in the soil in response to moisture and other factors required for life. Deep placement of Telone C-35 during broadcast application is most likely of great benefit

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for nematode control because the pest is generally deeper in the profile at the beginning of the season. However, spores and other dissemination propagules of soilborne diseases are not mobile in the soil and generally are well distributed throughout the upper soil profile at the time of land preparation. Since the half-life of chloropicrin is much shorter than that of Telone, and the effective dosage must be maintained throughout the rhizosphere, outgassing is even more critical with soilborne diseases. Raised, mulched beds are not formed until 7 or more days after broadcast application of Telone C-35. The absence of polyethylene mulch at this time provides greater potential for excessive outgassing and loss of efficacy during broadcast application than during in-bed application.

Recognizing that the potential exists for loss of efficacy as a result of volatilization of chloropicrin during broadcast applications of Telone C-35, a two season study was conducted to determine if efficacy declines over time with broadcast application as compared to in-bed application of Telone C-35 and if additional chloropicrin placed in the bed at the time of bed formation is beneficial for soilborne pest control.

Materials and Methods

Two experiments were conducted at the Gulf Coast Research and Education Center in Bradenton, Fla. during the fall of 2000 and the spring of 2001. Treatments (Table 1) were assigned to 40-ft-long, single bed plots, which were arranged in a randomized complete block design and replicated five times. Treated beds were separated by nontreated beds to maintain treatment integrity over time. Physical reference points were established to allow relocation of each plot in the exact same spot over the life of the study, thus assuring continued monitoring of treatment effects over more than one season. The test area was chosen because of a past history of Fusarium wilt race 3. The 28-inch-wide, 8- inch-tall raised beds were spaced 5 ft apart with treated beds 10 ft apart on centers. Subsurface irrigation and overhead sprinklers were used to provide sufficient moisture for initial land preparation and construction of beds. A tank mix of Tillam (Zeneca Agr. Prod., Wilmington, Del.) + Devrinol (United Phosphorus, Inc., Trenton, N.J.) (4 and 2 lb a.i./acre, respectively) was applied broadcast and incorporated in the soil in all Telone plots using a boom mounted on the front of a tractor-drawn 7-ft disk, which mixed the soil to a depth of 6 inches. Herbicide was applied just prior to broadcast fumigant applications in the fall and the day before broadcast fumigant application in the spring. Broadcast applications of Telone II and Telone C-35 (Dow AgroSciences LLC, Indianapolis, Ind.) were made with a Yetter Avenger coulter applicator (Yetter Farm Equip., Colchester, Ill.) with knives spaced 12 inches apart delivering fumigant at a depth of 12 inches in non-bedded soil. Broadcast applications were made on 10 Aug. 2000 in the fall experiment and on 1 Feb. 2001 in the spring. False beds were formed with a three-row disk hiller type of pre-bedder. Finished beds were formed with a Kennco® bedder (Kennco Mfg., Inc., Ruskin, Fla.) fitted with three gas knives spaced 12 inches apart. In-bed applications were made on 23 Aug. 2000 in the fall and on 9 Feb. 2001 in the spring by delivering fumigant through the three knives to a depth of 10 inches below the bed top. A single micro-irrigation tube (T-Tape®, T-Systems International, Inc., San Diego, Calif.) (0.45 gpm, 12-inch spacing) was placed 4 inches from bed center and buried 2 inches deep and beds were covered with low density polyethylene film mulch (0.00125-inch-thick). Tomato ('Florida 47') was grown using micro-irrigation in each experiment. Five- to 6-week-old tomato seedlings were transplanted on 13 Sept. 2000 in the fall experiment and 1 March 2001 in the spring.

Table 1. Tomato plant vigor and incidence of Southern blight and Fusarium wilt race 3 in tomato plants with in-bed and broadcast applications of Telone C-35, alone or in combination with additional in-bed application of chloropicrin. Fall 2000 and Spring 2001.

					Incidence (%)				
			Vigor (%)		Southern blight		Fusarium wilt		Dead plants
Treatment	Rate per acre	Method of application	Fall	Spring	Fall	Spring	Fall	Spring	Spring
Nontreated	0	n/a	48 b[z]	30 b	10 a	45 a	50 a	21 a	76 a
Methyl bromide	350 lb	in bed	87 a	91 a	20 a	19 b	0 b	11 a	22 c
67/33									
Telone C-35	35 gal	in bed	78 a	91 a	10 a	13 b	0 b	11 a	18 c
Tillam +	4 lb a.i.	ppi							
Devrinol	2 lb a.i.								
Telone C-35	26 gal	broadcast	81 a	85 a	20 a	44 a	0 b	15 a	49 b
Tillam +	4 lb a.i.	ppi							
Devrinol	2 lb	a.i.							
Telone C-35	26 gal	broadcast	84 a	87 a	10 a	19 b	0 b	11 a	21 c
Tillam +	4 lb a.i.	ppi							
Devrinol	2 lb	a.i.							
Chloropicrin	137 lb	in bed	a week later						
Telone II	18 gal	broadcast	80 a	90 a	10 a	19 b	10 b	5 a	24 c
Tilllam +	4 lb a.i.	ppi							
Devrinol	2 lb.	a.i.							
Chloropicrin	137 lb	in bed	a week later						

[z]Mean separation within columns by Duncan's multiple range test, 5% level.

