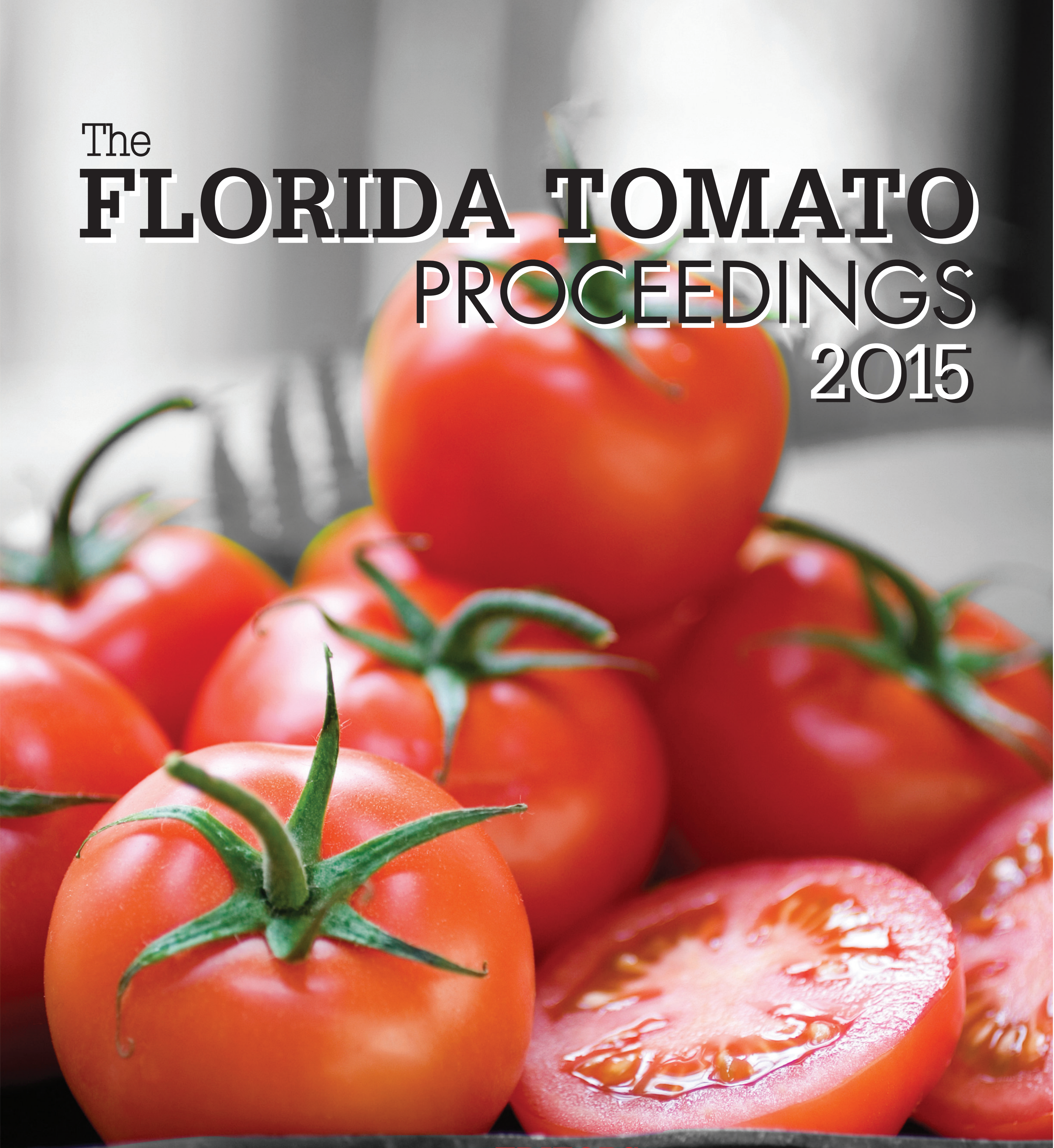

The FLORIDA TOMATO PROCEEDINGS 2015

EDITORS

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VANCE
INNOVATIVE SOLUTIONS THAT GROW BUSINESSES

UNIVERSITY OF FLORIDA
IFAS EXTENSION

2015 FLORIDA TOMATO INSTITUTE PROGRAM

The Ritz-Carlton, Naples, Florida | September 9, 2015/PRO 531

MODERATOR: Monica Ozores-Hampton, UF/IFAS, Immokalee

9:00 **Welcome** – Dr. Calvin Arnold, UF/IFAS, SWFREC, Immokalee.

9:10 **State of the industry** – Reggie Brown, Florida Tomato Committee, Maitland.

9:20 **Recent progress in TYLCV resistance breeding and implications for tomato varieties of the future -** Samuel Hutton, UF/IFAS, GCREC, Wimauma. **Page 6**

9:40 **Controlled-release fertilizer as a BMP for tomato production** – Monica Ozores-Hampton, UF/IFAS, SWFREC, Immokalee. **Page 9**

10:00 **Production and Environmental Aspects of Compact Bed Geometry Design** – Sanjay Shukla, UF/IFAS, SWFREC, Immokalee. **Page 13**

10:20 **Supplemental fumigation strategies for the management ofsoilborne diseases in tomato production -** Gary Vallad, UF/IFAS, GCREC, Wimauma. **Page 14**

10:40 **New Insights Regarding the Spatial Distribution of Nematodes and Soil Applied Fumigants and the Needs for New Strategies Considering Vertical Management Zones for Nematode Control -** Joe Noling, UF/IFAS, CREC, Lake Alfred. **Page 16**

11:00 **Risk management and fumigation choice in tomato production** – John Vansickle, UF/IFAS, Food and Resource Economics Department, Gainesville. **Page 19**

11:20 **Evaluation of the usefulness of a late blight decision support system in Florida tomato** – Pamela Roberts, UF/IFAS, SWFREC, Immokalee. **Page 22**

11:30 Lunch (on your own)

MODERATOR: Crystal Snodgrass, Manatee County Extension, Palmetto.

1:00 **Recruiting H-2A Workers into Florida Vegetable Operations** – Fritz Roka, UF/IFAS, SWFREC, Immokalee. **Page 23**

1:20 **Western flower thrips and tospoviruses emerging as serious threats to tomato in central and southern Florida -** Joseph Funderburk, UF/IFAS, NFREC, Quincy and Scott Adkins, USDA-ARS, Ft. Pierce. **Page 25**

1:40 **Evaluation of tomato cultivars and insecticides for management of Tomato chlorotic spot virus (TCSV) and thrips species recorded in virus-infected tomato fields"** – Shouan Zhang & Dakshina Seal, UF/IFAS, TREC, Homestead. **Page 28**

2:00 **Managing Pests and Insecticide Resistance in Florida Tomato -** Hugh Smith, UF/IFAS, GCREC, Wimauma. **Page 31**

2:20 **Effect of acibenzolar-s-methyl on bacterial wilt incidence of grafted tomatoes** – Mathews Paret, UF/IFAS, NFREC, Quincy. **Page 33**

2:40 **Eliminating Transplant Shock by Hormonal Control to Improve Growth and Yield of Tomato -** Shinsuke Agehara, UF/IFAS, GCREC, Wimauma. **Page 34**

3:00 **Industry Updates** – Qingren Wang, Miami-Dade County Extension Service, Homestead.

3:45 Adjourn

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Fertilizer and nutrient management for tomato - Monica Ozores-Hampton, UF/IFAS, SWFREC, Immokalee. **Page 38**

Water management for tomato - Monica Ozores-Hampton, UF/IFAS, SWFREC, Immokalee. **Page 41**

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Tomato fungicides - Gary E. Vallad, UF/IFAS GCREC, Wimauma. **Page 46**

Tomato biopesticides and other disease control products - Gary E. Vallad, UF/IFAS GCREC, Wimauma. **Page 58**

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Recent Progress in TYLCV Resistance Breeding, and Implications for Tomato Varieties of the Future

S.F. Hutton and J.W. Scott

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INTRODUCTION

Begomoviruses pose a major threat to tomato production in many tropical and subtropical environments. Yield losses due to this disease complex can be severe and if infection is early can reach 100%. The emergence of *Tomato Mottle Virus* (ToMoV) in 1989 marked the introduction of begomoviruses to Florida. *Tomato Yellow Leaf Curl Virus* (TYLCV) entered the state in 1997 and quickly became endemic by displacing ToMoV. Since 1990, breeding for begomovirus resistance has been a major goal of the University of Florida (UF/IFAS) tomato breeding program. Throughout most of these years, the program utilized both TYLCV and ToMoV inoculations to select for resistance that is broadly effective against many begomoviruses. Several resistance genes (termed *Ty* genes) have been identified in and introgressed from wild relatives of tomato by the UF/IFAS tomato breeding program and by other researchers. Some of these genes, however, have been overcome by various begomovirus strains (e.g. *Ty-2* is not effective against the bipartites or against some strains of TYLCV; and *Ty-1* is not effective against some strains of TYLCV in Spain and some areas of Asia South America).

Despite more than two decades of variety improvement efforts by the UF/IFAS program and by private company breeding programs, growers in Florida have been generally dissatisfied with TYLCV resistant varieties, feeling that most of these compromise on the yield and horticultural characteristics expected in commercial varieties. Probably the main reason for the underperformance of resistant varieties has to do with linkage drag associated with some of the resistance genes. The *Solanum chilense* introgressions containing *Ty-1* and *Ty-3*, two of the more widely used genes in commercial hybrids, each typically have undesirable effects on varieties' performance. Recent research efforts at UF have resulted in the fine mapping of these loci and the development of advanced breeding lines and parents with little or no linkage drag. These materials are available to seed companies for the development of improved TYLCV-resistant varieties, and they are also being used in the UF/IFAS breeding program for hybrid development. We have recently developed numerous hybrids containing *Ty-1* or *Ty-3*, some of which have shown commercial potential. Further evaluation of these in yield trials is needed to accurately measure their performance relative to currently-grown varieties.

In addition to each of the previously known resistance genes, the UF/IFAS tomato breeding program also utilizes *Ty-6*, a newly-identified resistance gene derived from *S. chilense* (Hutton and Scott, 2014). This gene was difficult to find because it did not have a typical *S. chilense* introgression around it. Since it was in a large number of our begomovirus resistant breeding lines that had been selected in the field without molecular markers, we strongly believe that there will be no linkage drag associated with this gene. Recently, after considerable research, we found a robust, tightly linked molecular marker that can be used for marker assisted selection of *Ty-6*, and this will greatly facilitate its use and more rapid incorporation into improved breeding lines. Our observations suggest that this gene provides a high level of resistance to TYLCV when combined with other *Ty* genes. Furthermore, because this gene was selected under both TYLCV and ToMoV inoculations, it is hypothesized to provide broad protection against bipartite begomoviruses as well. Gaining a clear understanding of how *Ty-6* functions when combined with other resistance genes is necessary for the deployment of this gene in varieties.

