EFFICACY OF DRIP-INJECTED FLUENSULFONE IN COMBINATION WITH 1,3-DICHLOROPROPENE/CHLOROPICRIN TO MANAGE ROOT-KNOT NEMATODES ON FRESH-MARKET TOMATOES

Gilma Castillo*[1], Dr. Monica Ozores-Hampton[1], and Pablo Navia[2]
[1]Southwest Florida Research and Education Center, Institute of Food and Agricultural Sciences, University of Florida, Immokalee, FL 34142, [2]ADAMA Agricultural Solutions, Raleigh, NC 27604.

Florida is the leader in fresh-market tomato (*Solanum lycopersicum* L.) production in the U.S with 13,030 ha harvested and a value of US$453 million (USDA, 2016). Previously, tomato growers relied on methyl bromide (MeBr) as a broad spectrum soil fumigant against soil-borne diseases, weeds, and root-knot nematodes (RKNs), *Meloidogyne spp*. However, after the phaseout of MeBr and the constant problem of RKNs, a need to evaluate the efficacy of further alternatives is vital. Among available chemical soil fumigants, Pic-Clor 60 [1,3-dichloropropene plus chloropicrin (40:60, w/w)] has been identified as one of the main alternatives to MeBr but has not shown to provide complete nematode management in sandy soils with drip irrigation (Noling, 1999; Di Gioia et al., 2016). Fluensulfone (Nimitz®) is a contact nematicide with less human and environmental restrictions that targets RKNs on low bush berries, cucurbit, leafy, and fruiting vegetables. Therefore, during the fall of 2014, a field experiment was conducted in Myakka City, FL with the objective to evaluate the efficacy of pre-plant, drip-injected fluensulfone at 1.96 and 2.80 kg a.i$\cdot$ha^{-1} combined with Pic-Clor 60 at 280 kg$\cdot$ha^{-1} on plant vigor, RKN soil population density, root galling index, and fruit yield of fresh-market tomatoes.

<u>Materials and Methods</u>. The field used for the trial had a history of high RKN pressure; however, the initial nematode population density before treatment application (16 July 2014) was 10 RKNs/100 cm^3 soil. The field was irrigated with drip irrigation. Treatments are described in Table 1. Fluensulfone treatments were injected in a randomized complete block design with four replications and plots were 12 m long on a 20-cm tall bed with a width of 91 cm on 1.83-m centers. Treatments were injected into the drip tape using a spot sprayer (Model GRN-7822-201; Countyline Tractor Supply Co., LaBelle, FL). Tomatoes were grown following industry standards for production practices and UF/IFAS recommendation for pest and disease control (Santos et al., 2013).
Data collection and analysis. Soil samples were randomly collected in each plot and then sent to LLH Ag and Research Services, LLC (Tifton, GA) for nematode quantification and identification. At midseason (31 Oct. 2014) and final harvest (23 Dec. 2014), three plants at the edges of the representative harvest unit [10 plants (RHU)] and six plants within RHU were

selected for RKN galling evaluation, respectively. RKN galling was assessed according to Hussey and Janssen (2002) rating system, where zero = no traces of galling, 1 = infection with few small galls, 2 = less than 25% of roots galled, 3 = between 25 to 50%, 4 = between 51 and 74%, and 5 = greater than 75 % of roots galled. Plant vigor and health parameters were visually assessed at 21 days after treatment (DAT) based on a 1-10 scale, where 1 = poor overall plant growth and 10 = optimal uniform plant growth. Yield was classified into marketable and unmarketable. Marketable fruit yield was graded according to USDA size category specifications—extra-large (diameter > 7.00 cm), large (6.35 to 7.00 cm), and medium (5.72 to 6.43 cm). Root galling index, RKN soil population density, and fruit yield were subjected to analysis using analysis of variance (ANOVA) and means were separated according to Duncan's multiple range test at 5% confidence level using SAS (SAS 9.3, SAS Institute Inc., Cary, NC, 2012). RKN count data were transformed using the square root function prior to analysis.

Results and Discussion. Tomato plants among all treatments presented optimal growth (Table 2). At midseason and final harvest, Pic-Clor 60 combined with fluensulfone showed lower galling index as compared to Pic-Clor 60 alone, decreasing root galling by approximately 61% and 55%, respectively (Table 2). Nevertheless, there were no significant differences among fluensulfone rates. Population densities of RKN second-stage juveniles (J2) before treatments were considered low at 10/100 cm^3 soil but acceptable for a nematode study. Pic-Clor 60 combined with fluensulfone decreased population densities of RKN J2 by 88% at final harvest whereas no differences were found among treatments at midseason (Table 2). Although initial RKN population densities were low, RKN densities increased throughout the season in which fluensulfone application provided an effective management.