Tomato plant vigor was evaluated visually 6 weeks after planting on a percentage rating scale by comparing all plots to the most vigorous plot within the test. Nutsedge populations were determined each season by counting the number of plants emerged through the mulch film and in the plant holes in each plot approximately 6 and 9 weeks after planting. The incidences of southern blight (incited by *Sclerotium rolfsii*) and Fusarium wilt race 3 (incited by *Fusarium oxysporum f.sp. lycopersici* race 3) were enumerated within each plot at the time of the second harvest and soil samples were collected for nematode assay. Tomato fruit were harvested twice each season, sorted into marketable and cull categories and marketable fruit were sorted by size grade, then the fruit of each size and category were weighed.

Results and Discussion

Tomato plant vigor was greatly improved by soil fumigation and there were no differences in plant vigor among the fumigant treatments in either season (Table 1). Incidence of southern blight of tomato was low during the fall of 2000 and was not affected by fumigant treatment; however, in the spring of 2001 incidence of blight increased greatly. Broadcast application of Telone C-35 alone did not control southern blight of tomato; the addition of chloropicrin to the bed was necessary for blight control equal to in bed applications of Telone C-35 or methyl bromide. Approximately 50% of the tomato plants in the nontreated control plots had Fusarium wilt race 3 during the fall season and all fumigant treatments provided good control. In the spring, there was no difference in wilt incidence among the treatments with the incidence level much lower in the control plots than was observed during the fall. A few plants died in the fall, but in the spring 76% of the plants in the nontreated control plots were dead by the time of the second harvest. Although plant mortality was lower in the broadcast Telone C-35 plot as it was in the nontreated control, it was still greater than what was observed where Telone C-35 was placed in the bed or where additional chloropicrin was placed in the bed.

A mix of yellow and purple nutsedge (*Cyperus esculentus* L. and *C. rotundus* L., respectively) was present in the test area; however, few plants were observed in the fall (data not presented). Nutsedge populations increased such that in the spring some differences in treatments were observed, in spite of broadcast application of Tillam + Devrinol (Table 2). Where Telone C-35 was applied broadcast by itself, there was no control of nutsedge emergence through the polyethylene mulch or in plant holes, but when Telone C-35 was applied in bed or broadcast application was followed by in bed application of chloropicrin, nutsedge control was comparable to methyl bromide in the spring.

Populations of stunt nematodes (*Tylenchorhynchus* sp.) and stubby-root nematodes (*Paratrichodorus* and *Trichodorus* spp.) increased from the first to second experiment (Table 3). Stunt nematode control was good with all fumigant treatments during the first experiment (fall 2000), except Telone C-35 broadcast followed by chloropicrin in the bed. During the second season (spring of 2001) on the same site, the best control of stunt nematode was obtained with methyl bromide, Telone C-35 in bed, and C-35 broadcast followed by chloropicrin in the bed. The addition of chloropicrin to the broadcast treatment appeared to improve stunt nematode control. Stubby-root nematode populations were not affected by treatment in this study, and they increased with time. There was no difference among treatments in sting nematode (*Belonolaimus longicaudatus*) populations in the fall study, but in the spring, all fumigants controlled sting nematodes equally well. While the response to the addition of chloropicrin in the bed following broadcast application of Telone C-35 was not as clear for nematodes as it was for control of Southern blight, there was

Table 2. Nutsedge control with in-bed and broadcast applications of Telone C-35, alone or in combination with additional in-bed application of chloropicrin, in tomatoes. Spring 2001.

			Number of nutsedge plants per plot	
Treatment	Rate per acre	Method of application	Through mulch	In plant hole
Nontreated	0	n/a	54 a[z]	6 a
Methyl bromide 67/33	350 lb	in bed	1 b	0 b
Telone C-35	35 gal	in bed	1 b	1 b
Tillam +	4 lb a.i.	ppi		
Devrinol	2 lb	a.i.		
Telone C-35	26 gal	broadcast	31 a	11 a
Tillam +	4 lb a.i.	ppi		
Devrinol	2 lb	a.i.		
Telone C-35	26 gal	broadcast	4 ab	1 b
Tillam +	4 lb	a.i.	ppi	
Devrinol	2 lb	a.i.		
Chloropicrin	137 lb	in bed	a week later	
Telone II	18 gal	broadcast	4 ab	1 b
Tilllam +	4 lb a.i.	ppi		
Devrinol	2 lb	a.i.		
Chloropicrin	137 lb	in bed	a week later	

[z]Mean separation within columns by Duncan's multiple range test, 5% level. Data present are weighted means after log + 1 transformation of original count data.