MATERIALS AND METHODS

Hybrid trials were conducted at the Gulf Coast Research and Education Center (GCREC) in Balm, FL during the fall 2014 and spring 2015 seasons. Seeds were sown directly into 128-well transplant trays, and transplants were grown in a greenhouse and planted to the field approximately five (for the fall trial) to six (for the spring trial) weeks after sowing. Transplants were planted to field beds that were eight inches high, 32 inches wide and had been fumigated with 300 lbs/A Pic-Clor 60 and covered with plastic mulch. Beds were fertilized with 300-150-500 lbs/A N-P_2O_5-K_2O and irrigated using drip tape beneath the plastic mulch. Hybrids were evaluated using a randomized complete block design, with two blocks and 10-plant plots. In-row spacing was 18 inches, and between-row spacing was five feet; however, yields were calculated on a six-foot between-row basis. Three vine-ripe harvests were conducted each season at weekly intervals, wherein the center eight plants of each plot were picked. Fruit were graded into marketable yield size categories according to the USDA specifications, and yields were converted to 25 lb boxes/A. Statistical analysis and mean separation was performed using SAS (Version 9.1; SAS Institute, Cary, NC).

To investigate the effect of *Ty-6* in combination with other resistance genes, two F_2 populations segregating for *Ty-6* and either *Ty-3* or *ty-5* were evaluated. For one of these populations, Fla. 8680, which contains *Ty-3* and *Ty-6*, was crossed to the susceptible parent, Fla. 7781. Four-week old F_2 seedlings were inoculated as described previously using whiteflies viruliferous for TYLCV (Griffiths and Scott, 2001; Hutton et al., 2012). Whiteflies were subsequently killed prior to transplanting to the field. Each of 666 F_2 plants were genotyped using markers specific to the two resistance genes, and each plant was evaluated for TYLCV disease severity. For the second population, Fla. 8638B, which contains *ty-5* and *Ty-6*, was crossed to the susceptible parent, Fla. 7987. 217 F_2 seedlings were similarly inoculated with TYLCV, planted to the field, genotyped and evaluated for disease severity. For each population, experiments included resistant and susceptible controls. Disease severity was evaluated approximately 40 days after inoculation on a 0 to 4 scale, where 0 = no symptoms, 1 = slight symptoms visible only upon close inspection, 2 = clear symptoms evident on a portion of the plant, 3 = heavy symptoms on the entire plant and some plant stunting, and 4 = severe symptoms and stunting on the entire plant. Statistical analysis and mean separation was performed using SAS.

RESULTS

A number of hybrids evaluated in fall 2014 and spring 2015 yield trials demonstrated commercial potential, and some of these are resistant to TYLCV (Tables 1 and 2). Several hybrids, including Fla. 8970, Fla. 8972, Fla. 8946, and Fla. 8942, involve crosses with Fla. 8872B, a very large-fruited parent which has repeatedly demonstrated parental potential. Of these, Fla. 8970 was among the top performers in both trials. The other parent of Fla. 8970 is an improved, TYLCV resistant version of Fla. 7781, a released breeding line with fusarium crown rot (FCR) resistance (Scott and Jones, 2000). Even more notably, the fall 2014 trial experienced several days of rainy weather after the first harvest, which resulted in high cull rates due to severe cracking and checking of fruit for many hybrids, including some of the commercial controls. Despite this, Fla. 8970 maintained a high percentage of marketable fruit with excellent quality. Fla. 8973, which has resistance to TYLCV and the tospovirus Tomato Spotted Wilt Virus (TSWV) also performed well across both seasons. Evaluations of this hybrid are continuing, and it will also be tested in Dade County, where its tospovirus resistance would be useful against the new viruses *Tomato chlorotic spot virus* and *Groundnut ringspot virus* that have emerged there. Fla. 8971 and Fla. 8974 also performed well, and both utilize Fla. 8923 as a parent. This parent is a recently developed, very large-fruited inbred which contains a reduced *Ty-3* introgression, providing a level of tolerance to TYLCV in the hybrids without linkage drag effects (Hutton et al., 2015).

Analysis of the Fla. 8680 X Fla. 7781 F_2 population indicated that both *Ty-3* and *Ty-6* effectively reduced TYLCV disease severity, but that *Ty-3* provided a higher level of control than *Ty-6* (Table 3). Both genes displayed incompletely dominant resistance, where homozygosity for the resistance gene provided a higher level of control than heterozygosity. The highest level of resistance was observed in plants that contained *Ty-3* homozygously, and *Ty-6* either homozygously or heterozygously. Two-gene combinations consistently provided higher resistance than obtained by either *Ty-3* or *Ty-6* alone, except that homozygosity for *Ty-3* alone was equally effective as some two-gene combinations.

Planats in the Fla. 8638B X Fla. 7987 F_2 population with *Ty-6* in combination with *ty-5* likewise demonstrated a high level of resistance (Table 3). The highest level of disease control was observed in plants homozygous for both genes, and the second highest was in plants homozygous for *ty-5* and heterozygous for *Ty-6*. Heterozygosity at the *ty-5* locus provided no control, which is consistent with it being a recessive gene. Homozygosity for *Ty-6* provided control comparable to homozygosity for *ty-5*.

Further experiments have clearly demonstrated that *Ty-6* provides a particularly high level of resistance to ToMoV, whereas *Ty-1* and *Ty-3* alleles only provide a low level of tolerance to this bipartite begomovirus (data not shown). This is reinforced by observations made in Guatemala in 2001, where UF/IFAS breeding lines containing *Ty-6* maintained high levels of resistance against severe disease pressure from multiple bipartite begomoviruses. Thus, it is likely that *Ty-6* confers broad-spectrum begomovirus resistance and will be useful against other virus strains that may emerge in Florida in the future.

CONCLUSIONS

Several recently developed begomovirus resistant hybrids have demonstrated commercial potential and are being considered for release. Among these, Fla. 8970 may have particular utility as a Fusarium crown rot resistant hybrid with high resistance to TYLCV and excellent fruit quality. *Ty-6* provides moderate resistance to TYLCV and high resistance to ToMoV. This gene is thus anticipated to be broadly utilized in the future, and we infer that it may provide protection against begomoviruses that could emerge in Florida. Breeding lines containing *Ty-6* have been released and are available for private sector use (Scott, et al., 2015).

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Table 1. Total and extra-large marketable yields, percentage of marketable fruit and fruit size for hybrids for fruit harvested breaker and beyond at the Gulf Coast Research and Education Center in fall 2015.

		Yield (25lb boxes/A)											
		1st Harvest				Total of 3 harvests							
Hybrid	Resistances[z]	Total		Extra-large		Total		Extra-large		Percent Marketable		Fruit size (oz)	
Fla. 8969	TSWV	649	a[y]	556	a	1738	a	1312	a	80	ab	6.7	b
Fla. 8970	TYLCV, FCR	271	b-d	246	b-d	1674	a	1239	ab	80	a	6.9	ab
Fla. 8971	TSWV-tol, TYLCV-tol	97	c-e	93	de	1646	a	1478	a	73	ab	8.4	a
Fla. 8972		479	ab	439	ab	1537	a	1172	ab	67	ab	6.6	b
Fla. 8973	TYLCV, TSWV	202	c-e	198	c-e	1407	ab	1162	ab	72	ab	7.6	ab
Fla. 8866	TSWV	272	b-d	238	cd	1284	ab	1071	ab	62	a-d	7.4	ab
HM 1823	FCR	323	bc	311	bc	1247	ab	1092	ab	73	ab	7.7	ab
Fla. 8946		102	c-e	96	de	1234	ab	1027	a-c	66	a-c	7.2	ab
Fla. 8891	TSWV	275	b-d	230	cd	1203	ab	970	a-c	63	a-d	6.8	ab
HM 8849	FCR	164	c-e	158	c-e	1199	ab	947	a-c	60	a-d	7.3	ab
Fla. 8974	TYLCV-tol	215	c-e	209	cd	1189	ab	1028	a-c	61	a-d	7.6	ab
Ridge Runner	TYLCV, FCR	194	c-e	185	c-e	789	bc	687	b-d	56	b-d	7.7	ab
Florida 91		4	e	4	e	478	c	415	cd	40	d	8.4	a
Dixie Red	TSWV, N	59	de	59	de	460	c	419	cd	41	d	7.6	ab
Florida 47		11	e	8	e	446	c	317	d	42	cd	6.8	ab

[z] In addition to resistance to gray leaf spot, Fusarium wilt races 1 and 2, and Verticillium wilt. TYLCV = Tomato Yellow Leaf Curl Virus; FCR = Fusarium crown and root rot; F3 = Fusarium wilt race 3; N = nematode; tol = tolerance

[y] Mean separation by Duncan's multiple range test at P ≤ 0.05 based on a larger number of hybrids. Means within columns followed by the same letter are not significantly different.

Table 2. Total and extra-large marketable yields, percentage of marketable fruit and fruit size for hybrids for fruit harvested breaker and beyond at the Gulf Coast Research and Education Center in spring 2015.

Hybrid	Resistances[z]	Yield (25lb boxes/A)								Percent Marketable		Average Fruit Wt. (oz)	
		1st Harvest				Total of 3 harvests							
		Total		Extra-large		Total		Extra-large					
Fla. 8972		358	a[y]	281	a	2273	a	1820	a	82	a	6.6	ns
Fla. 8970	TYLCV, FCR	68	b	66	b	1818	ab	1620	ab	90	a	7.4	
Fla. 8942	TSWV, F3	105	b	95	b	1814	ab	1663	ab	89	a	7.6	
Fla. 8973	TYLCV, TSWV	176	b	149	b	1812	ab	1555	ab	81	a	7.0	
Fla. 8971	TYLCV-tol, TSWV-tol	43	b	43	b	1669	bc	1630	ab	80	a	9.0	
Fla. 8946-Ty	TYLCV	81	b	74	b	1661	bc	1574	ab	90	a	7.9	
Florida 91		39	b	39	b	1222	cd	1196	bc	82	a	8.6	
Florida 47		56	b	50	b	1034	d	891	c	66	b	7.1	

[z] In addition to resistance to gray leaf spot, Fusarium wilt races 1 and 2, and Verticillium wilt. TYLCV = Tomato Yellow Leaf Curl Virus; FCR = Fusarium crown and root rot; F3 = Fusarium wilt race 3; tol = tolerance

[y] Mean separation by Duncan's multiple range test at P ≤ 0.05 based on a larger number of hybrids. Means within columns followed by the same letter are not significantly different. ns = no significant differences in column

Table 3. Mean TYLCV disease severity of *Ty6* in combination with *Ty-3* or *ty-5* in two F_2 populations.