Tomato fruit yield. At first and second harvests combined, Pic-Clor 60 alone and Pic-Clor 60 combined with fluensulfone at 2.80 kg $a.i \cdot ha^{-1}$ accounted for the greatest extra-large fruit yield (Table 3). However, there were no differences among fluensulfone rates. At third harvest, both fluensulfone rates produced the highest fruit yield for all tomato size categories and total marketable yield, except for the unmarketable yield where no differences were found among treatments. Pic-Clor 60 alone and Pic-Clor 60 combined with fluensulfone at 2.80 kg $a.i \cdot ha^{-1}$ accounted for the greatest total season extra-large fruit yield. There were no differences for the remaining tomato size categories and total season marketable and unmarketable yields. In this experiment, combining fluensulfone and Pic-Clor 60 as part of the nematode management program provided a level of RKN management more effective than Pic-Clor 60 alone in high nematode pressure.

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Table 1. Treatments applied to manage root-knot nematodes (*Meloidogyne* spp.) on tomato grown during fall 2014 in Myakka City, FL.

Treatment	Fumigation (5 Aug.)	Fluensulfone application rate (2 Sept.)[a]	Water application rate (6 Sept.)
Control	Pic-Clor 60 at 280 $kg \cdot ha^{-1}$	None	None
Fluensulfone	Pic-Clor 60 at 280 $kg \cdot ha^{-1}$	1.96 kg a.i$\cdot ha^{-1}$	6 $m^3 \cdot ha^{-1}$
Fluensulfone	Pic-Clor 60 at 280 $kg \cdot ha^{-1}$	2.80 kg a.i$\cdot ha^{-1}$	6 $m^3 \cdot ha^{-1}$

[a] For treatment injection, 10 $m^3 \cdot ha^{-1}$ of water were first applied, followed with 47 $m^3 \cdot ha^{-1}$ for fluensulfone application, and 6 $m^3 \cdot ha^{-1}$ to flush and clear the drip tape.

Table 2. Effect of pre-plant, drip-injected fluensulfone on plant vigor, root-knot nematode (*Meloidogyne* spp.) galling index, and soil population density in tomato grown during fall 2014 in Myakka City, FL.

Treatment	Plant vigor (rating 1-10)	Root galling index (rating 1-5)		Nematodes/100 cm^3 soil	
	7 Oct.	31 Oct.	23 Dec.	31 Oct.	23 Dec.
Pic-Clor 60	10	1.9a[a]	4.4a	7.5	3265.0a
Pic-Clor 60+fluensulfone 1.96 kg a.i·ha^{-1}	10	0.7b	1.9b	5.0	120.0b
Pic-Clor 60+fluensulfone 2.80 kg a.i·ha^{-1}	10	0.8b	2.1b	5.0	632.5b
P-value	-	0.0001	0.0001	0.96	0.001
Significance	-	***	***	NS	***

[a] Within columns means followed by different letters are significantly different according to Duncan's multiple range test at 5%.

NS *, **, *** Nonsignificant or significant at P ≤ 0.05, 0.01, or 0.001, respectively.

Table 3. First and second harvests combined, third, and total marketable and unmarketable tomato fruit yield by size categories in response to pre-plant, drip-injected fluensulfone during the fall of 2014 in Myakka City, FL.

Treatment	First and second harvests				Third harvest				Total season harvest				
	XL[a]	L	M	TM	XL	L	M	TM	XL	L	M	TM	UM
	Yield (Mg·ha^{-1})												
Pic-Clor 60	20.4a[b]	7.9	6.4	34.7	0.3b	1.8b	5.9b	8.0b	20.7a	9.7	12.2	42.6	2.5
Pic-Clor 60+fluensulfone 1.96 kg a.i·ha^{-1}	16.9b	9.0	6.0	31.8	1.1a	3.6a	11.3a	16.0a	18.0b	12.5	17.3	47.8	3.3
Pic-Clor 60+fluensulfone 2.80 kg a.i·ha^{-1}	19.3ab	8.3	4.7	32.3	1.0a	4.1a	11.7a	17.0a	20.3a	12.4	16.4	49.1	4.1
P-value	0.04	0.58	0.12	0.24	0.03	0.02	0.007	0.007	0.05	0.10	0.07	0.08	0.3
Significance	*	NS	NS	NS	*	*	**	**	*	NS	NS	NS	NS

[a] XL = extra-large (greater than 7.00 cm); L = large (6.35 to 7.00 cm); M = medium (5.72 to 6.43 cm);); TM = total marketable, UM = unmarketable [fruit with defects such as sunscald, scratch, off-shape, catface, and graywall (Jones et al., 1991; Ozores-Hampton et al., 2010)].

[b] Within columns means followed by different letters are significantly different according to Duncan's multiple range test at 5%.

NS *, **, *** Nonsignificant or significant at P ≤ 0.05, 0.01, or 0.001, respectively.