Table 3. Nematode control with in-bed and broadcast applications of Telone C-35, alone or in combination with additional in-bed application of chloropicrin, in tomatoes. Fall 2000 and Spring 2001.

			Number of nematodes per 100 cc of soil					
			Fall			Spring		
Treatment	Rate per acre	Method of application	Stunt	Stubby-root	Sting	Stunt	Stubby-root	Sting
Nontreated	0	n/a	16 a	39 a	21 a	28 a	141 a2	4 a
Methyl bromide 67/33	350	in bed	2 b	30 a	0 a	0 b	149 a	0 b
Telone C-35	35 gal	in bed	0 b	52 a	0 a	0 b	175 a	0 b
Tillam +	4 lb a.i.	ppi						
Devrinol	2 lb	a.i.						
Telone C-35	26 gal	broadcast	3 b	47 a	3 a	20 ab	174 a	0 b
Tillam +	4 lb	a.i.	ppi					
Devrinol	2 lb	a.i.						
Telone C-35	26 gal	broadcast	8 ab	13 a	2 a	0 b	102 a	0 b
Tillam +	4 lb	a.i.	ppi					
Devrinol	2 lb	a.i.						
Chloropicrin	137 lb	in bed a week later						
Telone II	18 gal	broadcast	2 b	56 a	16 a	7 ab	156 a	0 b
Tilllam +	4 lb	a.i.	ppi					
Devrinol	2 lb	a.i.						
Chloropicrin	137 lb	in bed a week later						

[z]Mean separation within columns by Duncan's multiple range test, 5% level.

a noticeable trend for increased control of stunt nematodes during the spring.

During the first experiment (fall 2000), tomato fruit yield generally was improved with all soil fumigants with the exception of methyl bromide and in-bed application of Telone C-35 in the first harvest (Table 4). There were no differences in marketable fruit yield among the various fumigant treatments during the fall. In the spring experiment, marketable tomato fruit yield was similar among fumigant treatments for the first harvest, but was reduced in the second harvest and season to-

Table 4. Effect of in-bed and broadcast applications of Telone C-35, alone or in combination with additional in-bed application of chloropicrin, on yield of marketable tomatoes in each of two harvests and seasonal total. Fall 2000 and Spring 2001.

			Weight (kg) of fruit per 10 plants					
			Fall			Spring		
Treatment	Rate per acre	Method of application	1st Harv.	2nd Harv.	Total	1st Harv.	2nd Harv.	Total
Nontreated	0	n/a	13.8 b[z]	10.5 b	24.3 b	3.4 b	1.2 b	4.6 c
Methyl bromide 67/33	350 lb	in bed	20.1 ab	33.4 a	53.5 a	25.6 a	19.6 a	45.3 a
Telone C-35	35 gal	in bed	21.7 ab	33.5 a	55.2 a	22.6 a	18.7 a	41.3 ab
Tillam +	4 lb	a.i.	ppi					
Devrinol	2 lb	a.i.						
Telone C-35	26 gal	broadcast	27.4 a	36.2 a	63.6 a	26.0 a	6.8 b	32.8 b
Tillam +	4 lb	a.i.	ppi					
Devrinol	2 lb	a.i.						
Telone C-35	26 gal	broadcast	26.0 a	36.7 a	62.8 a	26.5 a	17.6 a	44.1 a
Tillam +	4 lb	a.i.	ppi					
Devrinol	2 lb	a.i.						
Chloropicrin	137 lb	in bed a week later						
Telone II	18 gal	broadcast	25.4 a	33.3 a	58.7 a	27.3 a	17.1 a	44.4 a
Tilllam +	4 lb	a.i.	ppi					
Devrinol	2 lb	a.i.						
Chloropicrin	137 lb	in bed a week later						

[z]Mean separation within columns by Duncan's multiple range test, 5% level.

tal where Telone C-35 was applied broadcast without additional chloropicrin placed back in the bed. Yields equal to methyl bromide were obtained in each harvest and total in both experiments by applying Telone C-35 or Telone II broadcast then following that with additional chloropicrin applied to the bed at the time of bed formation.

Telone / chloropicrin mixtures applied to the bed have provided soilborne pest control and tomato fruit yields equal to methyl bromide in a number of studies (Gilreath et al., 1994; Jones et al., 1995; Locascio et al., 1997). Good pest control and yield have been observed in grower trials with broadcast applications of Telone C-35; however, these generally are trials conducted in fields previously treated with methyl bromide so there often is little soilborne pest pressure. This study was conducted in the same site for two consecutive seasons, which allowed for pest development as influenced by the fumigant treatments themselves. Results of this study suggest that when soilborne disease pressure is low, broadcast application of Telone C-35 is as effective as in bed application; however, when disease pressure is greater, broadcast application of Telone C-35 benefits from the addition of chloropicrin to the finished bed. This research is continuing in an effort to more clearly define these results and their implications for tomato growers.

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