F_2 population: (Fla. 8680 X Fla. 7781)					F_2 population: (Fla. 8638B X Fla. 7987)				
	Ty-3[z]	*Ty-6*[z]	N	Mean DSI[y]		*ty-5*[z]	*Ty-6*[z]	N	Mean DSI[y]
Fla. 8680	+	+		1.0 e	Fla. 8638B	+	+		0.5 e
	+	+	37	1.2 e		+	+	20	0.9 e
	+	/	75	1.4 e		+	/	30	1.4 d
	+	--	40	1.9 d		+	--	22	2.1 c
	/	+	76	1.8 d		/	+	19	2.3 c
	/	/	179	2.0 d		/	/	27	2.8 b
	/	--	82	2.3 c		/	--	28	3.7 a
	--	+	31	2.5 c		--	+	17	2.1 c
	--	/	93	2.9 b		--	/	33	2.9 b
	--	--	53	3.3 a		--	--	21	3.7 a
S. control	--	--		3.6 a	S. control	--	--		4.0 a

[z] + = homozygous for the resistant allele; / = heterozygous for the resistant allele; -- = homozygous for the susceptible allele.

[y] DSI = Disease severity index, where 0 = no visible symptoms, 1 = very slight symptoms, 2 = clear symptoms on part of the plant, 3 = clear symptoms on the entire plant and some plant stunting, 4 = severe symptoms on the entire plant and severe stunting); Mean separation in columns by Duncan's Multiple Range Test at P ≤ 0.05

Controlled-release Fertilizer Use on Tomato Production in Florida

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INTRODUCTION

Florida had the second largest fresh-market tomato acreage in the US with 26,500 acres with a value of $437 million produced on 32,987 acres in the 2014 season (USDA-NASS, 2015). The Federal Environmental Protection Agency and Florida Department of Environmental Protection recognize the importance of water quality through the enforcement of the Federal Clean Water Act of 1972 and the Florida Restoration Act of 1999 (Ozores et al., 2009). The Florida Vegetable and Agronomic Crops Best Management Practices (BMPs) manual (www.floridaagwaterpolicy.com), adopted by the Florida Department of Agriculture and Consumer Services, contains a series of BMPs to maintain and ameliorate water quality. A BMP must be technically feasible, economically viable, socially acceptable, and based on sound science.

WHAT IS ENHANCED EFFICIENCY FERTILIZER (EEF)

The used of EEF are recognized as nutrient management BMPs. The use of EEF may reduce the risk of nutrient loss to the environment and subsequently increase nitrogen use efficiency (NUE) in a seepage irrigated tomato production system were the majority of the fertilizer will be pre-planted incorporated in the polyethylene mulched bed (Carson and Ozores, 22012, 2013 and 2014). There are three subgroups of EEF: slow-release fertilizers, controlled-release fertilizers (CRFs) and stabilized fertilizers. Controlled release-fertilizer are soluble fertilizers (SF) encapsulated in a polymer, resin, or a hybrid of sulfur coated urea occluded in a polymer coating. Several factors influence N release from CRFs including soil temperature, moisture content, osmotic potential, nutrient composition, coating thickness, and prill diameter. Manufacturers of CRF manipulate the N release duration of resin-coated fertilizer, polymer-coated fertilizer, and polymer sulfur-coated urea by adjusting the coating thickness and composition, with thicker coatings having longer release durations. Also, manufacturers measure CRF release duration as 75% N release at a constant temperature (e.g., 68 to 77 °F).

OBJECTIVES

1. Evaluate N release from CRFs buried pouches method (real-time field) in seepage-irrigated tomato mulched beds.
2. Evaluate N release from CRFs in a laboratory accelerated temperature controlled incubation method (ATCIM).
3. Correlate the N release between ATCIM and pouches methods to predicted N release.
4. Selected N and CRF technologies were used in a "hybrid fertilizer system" CRF N rates with SF in seepage-irrigated tomato mulched beds.

MATERIALS AND METHODS

In 2011 and 2013, 12 and 14 CRFs, respectively, were incubated in pouches contained CRF (3.5 g) N placed in polyethylene mulched raised beds in Immokalee, FL and extracted in the ATCIM during 2013 (Table 1). The ATCIM consisted in a 30 g CRF exposed to four increasingly aggressive (in length and temperature) extractions, using 0.2% citric acid as a solvent, during the course of 72 hours. The hybrid fertilizer system studies were conducted on a commercial tomato farm Immokalee, FL during fall 2011 and 2012, using tomato 'BHN 726'. A CRF mix was applied at different N rates (100, 150 and 200 lb/acre) applied bottom of the bed in combination with SF at 50 lb/acre banded in the shoulders of the bed with a total of 150, 200, and 250 lb/acre N. Data collection consisted on marketable fruit yield, postharvest quality, leaf tissue N content (LTNC), and post season soil N content. The ATCIM, field pouches methods and hybrid fertilizer tomato system field studies used a randomized complete block design with four replications and data was subjected to analysis of variance, correlation and regression analysis or orthogonal contrasts using the general linear model procedure.

RESULTS AND DISCUSIONS

High soil temperatures in polyethylene mulched tomato beds (Table 2) resulted in CRF-N release duration reductions from pouch-incubated CRFs compared to the manufacturers stated release duration (RD) of 23% to 88% in 2011 and 23% to 79% in 2013 [(Table 3) Carson et al., 2014a]. Also, CRFs must release greater than 75% N during the season, which was not found with all CRFs tested in these studies. Since, the pouch field method takes 120 to 140 days and requires numerous samples with high laboratory N analysis costs, an N release model that correlates the ATCIM and pouch field method was used to predict CRF N release in a tomato production system (Carson el al., 2014b). The correlation model pre-

Table 1. Controlled release fertilizer (CRF) used in the field pouch incubation and laboratory accelerated temperature controlled incubation method (ATCIM) during fall 2011 and 2013 seasons.

CRFs	Abbreviation[z]	Release duration	Grade[y]	Manufacturer[w]
PCU	PCU90	90	44-0-0	Agrium AT
PCU	PCU120	120	43-0-0	Agrium AT
PCNPK	PCNPK120	120	19-2.6-10.8	Agrium AT
PCU	PCU180	180	43-0-0	Agrium AT
PCNPK	PCNPK180	180	18-2.6-10	Agrium AT
PSCU	PSCU	180	37-0-0	Everris NA
RCNPK	RCNPK	120	19-2.6-10	Everris NA
PCN	FL100	100	28-0-0	JCAM Agri Co.
PCN	FL140	140	28-0-0	JCAM Agri Co.
PCKN	FL180	180	12-0-33.2	Florikan ESA
PCM	FLMix	100 to 180	19.2-0-11.3	Florikan ESA
Fall Mix 100	M100	100 to 180	7.5-3.6-10.3	Florikan ESA
Fall Mix 150	M150	100 to 180	12.3-3.6-10.3	Florikan ESA
Fall Mix 200	M200	100 to 180	15-3.6-10.3	Florikan ESA

[z] PCU, polymer coated urea; PCNPK, polymer coated compound nitrogen (N), phosphorus (P), and potassium (K) fertilizer; PSCU, polymer sulfur coated urea; RCNPK, resin coated compound N, P, and K fertilizer; PCN, polymer coated N, PCNK, polymer coated potassium nitrate; PCM, polymer coated mix containing FL100, FL140, and FL180; M100, M150, and M200 are mixes of CRF and SF that when applied at 1493 $kg \cdot ha^{-1}$ supply 100, 150, and 200 $kg \cdot ha^{-1}$ CRF N.

[y] Fertilizer grade = (%N,%P,%K).

[w] Agrium Advnaced Technology, Loveland, CO; Everris NA, Inc., Dublin, OH; Florikan ESA, LLC., Sarasota, FL; Chisso-Asahi Fertilizer Co. Ltd., Tokyo, Japan.

dicted the percentage N release of individual CRF with R^2 of 0.95 to 0.99 and 0.61 to 0.99 and CRFs grouped by release duration with R^2 of -0.64 to 0.99 and -0.38 to 0.95 in 2011 and 2013, respectively (Figure 1). Modeling CRF N release using CRFs grouped by release duration would not be recommended for CRF 180 days release; due to the coating technologies behaviors apparently differ in response to high fall soil temperature in polyethylene mulched tomato beds. However, with further model validation grouping CRFs of 90 to 140 days release to simulate the CRF N release profile may allow the ATCIM to predict CRF N release without performing the pouch field method.

The hybrid fertilizer system produced similar or greater marketable tomato yields and low residual soil N post season with CRF100/SNF50 (150 lb/acre) or CRF150/SNF50 (200 lb/acre) compared to the grower standard SNF (250 lb/acre N), CRF200/50SNF (250 lb/acre N), or the University of Florida/Institute of Food and Agricultural Sciences (UF/IFAS) SNF (200 lb/acre) rates [(Table 4) Carson et al., 2014a and b]. Thus, the hybrid fertilizer system may allow for reduced N rates by 25% to 46%. There were no commercially important differences in stage 5 or 6 (red ripe) tomato firmness and skin color for any CRF after mature green tomatoes were subjected ethylene treatment. Also, no negative impacts of CRFs were found LTNC during the seasons.

In 2011, CRF200/SNF50 had a greater NH_4^+-N and urea-N content remaining in the soil post season compared to the other treatments (Table 5). Grower, UF/IFAS and CRF200/SNF50 had the highest NO_3^--N content remaining in the soil post season, but CRF200/SNF50 was not different than CRF100/SNF50 and CRF150/SNF50. There were no differences in $NH4^+$-N, NO_3^--N, or urea-N content in the fertilizer prills among treatments with an averaged 1.2, 1.6, and 0.3 kg·ha^{-1}, respectively. There were no differences in TN remaining in the soil post season among treatments with an average of 14.9 lb/acre. The linear contrasts were significant, among the CRF N treatments, for NH_4^+-N and urea-N in the soil, and for TN post season. Therefore, increasing CRF N rates increased $NH4^+$-N, urea-N and TN remaining in the soil post season. All CRFs released 96.4% of the N or greater during the season. In 2012, soil urea-N contents from CRF200/SNF50 and CRF150/SNF50 were higher than the other treatments. There were no differences among treatments in any other N category. Linear contrasts among N CRF were significant for urea-N in soil and CRF prills indicating increasing CRF N rates will increase the amount of urea-N remaining post season. All CRFs released 86.8% or higher N during the season.

CONCLUSSIONS

CRFs can be partially incorporated in a fall tomato fertility program maintaining marketable yields and fruit quality at reduced N rates with a low soil residual N. Despite the fact that CRF utilization may be socially acceptable and science indicates that can be technically feasible the use of CRF does not meet the economic and environmental criteria to be a BMP for seepage produced tomato in south Florida. Therefore, further investigations into CRF as a BMP must include an environmental and economic analysis.

Table 2. Minimum (Min.), mean, and maximum (Max.) soil temperatures at 4-inches below the bed surface during Fall 2011 and 2013 in Immokalee, FL.

	Min.		Mean		Max.	
Week ending [z]	**2011**	**2013**	**2011**	**2013**	**2011**	**2013**
9 Aug.	78.26	-	86.54	-	104.18	-
16 Aug.	77.36	-	86.54	-	103.28	-
23 Aug.	76.46	-	85.46	-	104.18	-
30 Aug.	77.00	-	84.74	-	99.68	-
6 Sept.	76.10	-	83.30	-	98.06	-
13 Sept.	76.46	-	87.08	-	102.38	-
20 Sept.	77.00	-	86.54	-	100.58	-
27 Sept.	75.20	77.36	82.94	82.58	96.80	93.02
4 Oct.	72.50	76.46	83.48	83.12	96.80	93.92
11 Oct.	71.96	74.66	79.52	82.04	90.86	91.76
18 Oct.	74.30	74.12	78.80	81.50	90.86	89.96
25 Oct.	64.76	70.16	73.58	81.14	82.76	91.76
1 Nov.	68.36	69.26	75.20	76.28	82.40	84.92
8 Nov.	62.96	68.36	72.32	76.10	81.86	85.46
15 Nov.	61.70	66.02	71.06	74.48	80.06	80.42
22 Nov.	70.16	71.42	75.74	76.46	83.66	81.32
29 Nov.	66.20	62.42	72.50	72.50	81.86	79.16
6 Dec.	58.46	64.22	68.00	70.70	77.00	76.82
13 Dec.	63.50	65.12	70.34	72.86	78.80	77.72
20 Dec.	60.26	62.06	69.26	69.08	75.56	75.02
27 Dec.	62.96	66.92	68.90	71.60	75.56	76.82
3 Jan.	-	62.42	-	71.42	-	74.66
10 Jan.	-	58.46	-	65.48	-	74.66
17 Jan.	-	55.76	-	68.00	-	75.92
24 Jan.	-	53.42	-	61.16	-	68.72
Average	**70.09**	**66.59**	**78.18**	**74.25**	**89.87**	**81.78**

[z] Collection dates began on 3 Aug. 2011, and 24 Sept. 2013, and ended on 22 Dec. 2011, and 23 Jan. 2014.

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Table 3. Percentage nitrogen (N) release from controlled-release fertilizers (CRFs) incubated in pouches 4-inches below the surface of white polyethylene mulch covered raised bed during Fall 2011 and 2013 tomato production seasons in Immokalee, FL.

CRF[z]	Year	7	14	28	42	60	90	120	150
		Day after bedding							
		----------------------------N Release (%) ----------------------------							
PCU90	2011	22.9	37.9	64.3	77.8	82.4	89.2	92.6	93.8
	2013	16.0	35.7	62.4	65.3	70.3	87.6	94.3	90.0
PCU120	2011	19.5	33.0	48.6	70.6	77.3	84.5	88.3	91.1
	2013	41.2	44.5	59.4	55.9	68.6	81.9	79.9	76.0
PCNPK120	2011	27.7	37.0	51.7	71.4	79.2	83.3	86.7	90.2
	2013	47.5	61.6	71.1	79.7	85.0	94.8	94.3	94.0
PCU180	2011	23.0	24.4	52.1	69.0	81.8	85.6	88.7	91.5
	2013	29.5	38.6	64.4	51.6	73.0	80.6	83.8	82.3
PCNPK180	2011	-	-	-	-	-	-	-	-
	2013	36.5	34.4	42.6	51.9	61.6	78.3	83.4	85.9
PSCU	2011	31.9	33.6	36.2	45.9	60.6	69.5	77.6	78.2
	2013	41.5	40.8	44.6	43.3	35.8	60.8	63.4	64.0
RCNPK	2011	29.3	42.6	52.3	69.3	76.8	85.5	87.6	90.2
	2013	50.5	60.3	65.6	70.7	78.7	92.4	93.9	91.6
FL100	2011	57.5	69.4	80.0	88.2	92.0	86.0	87.2	91.5
	2013	60.1	65.0	77.3	81.2	87.4	90.1	94.0	92.7
FL140	2011	52.1	68.8	87.0	88.5	94.3	86.9	89.0	91.3
	2013	65.5	65.6	75.4	78.0	82.9	86.3	87.4	88.0
FL180	2011	6.6	10.0	63.3	61.3	87.5	62.5	75.1	77.6
	2013	19.0	19.1	43.0	44.4	41.1	50.1	59.4	58.3
FLmix	2011	-	-	-	-	-	-	-	-
	2013	64.3	61.5	66.4	74.5	69.1	79.4	81.9	77.4
M100	2011	14.2	34.5	47.9	54.5	61.1	78.2	81.4	82.5
	2013	47.2	49.8	49.8	68.0	64.5	77.1	84.9	80.5
M150	2011	38.4	50.3	68.1	71.1	75.8	81.9	84.5	88.0
	2013	57.2	64.3	62.6	72.3	77.3	81.6	88.8	87.6
M200	2011	45.9	57.2	70.8	80.2	80.8	83.2	84.6	86.8
	2013	48.5	58.5	69.7	74.9	79.0	87.3	85.9	86.2

[z] PCU90 = polymer coated (PC) urea, 90 d release (DR); PCU120 = PC urea, 120 DR; PCNPK120 = PC nitrogen, phosphorus and potassium (NPK),120 DR; PCU180 = PC urea, 180 DR; PSCU = polymer sulfur coated urea, 180 DR; RCNPK = resin coated NPK, 120 DR; FL100 = PC urea, ammonium nitrate, 100 DR; FL140 = PC urea and ammonium nitrate, 140 DR; FL180 = PC potassium nitrate, 180 DR; FLmix = mix of FL100, FL140 and FL 180 ; M100, M150 and M200 = mixes of CRF and SF that when applied at 1,333 lb/acre supply 100, 150, and 200 lb/acre CRF N.

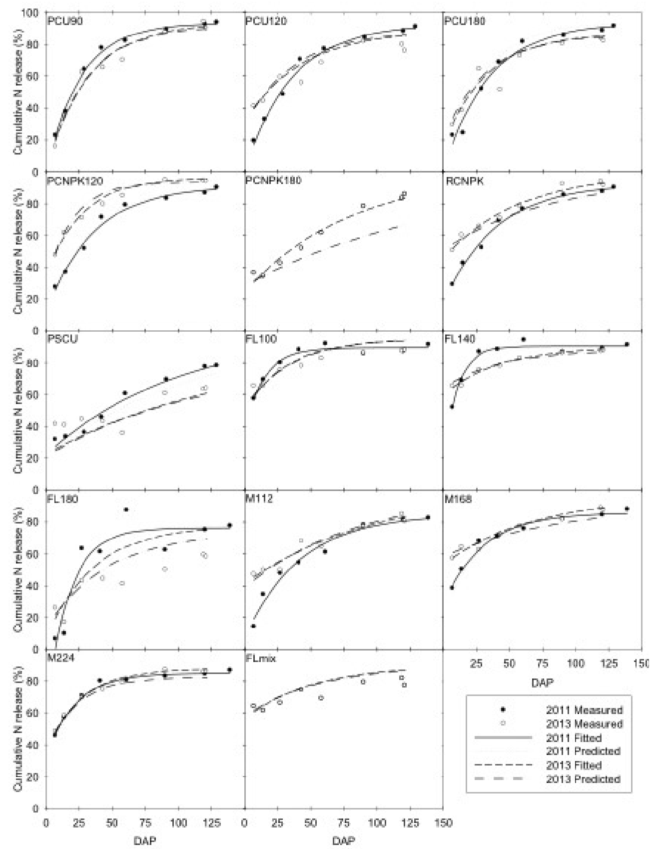

Figure 1. Field release points for nitrogen (N) controlled release fertilizers on-farm pouch method incubated 10 cm below the surface of a white polyethylene mulched raised bed during Fall 2011 and 2013 in Immokalee, FL and fitted and predicted

Table 4. Fruit yield by size categories for first harvest, first and second harvest combined, and season total harvest (three harvests combined) for five controlled-release fertilizer (CRF)/soluble nitrogen fertilizer (SNF) programs used to grow tomato in Immokalee, FL during Fall 2011 and 2012.

		First Harvest				Season Total				
	Treatments	Xlg	Lg	Med	Total	Xlg	Lg	Med	Total	Cull
		--------------------------------------- (boxes/acre) -----------------------------------								
2011	Grower standard	332	61	21	414	771	535	521b	1,827b	350b
	UF/IFAS	368	64	14	446	628	585	881a	2,091a	546a
	CRF100/SNF50	400	68	21	489	810	674	689b	2,173a	375b
	CRF150/SNF50	282	82	18	382	689	696	664b	2,048a	425b
	CRF200/SNF50	307	78	21	407	699	674	674b	2,048a	549a
	P value	0.07	0.79	0.7	0.18	0.11	0.12	0.001	0.02	0.0002
	Sig.	ns	ns	ns	ns	ns	ns	***	*	***
2012	Grower standard	610b	93	-	703cd	1,056	1,017	528	2,601	253
	UF/IFAS	496b	57	-	553d	1,017	1,056	517	2,587	211
	CRF100/SNF50	785a	100	-	885ab	1,131	853	471	2,458	293
	CRF150/SNF50	806a	139	-	946a	1,260	981	446	2,687	218
	CRF200/SNF50	628b	118	-	746bc	1,156	1,110	450	2,715	271
	P value	0.004	0.06	-	0.008	0.06	0.24	0.08	0.30	0.22
	Sig.	**	ns	-	**	ns	ns	ns	ns	ns

Table 5. Total post season soil test nitrogen (N) as ammonium-N (NH_4^+-N), nitrate-N (NO_3^--N), and urea-N in the soil and controlled-release fertilizer (CRF) prills from five CRF/soluble nitrogen fertilizer (SNF) programs used to grow tomato in Immokalee, FL during Fall 2011 and Fall 2012.

	Soil[z]			CRF prills				
	NH_4^+-N	NO_3^--N	Urea-N	NH_4^+-N	NO_3^--N	Urea-N	Total N	N release (%)[y]
Treatment				(lb/acre)				
				2011				
Grower standard	4.3b[x]	12.8a	0.0b	-[w]	-	-	17.0	-
UF/IFAS	2.3b	14.2a	0.1b	-	-	-	16.6	-
CRF100/SNF50	4.3b	2.4b	0.8b	1.3	1.9	0.4	11.1	96.4
CRF150/SNF50	4.2b	1.7b	0.4b	1.1	1.8	0.2	9.4	97.8
CRF200/SNF50	7.6a	7.9ab	2.3a	1.2	1.2	0.2	20.4	98.7
P value	0.006	0.016	0.004	0.78	0.52	0.64	0.12	-
Significance[v]	**	**	**	NS	NS	NS	NS	-
Contrast linear (CRF only)	0.040	0.10	0.047	0.59	0.31	0.49	0.039	-
Significance	*	NS	*	NS	NS	NS	*	-
				2012				
Grower standard	6.7	9.3	0.0b	-	-	-	16.0	-
UF/IFAS	5.5	3.2	0.0b	-	-	-	8.7	-
CRF100/SNF50	6.0	2.7	0.0b	1.5	10.1	0.0	19.2	89.5
CRF150/SNF50	4.6	2.9	0.1a	2.1	13.8	0.0	22.0	90.4
CRF200/SNF50	3.8	5.7	0.1a	2.7	26.5	0.1	36.0	86.8
P value	0.09	0.20	0.01	0.71	0.32	0.06	0.07	-
Significance	NS	NS	*	NS	NS	NS	NS	-
Contrast linear (CRF only)	0.13	0.29	0.037	0.43	0.16	0.027	0.20	-
Significance	NS	NS	*	NS	NS	*	NS	-

[z] An 3.6-inches wide × 8-inches deep cross section of the tomato bed was taken from each treatment in all four replications. The cross section was divided into three vertical sections, mixed and sampled. Each number is the mean of 12 measurements.
[y] N release = (total CRF N applied-N remaining in CRF prills)/total CRF N applied.
[x] Within columns, means followed by different letters are significantly different according to Duncan's Multiple Range Test, 5% level.
[w] No CRF were used in the grower standard and University of Florida, Institute of Food and Agriculture Science (UF/IFAS) treatments, thus analysis of variance was carried out on only CRF treatments for these columns.
[v] NS,*,**=Non-significant or significance at $P \leq 0.05$ or ≤ 0.01, respectively.

Production and Environmental Aspects of Compact Bed Geometry Design

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INTRODUCTION

Commercial vegetable and melon production in Florida plays a noteworthy role in the state's economy with annual sale values over $1.5 billion (USDA, 2011). Tomato is Florida's largest single vegetable crop in terms of value accounting for 45% of the United States' fresh market tomato production at over $600 million annually. Tomato along with most vegetable and melon crops are usually grown on raised soil beds covered by impermeable plastic mulch in a practice known as raised-bed plasticulture. Commercial plasticulture is intensive as it requires large inputs of water, fertilizer, and energy and has higher production costs compared to open field systems. Finding ways to improve the efficiency of plasticulture production (i.e. lowering inputs while maintaining or increasing output) can help growers remain economically competitive and reduce production impacts on surrounding environments.

One potential avenue for improving production efficiency is re-designing the raised soil beds employed in commercial plasticulture production. The conventional bed geometry of soil beds found in practice today tend to be wide (30 to 36 in.) and short (4 to 8 in.) (Clark and Maynard, 1992; Lamont, 1996). These bed dimensions were developed as plasticulture was being introduced into commercial production in the 1950s and 1960s. As plasticulture has undergone significant changes since first being introduced to improve production, including new plant varieties as well as enhanced water, nutrient, and chemical delivery methods (i.e. drip irrigation, fertigation, and fumigation), the bed geometries found in vegetable production have yet to evolve. Re-designing the bed geometry found in raised be plasticulture to be taller (10-12 in.) and narrower (16-24 in.) can better fit modern water, nutrient, and chemical delivery technologies, reduce production costs for growers, lower flood and runoff risks, and decrease environmental impacts. A variety of crops, including tomato and eggplant, have been grown successfully on narrower beds without compromising yield (Clark and Maynard, 1992; Kovach et al., 1983). However, limited work has been done to evaluate compact bed geometries that are both narrower and taller in commercial plasticulture production. The goal of this study was to compare conventional bed geometries (widths: 30-36 in., heights: 6-8 in.) to compact bed geometries (widths: 16-24 in., heights: 10-12 in.) for commercial vegetable production in Florida.

METHODS AND MATERIALS

Compact beds were evaluated for commercial production of two crops: tomato (*Solanum lycopersicum*) and eggplant (*Solanum melongena*). A two-season tomato field study was conducted at a commercial farm within southwest Florida near the town of Immokalee. The study site had flat topography, sandy topsoil underlain by a restrictive layer, and a shallow water table. In the study, the farm's conventional bed geometry–30 in. x 8 in.–was evaluated against three compact bed geometry alternatives–24 in. x 10 in., 18 in. x 12 in., and 16 in. x 12 in. A single drip tape and solid granular fertilizer was incorporated into the different beds which were covered with black plastic mulch. Fertigation was used to deliver nutrients in conjunction with the granular fertilizer. All beds were constructed on a center spacing of six feet and received the same water and fertilizer rates representative of standard farm practices. Three bi-weekly harvests were conducted in each season to compare yield for tomato between the conventional and compact bed geometries under standard grower practices. The field study was conducted for the 2012-2013 and 2013-2014 growing seasons with tomatoes transplanted in December and final harvests occurring in April.

Eggplant was evaluated for one growing season at a commercial vegetable farm located within the Everglades Watershed. The study site consisted of sandy topsoil and a shallow water table. The farm's conventional bed geometry–36 in. x 6 in.–under standard management was evaluated against two compact bed geometries under improved management. Two drip tapes were incorporated into the conventional bed geometry and used for water and nutrient delivery. The compact beds used only a single drip tape. Eggplant was transplanted in October 2013. Yield was collected on a weekly basis with final harvest on January 5, 2014. Yield data represented production from a 13-week transplanted crop.

In conjunction with yield monitoring, hydrologic (irrigation, soil moisture, and water table), weather, and growth (leaf-area-index, tissue nutrient concentrations, and plant height) data was collected from the different bed geometries in the tomato and eggplant field studies. Production cost differences between the conventional and compact bed geometries were compared in both field studies to assess the economic impact of compact bed geometries.

RESULTS AND DISCUSSION

Compact beds were able to successfully grow tomato without compromising yield compared to the conventional bed geometry. No statistical difference ($\alpha = 0.05$) in yield was observed between the conventional 30 in. x 8 in. bed and the 24 in. x 10 in. and 16 in. x 12 in. compact beds in either season (Holt, 2015). Differences were observed between the conventional bed and the 18 in. x 12 in. bed in season 1. With improvements in construction of the 18 in. x 12 in. bed made in season 2, no statistically significant differences were observed. Plants were not observed to be water stressed in any bed geometry as average levels of soil moisture in all beds were at or above field capacity (7–12% volumetric water content). Seasonal averages of tissue nutrient concentrations from plants grown on the different beds fell within or above UF-IFAS sufficiency ranges, indicating plants were not nutrient limited in any bed geometry (Hochmuth et al., 2012).

No statistical differences in yields were observed between the 36 in. x 6 in. conventional bed with two drip tapes and the 24 in. x 12 in. and 18 in. x 12 in. compact beds with one drip tape in the eggplant field study (Holt and Shukla, 2015). Compact beds were able to reduce water applied by 50% and nitrogen and phosphorus applied by 10–15%. Soil moisture measured in the beds revealed plants grown on the compact beds with a single tape were not water stressed. Leaf tissue concentration averages also indicated plants were not nutrient limited as N, P, K concentrations from all bed geometries fell within UF-IFAS sufficiency ranges (Hochmuth et al., 2012).

Economic and environment benefits can be achieved by transitioning to compact beds. Seasonal production costs can be reduced by up to $300/acre with compact beds compared to conventional beds through savings in fumigant, plastic mulch, irrigation fuel, and drip tape. For the same plant population, fumigant represents the greatest area for savings as the narrower compact beds directly reduce bedded area that must be treated compared to conventional beds. Thus, the amount of fumigant which must be applied to a field is reduced. Because beds are covered by plastic mulch which is impervious, reducing bedded area also increases field permeability and soil water storage capacity allowing for improved flood and disease protection as well as decreased field runoff. For growers who pay to lease land, compact beds also allow spacing between rows to be reduced without increasing bedded field area compared to conventional beds on standard spacing. Decreasing bed spacing allows plant population to be increased creating an opportunity to take land out of production, which can represent significant annual savings in land lease costs for growers.

SUMMARY AND FUTURE WORK

Tomato and eggplant field studies were conducted at commercial vegetable farms to compare compact (widths: 16-24 in., heights: 10-12 in.) and conventional (widths: 30-36 in., height: 6-8 in.) bed geometries. When evaluated against the conventional beds, the compact beds were not found to compromise yield of tomato or eggplant. With similar production, adoption of compact beds can provide several potential benefits to growers. Compact beds can conservatively save growers up to $300/acre in seasonal production costs through potential reductions in fumigant, plastic mulch, drip tape, and irrigation fuel. Compact beds also appear better suited for drip irrigation, fertigation, and fumigation on Florida's sandy soils compared to the short and wide conventional beds. Transitioning plasticulture production from conventional to compact bed geometries also facilitates reductions in water and nutrient application rates and leaching.

Future studies are currently planned to further assess the impact compact bed geometries (width: 16-24 in., height: 10-12 in.) have on commercial plasticulture production in Florida. Another two-season tomato field study will be conducted at a commercial tomato farm to continue to evaluate the potential economic and environmental impacts of compact beds. A separate two-season study is also planned to start in fall 2015 for pepper to evaluate the feasibility of using of compact beds for commercial plasticulture production where crops are grown in double-rows. With continued evaluations, conclusions can be made on what bed geometries are most economically and environmentally advantageous for vegetable and melon production using plasticulture.

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Supplemental Fumigation Strategies for the Management of Soilborne Diseases in Tomato Production

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BACKGROUND

Since the phase-out of methyl bromide (MBr), several alternative fumigants have reached the market, to include chloropicrin (Pic), dimethyl disulfide (DMDS), 1,3-dichloropropene (1,3-D), and several isothiocyanate (ITC) generators that include metam sodium (Vapam), metam potassium (Kpam), and allyl isothiocyanate (AIT). Two to three of these alternative fumigants are typically co-formulated or co-applied to improve their activity against a broad spectrum of weeds, nematodes, and pathogens that reside in soil; which I'll refer to here as a fumigant system. Regardless of the current fumigant system, all the fumigants lack the ability to disperse in soil to the extent of MBr, as a function of their lower volatility. Volatility is the tendency of any substance, in this case the fumigant, to convert to a gas, and is directly related to the substance's vapor pressure. The vapor pressure and boiling point information for each currently available fumigant is shown in Table 1 and can also be found on the material safety data sheet (MSDS) available for all fumigants. The vapor pressure values for Pic and 1,3-D are on average ~70-fold less than MBr at 68°F. The ITC generators are even less volatile than Pic and 1,3-D with physical characteristics more akin to water; explaining why these products are typically applied via chemigation. The reduced volatility of current fumigant systems has a huge impact on the distance to which a fumigant will disperse, the time it takes to disperse, and the relative concentration of the fumigant at any given time throughout the treated soil profile.

Our research goal was to investigate field sites where the currently available fumigant systems failed to manage Fusarium wilt caused by the soilborne fungus *Fusarium oxysporum* f.sp. *lycopersici* (*FOL*). Our initial observations were that most of the field sites having issues with Fusarium wilt were drip-irrigated, and that tomato roots could frequently be found growing along bottom bed edges and below the plastic mulch tuck. Based on these observations, we hypothesized that the increase in Fusarium wilt was due to the under-fumigation of the soil beneath the shoulder of the bed (also referred to as the bed edge) and soil immediately below the mulch tuck. We further hypothesized that the return to a MBr-based fumigation system would 'rescue' these fields. Indeed, field trials at Gulf Coast REC (Wimauma, FL) and at a grower site (Myakka, FL) demonstrated that the application of MBr:Pic (67:33 or 50:50 at 350 lbs/treated acre) significantly reduced the incidence of Fusarium wilt to an acceptable level compared to the standard application of Pic-Clor 60 (300 lbs/treated acre) (Fig. 1).

Additional evidence pointing to the inability of the alternative fumigant systems to effectively disperse in the bed, came from the recovery of total *Fusarium oxysporum* from soil cores collected from throughout the bed profile and from the recovery of either *FOL* or *Sclerotium rolfsii* from nylon bags that were strategically placed throughout beds immediately following fumigation. These assay results demonstrated the inability of the applied Pic-Clor 60 fumigant to effectively reduce levels of total *Fusarium oxysporum* in soils, or *FOL* or *S. rolfsii* in soils near the edge of the bed or below the mulch tuck, as compared to MBr:Pic fumigant systems.

In an effort to better treat soils in these under-fumigated regions of the bed, a Yetter Avenger coulter system was adapted to apply supplemental Pic (200 lbs/treated acre) immediately prior to mulch application along the bed edges, corresponding to the soils immediately below the mulch tuck at an 8 inch depth. A replicated, strip trial was established in the spring of 2014 at a grower site with a history of high levels of Fusarium wilt to test the supplemental Pic application. Plots consisted of 3 beds (34 inch bottom width and 28 inch top width) on 6 foot row spacing at 700 foot length. Bed fumigation consisted of a standard 8" shank application of Pic-Clor 60 (300 lbs/treated acre). The supplemental Pic treatment was alternated with non-treated plots throughout the field (12 plots total) in the spring of 2014. The supplemental Pic treatment reduced the incidence of Fusarium wilt from 35% in the standard Pic-Clor 60 plots to 6% ($P < 0.0001$) and improved yield by 400 boxes ($P = 0.0690$) per an acre, based on field pack-out weights. Additionally, measurements of root biomass indicated that the supplemental Pic treatment more than doubled root growth at the edge and tuck regions of the bed, based on the dry weight of root tissue recovered at the end of the trial.

A follow-up trial was performed in the fall of 2014 to address supplemental Pic rate on disease incidence and corresponding tomato yields. Trial format was similar to the spring, except supplemental Pic rates of 150, 100 and 50 lbs/treated acre were compared to beds treated with just the grower standard Pic-Clor 60 (300 lbs/treated acre). In addition, since disease levels were lower at this particular grower site, each 3-row plot was 1,400 ft long. Results showed that the supplemental Pic applied at 100 and 150 lbs/treated acre reduced disease incidence by 78% (Fig. 2) and increased pack-out yields by 322 boxes, on average (Fig. 3).

Repeated field trials in the spring of 2015 gave similar results, demonstrating that the supplemental Pic treatment reduced the incidence of Fusarium wilt, improved root biomass and overall yields. Our current recommendations for the supplemental Pic treatment are 125 lbs/treated acre or higher. Additional trials are underway to assess whether the fumigant rate within the bed can be reduced with the supplemental Pic treatment, to improve overall fumigation costs while maintaining efficacy.

Table 1. Vapor pressure and boiling point values for individual fumigants.

Fumigant	Vapor pressure (mm Hg)	Boiling point (°C at 1 atm)
Methyl bromide (100%)	1,420 (20 °C)*	4
Chloropicrin (100%)	18.3 (20 °C)	112
1,3-Dichloropropene (98%)	23.0 (20 °C)	107
Dimethyl disulfide (100%)	28.6 (25 °C)	109
Metam potassium (54%)	24 (25 °C)	97
Allyl isothiocyanate (94%)	4 (20 °C)	150
Water	17.5 (20 °C) 23.8 (25 °C)	100

* Values were obtained from various sources, including MSDS and chemical references. Please note that vapor pressure and boiling point values for these compounds will vary slightly depending on the specific formulation.

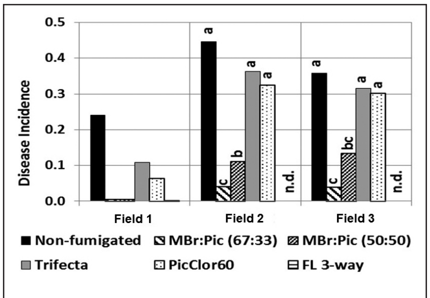

Figure 1. Incidence of Fusarium wilt from 3 separate field trails conducted at GCREC, Wimauma, FL. Treatments included a non-fumigated control, two MBr:Pic formulations (350 lbs/A); Trifecta (400 lbs/A); Pic-Clor 60 (300 lbs/A); and the Florida three way (FL 3-way) consisting of a broadcast application of Telone (122 lbs/A), followed by in a bed applications of Pic100 (150 lbs/A) and Kpam 54 (60 gal/A).

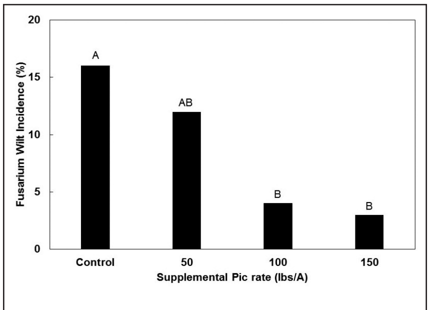

Figure 2. Field pack-out weight of fruit harvested from plots receiving supplemental chloropicrin (Pic) to bed edges, compared to the standard bed application of Pic-Clor 60 (300 lbs/A) alone (Control).

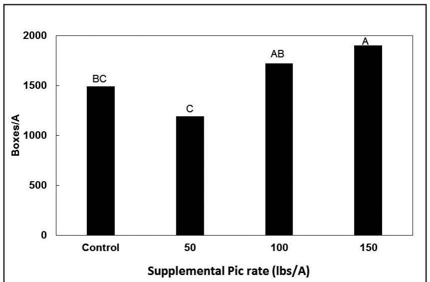

Figure 3. Field pack-out weight of fruit harvested from plots receiving supplemental chloropicrin (Pic) to bed edges, compared to the standard bed application of Pic-Clor 60 (300 lbs/A) alone (Control).

New Insights Regarding the Spatial Distribution of Nematodes and Soil Applied Fumigants and the Needs for New Strategies Considering Vertical Management Zones for Nematode Control

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This is not my first Tomato Institute presentation and proceedings paper talking and writing about nematodes and soil fumigants. Most of these former presentations describe 1) the importance of plant parasitic nematodes to tomato crop production in Florida; 2) the importance of soil temperature, soil moisture, and soil compaction, and their effects of inhibiting movement and or dissipation of fumigants from soil; 3) transition strategies from methyl bromide to the alternative fumigants with a focus on yield and pest control efficacy, and 4) the differences in chemical characteristics between the different fumigants and the vulnerabilities of the alternatives to suboptimal environmental conditions. As previously reported, the two biggest differences in chemical characteristics between methyl bromide and the alternative fumigants are vapor pressure and boiling point. Because of the significantly lower vapor pressure (sometimes as much as a hundred fold) and higher boiling points, the alternatives volatilize to gas and diffuse through soil much more slowly, and do not race through the vertical soil profile like that of methyl bromide. The presence of a traffic pan observed to occur just below the base of the raised, plastic mulch covered bed is another formidable barrier to diffusion of the alternative fumigants into deeper soil. In practical terms, the compacted traffic pan occurs just below the depth of the deepest tillage implement used in the field and has been shown to unavoidably cause changes in soil hydraulic conductivity, diffusion of fumigant gases, and thus soil fumigation efficacy and field distribution of nematodes and crop damage. We believe it is the presence of the traffic pan coupled with the differences in vapor pressure and boiling point which so limit soil movement and spatial distribution of the fumigant in soil which has resulted in the increase in root-knot nematode problems being reported in tomatoes and for the severe and reoccurring problems associated with sting nematode in Florida strawberry to specifically name but a few. The focus of today's presentation and proceedings paper is therefore to discuss new research tools being used that quantify the spatial distribution of nematodes and soil fumigants concentrations in soil air and how each of these factors are interrelated and contribute to what we believe are the inconsistencies in crop yield response to the alternative fumigants in Florida agriculture. It will conclude with the justification and need for developing new fumigant placement strategies that view nematode management as a composite and integration of vertical management zones.

In reflecting on the current state of fumigant use in Florida strawberry, we think it is fair to say that we have failed to provide a consistent and satisfactory level of sting nematode control, regardless of fumigant, rate or method of application, impermeability of the plastic mulch used, or combinations of the fumigant compounds and other IPM tactics employed. In many situations the stunting from the nematode is observed shortly after the fumigant has dissipated from soil and transplants are placed into the ground and before they have even completed their watering in, or *living-in* production phase. This is a scenario which has been getting worse since the CUE for methyl bromide expired in strawberry in 2012. To address the worsening problem, our research focus in strawberry was to determine where sting nematodes that recolonize the raised plant bed after fumigation application originate, where fumigants go, and more importantly, don't go after they are applied. In February of 2014, we commissioned the construction of the Probinator (**Figure 1**), a deep core soil sampling system which allowed us to quantitatively assess soil population densities of nematodes and concentration of fumigants in soil air with soil depth. The Probinator is designed to remove a 4 inch diameter by 40 inch deep soil core using a specialized stainless steel probe and hydraulic ram system that is tractor mounted as a 3 point attachment. The Probinator has allowed us to study, the depth distribution of nematodes, spatial movement of soil fumigants, and causes of fumigant treatment inconsistency. The Probinator has conveniently and very energy efficiently allowed us to ask: Where do nematodes reside in soil? How deeply in soil do they occur? And where do fumigants go, and more importantly don't go following application.

As indicated, the sampling platform and hydraulic cylinder used to drive the soil probe into soil was raised and lowered using tractor supplied hydraulics. During the sampling operation, soil cores were removed through the plant hole, from center locations on the plant bed after drip fumigation treatments, or between adjacent ripper shanks after summer broadcast applications within a field. Each soil core, collected as a contiguous column to a soil depth of 36-40 inches, was typically subdivided into 12 inch increments for nematode population density determinations and into 4 inch soil increments for monitoring fumigant gas concentrations in soil air with depth (**Figure 1**). After a drip or shank fumigant application, distribution of 1, 3-dichloropropene (1, 3-D) gases measured in soil air always proceeded from the bottom of the probe upwards to the soil

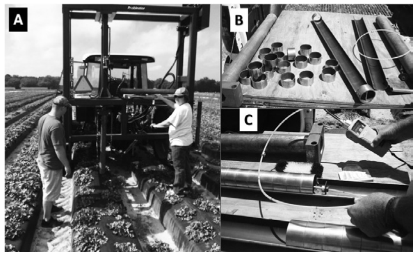

Figure 1. The Probinator (A), a hydraulically operated deep soil probe (B) used to study the depth distribution of nematodes, spatial movement of soil fumigants (C), and to identify causes of fumigant treatment inconsistency and origins of bed recolonizing populations of nematodes.

http://www.crec. ifas.ufl.edu/extension/saap/videos/video.zip surface using a MiniRae® 2000 PID VOC meter. For all studies reported herein, mean VOC concentrations for each fumigant treatment and depth location were averaged from 5-8 random measurements from each experimental field, treatment, and depth location. For these studies, peak concentration measurements from the MiniRAE 2000 over a 30 second sampling period were used to characterize soil atmosphere gas concentrations, retention characteristics of fumigants over time, as well as relative differences in vertical, gas phase movement of the fumigant with time. For most field locations, fumigant concentrations were monitored every other day until soil disappearance (typically 5-7 days).

The results from our very first deep core, Probinator field survey was very informative. What the results showed us was that Sting nematode could be found at depths of 3 feet, the maximum depth the system was capable of procuring a sample, and that they were found at these depths in every nematode infested field we sampled (**Figure 2a**). The presence of root-knot nematode has similarly been detected in deep flatwood soils under tomato and eggplant (**Figure 2b, 2c**). It also told us that these nematodes could occur at high density in deep soil even in the total absence of plant roots (food). I think it is worthy to note that these nematodes are occurring at soil depths that are seldom, if ever, sampled for nematode population assessment. After learning that the nematodes were occurring at such depths we decided to start examining the impact of crop termination treatments on soil population densities of nematodes with soil depth. For these trials, we used the Probinator to monitor soil air concentrations of drip applied 1,3 D at 4 inch increments from the soil surface to a depth of 36 inches. The results from these studies demonstrated that drip delivery of the fumigant achieved high fumigant concentrations in soil air above the traffic pan situated 1 to 2 inches below the level of the row middle and bottom of the bed (**Figure 3**). The results clearly showed that 1, 3-D was incapable of diffusion through the traffic pan into the deeper soil depths where the nematodes reside. Previous surveys we have conducted have documented that every field which is not subsoiled contains a traffic pan located just below the depth of the deepest tillage implement used in the field. So the crop termination drip fumigation treatment would have done a good job of controlling nematodes within the confines of the raised plant bed but nowhere else.

The next field in which we surveyed with the Probinator was one in which a crop termination treatment had been applied in early April (Vapam, 75 gpta) which was then followed by 3 months of bare fallow in preparation for a summer broadcast fumigant treatment of Telone II (15 gpa) for nematode control. The results of this field survey showed the absence of nematode (imagine that) in the surface 12 inches of soil that had received the crop termination in the preceding crop and fallow treatment but showed high populations of root-knot nematode (Meloidogyne sp.) at the intermediate and deepest soil depths between 1 to 3 feet (**Figure 4**). Soil population densities of root-knot nematode were observed at levels in excess of 500 juveniles per 100 cc soil at the deepest soil depth (2-3 feet). Following the pretreatment soil sampling for nematodes, the field was then broadcast treated with Telone II (15 gpa) to a depth of 14 inches using a chisel plow rig, after which the field was rolled to help seal the soil and slow the upward movement of Telone II from soil. The Probinator was then employed to monitor soil air concentrations of 1, 3-D at 4 inch increments to a depth of 3 feet at 2 to 3 day intervals until final disappearance of the fumigant from soil. The results of these

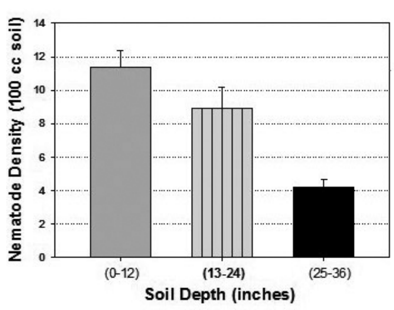

Figure 2a. Soil population density of the Sting nematode, Belonolaimus /ongicaudatus, within three 12 inch increments to a soil depth of 36 inches. Contiguous 4 inch diameter co lumns of soil were acquired via the Probinator,a specially designed soil probe and hydraulic ram used to deep sample field sites. FSGA: Sept 7, 2014 . - after a sorghum/sudan cover fb disking.

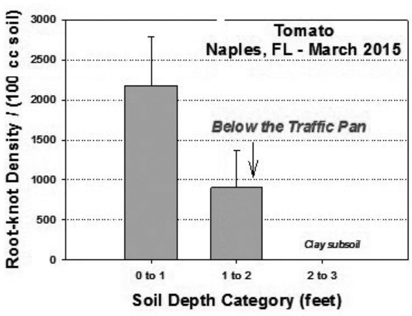

Figure 2b. Soil population: density of Root-knot anematode (Meloidogyne sp) within three 12 inch increments to a soil depth of 36 inches. Contiguous 4 inch diameter columns of: soil were acquired via the Probinator . a specially;designed soil probe and hydraulic ram used to deep sample field sttes. Tomato field site in Naplesj FL. March 2015.

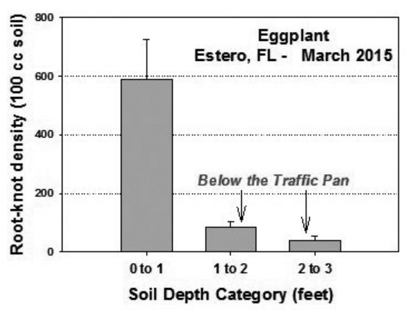

Figure 2c. Soil population density of Root-knot nematode (Meloidogyne) wtthin three 12 inch increments to a soil depth of 36 inches. Contiguous 4 inch diameter columns of soil were acquired via the Probinator . a specially designed soil probe and hydraulic ram used to deep sample field sites. Field site in Estero, FL. March 2015.

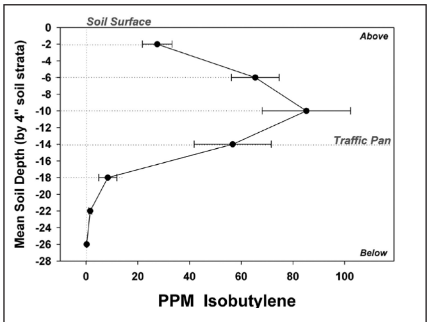

Figure 3. Concentration Isobutylene in soil strata above and below a 14 inch traffic pan. Soil air measurement obtained from soil cores thru the center of a 121/2" raised, mulch covered bed 3 days post application Telone EC (12 gpa). Data points-means of 8 reps MB farm, Dover, FL

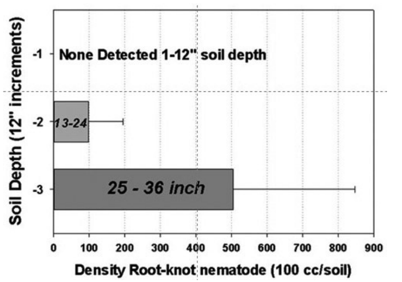

Figure 4. Soil population density and depth distribution of the root-knot nematode, *Meloidogynehapla*, within 1 foot soil incr~mentsatthe DB Farm, Plant City, FL. Soil samples procured to an overall soil depth of 3 feet following crop termination-drip fumigation treatment (Ap ril) and two mon~ h period of bare summer fallow. Data represent the means and standard error of 8 replicate samples.

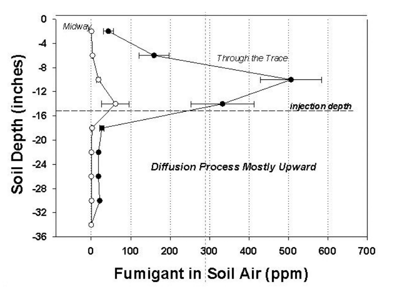

Figure 5. Fumigant Gas Concentration within the Shank Trace and midway between ripper shanks to a soil depth of 36 inches. Telone II fumigant broadcast and deep ripper shank applied (18 gpa) to a 15 inch soil depth. Datapoints are means and standard errors of 4 replicate observations. Plant City, FL. 1 DAA- July 12, 2014

samples indicated that the diffusion of 1, 3-D was primarily upward, back up through the shank trace, and that there was little fumigant penetration into the deeper soil profile below the level of injection and to where root-knot nematode was residing (**Figure 5**). In this field we were able to show that a dry top soil that was simply rolled failed to provide a conducive environment for radial expansion of gases into deeper soil from the point of injection, and in this case mostly upward. Again the Probinator demonstrated where fumigant gases go and more importantly where they do not go.

To further study the impact of subsurface compacted traffic pans and deep soil residence of nematodes, new deep placement fumigant application technologies were developed to study the spatial distribution and management of root knot and sting nematode. The research currently underway is testing a new deep shank fumigant delivery system so as to target soil treatments to the depths where nematode occur in soil. The new systems (**Figure 6**), developed by Mirusso Enterprises Inc., Boynton Beach, FL, are capable of either making a deep shank fumigant application to a depth of 15 inches and/or installing a subsurface drip irrigation line to a depth 15 inches as well. Fumigation was conceived as a 2 step, sequential process consisting of targeted delivery of fumigants to two different soil depths or what we now consider vertical management zones. As a prebed treatment, the deep shank unit injects the fumigant to a depth of 15 inches to the flat which is then immediately followed by a grower application of their separately applied fumigant to the raised plant bed during the bedding operation. The bed is firmly pressed (sometimes twice) and the drip tape and mulch (usually an impermeable film) installed as a covering over the bed. The covering of the deep shank trace by the formation of the raised plant bed serves to impede rapid escape of deeply placed fumigant gases out of the bed. At the same time, the injection of the grower standard applied fumigant fills the raised bed with fumigant occupied airspace with their soil treatment. The covering of the bed with an impermeable mulch film not only serves to impede fumigant outgassing from the bed but we believe when coupled with the other factors, serves to encourage radial expansion of the deep shank applied fumigant into the deeper soil profiles where nematodes reside. These are 3 reasons why we believe the new Prebed Deep Shank treatment appears to be pushed into deeper soil profiles.

During June 2015, five different experiments within nematode infested fields were deep drip fumigated using a subsurface drip line buried approximately 21 inches below the top of the mulch covered bed. The buried drip tape was installed 15 inches deep to the flat prior to bedding during fall 2014. For all experiments, Telone EC (15 gpta) was injected over a 3.5 hour injection period followed by a 30 minute flush. After injection, soil air concentrations of 1, 3-D were monitored at 6 inch increments from the soil surface to a depth of 36 inches using a series of soil probes hammered to the appropriate depth and gases measured with the MiniRae VOC meter. The results from these experiments clearly demonstrate the ability to move toxic concentrations of Telone EC via the irrigation stream into deeper soil profiles (36 inch) to the levels where pathogenic nematodes reside (Figure 7). There was also clear indication that some upward, probably capillary movement of fumigant in the water phase, occurred given the measurement of Telone EC gases well above the depth of injection and to the soil surface.

SUMMARY

What these studies have told us is that most of the alternative fumigants with low vapor pressure and high boiling point are unable to distribute vertically in the soil below the traffic pan (and oftentimes horizontally to the bed shoulders) with current delivery and application methods originally developed for methyl bromide. Our research conceives of nematode control as a composite of vertical management zones for nematode control and for sustaining optimum crop production (Figure 8). The new approach separately targets fumigant treatments to areas above (Zone 1) and below the traffic pan (Zone 2). The potential importance of the deeply distributed reservoir of nematodes and their effects on subsequent plant growth are now being considered within the testing phases of new deep shank and subsurface drip application technologies for soil fumigants. These new systems are expected to improve fumigant penetration, overall nematode control and crop yield response consistency. Our results would suggest that nematode damage potential to a given crop occurs from migrating individuals from soil depths below which fumigants distribute. Based on these findings, we believe we have identified the root causes of yield and nematode control inconsistencies associated with the alternative fumigants, and have the new technologies under evaluation which can help resolve these problems.

Figure 6. What is Needed: NEW TECHNOLOGY for DEEP SHANK & DRIP APPLICATION

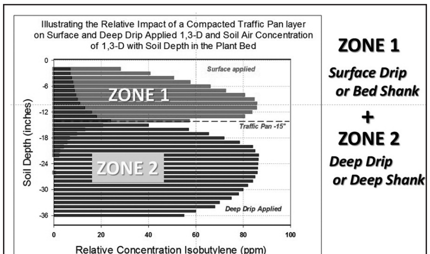

Figure 8. Structuring Soil Pest & Disease Control As a Composite of Vertical Management Zones

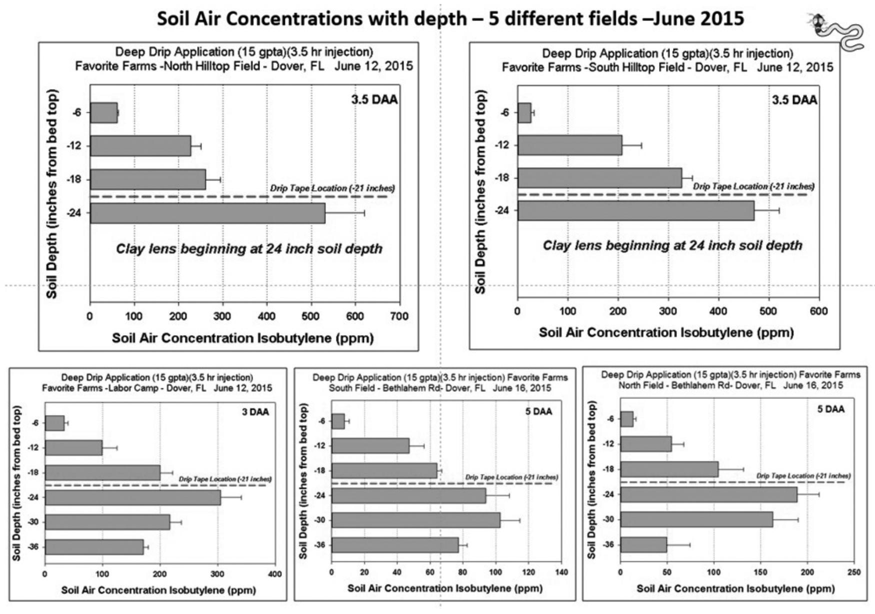

Figure 7. Deep Drip Applications of Te/one EC (15 ggg)

Risk Management and Fumigation Choice in Tomato Production

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ABSTRACT

The phase out of Methyl Bromide (MeBr) required by the Montreal Protocol on Substances that Deplete the Ozone Layer has decreased its use in soil fumigation in the United States (U.S.). Reduced supplies also increased the price of MeBr and affected producers' net revenues for tomatoes and the cost effectiveness of MeBr as a soil fumigant. The phaseout encouraged many producers to switch to available alternatives. Previous studies using partial budget analysis show that some alternatives are more cost effective with higher yields. Nevertheless, the share of crop acreage treated with MeBr remains high, especially for tomatoes and strawberries. Data collected from fresh tomatoes production trials with MeBr and alternatives were conducted at the Plant Science Research and Education Unit, University of Florida in Citra, FL. The results show that alternative fumigants (especially carbonated Telone C35 with totally impermeable films) are often cost effective and provide higher yields. However, a risk analysis indicates that MeBr has lower downside risk, a result that indicates why MeBr is still preferred by risk averse producers.

Keywords: Methyl Bromide and alternatives, yield risk, stochastic dominance and efficiency.

Acknowledgement. The authors would like to acknowledge funding support for this study from United States Department of Agriculture, National Institute of Food and Agriculture award #2010-51102-21657. We would also like to thank Mike Aerts, Director of Production and Supply Chain Management at the Florida Fruit & Vegetable Association, for his help and useful suggestions in budgeting the production costs of field-grown tomatoes.

INTRODUCTION

Methyl Bromide (MeBr) is used in agricultural production as a soil and structural fumigant to control pests, pathogens, and weeds (EPA, 2014). Historically the largest users of MeBr have been tomato and strawberry producers in Florida and California (Ristaino and Thomas, 1997). Widespread use of MeBr began in the 1960's for California strawberries and late 1970's for Florida tomatoes (Carpenter, Gianessi and Lynch, 2000). At one point MeBr was one of the top five most used pesticides in the United States (Ristaino and Thomas, 1997). After its implementation, yields increased significantly. Florida tomato yields doubled from the 1960's to the 1990's (Carpenter, Gianessi and Lynch, 2000) and California strawberry yields increased fourfold (Backstrom, 2002). MeBr has proven to be a cost effective single instrument for producers to control soil borne diseases, fungus, insects, and weeds.

Although MeBr has proven to be an essential tool in agricultural production it has been classified as an Ozone Depleting Substance. Ozone is a rare form of oxygen that plays a key function in moderating the Earth's climate by absorbing ultraviolet radiation (Ristaino and Thomas, 1997). Due to commitments in the Montreal Protocol on Substances that Deplete the Ozone Layer, the use of MeBr in the U.S. has been phased out. The Montreal Protocol outlined a timeline of incremental reductions in the use of MeBr. The phaseout began with a freeze at the 1991 baseline levels of U.S. Consumption of 25,000 metric tons from 1993 to 1998. From 1999 to 2000 a 25% reduction from baseline levels was required. From 2001 to 2002 a 50% reduction from baseline levels was required. From 2003 to 2004 a 70% reduction was required and in 2005 a 100% reduction of MeBr consumption was called for. The protocol allowed for critical use exemptions that were agreed upon by the signing nations (EPA, 2014). According to the EPA's record of critical use exemption nominations, tomatoes were last nominated for a critical use exemption in 2013 and California strawberries have been nominated through 2016 (EPA, 2014). Florida tomato growers have started to feel the effects of the loss of MeBr. Since the phaseout, pathogens have built up in the soil and contributed to a significant increase in disease incidence leading to crop loss (Vallad, 2014). We analyzed MeBr and its alternatives incorporating risk perception for understanding the decisions adopted by producers.

METHYL BROMIDE USE AND ALTERNATIVES FOR TOMATO PRODUCTION IN FLORIDA

Cash receipts for fresh market tomatoes account for around 8% of total cash receipts from farm marketing in Florida according to U.S. Department of Agriculture, National Agricultural Statistics Service (USDA-NASS 2014a). Florida still ranks first in terms of total value of production for fresh market tomatoes. The production area for tomatoes dropped significantly from 45,000 acres in 2005 to 35,000 acres in 2013 with a sharp decrease in cash receipts from $805 million to $456 million. We also witnessed a declining trend in market value of Florida fresh tomatoes and saw their yields in the last decade drop from 370 cwt/acre in 2005 to 265 cwt/acre in 2013 (USDA-NASS 2014a; Figure 1). Since Florida soil is generally sandy, the organic matter content and the fertility of the soil are low (Rosskopf et al. 2005). The development of plastic mulch in the early 1950s played a significant role in the commercial production and economic success of some vegetable production including tomatoes in Florida (Lament 1993). Early plastic mulch production used as a "raised bed-plastic mulch" system was dependent on fumigation with a mixture of MeBr and chloropicrin (Rosskopf et al. 2005). Estimates of MeBr use for Florida fresh tomatoes were 5.6 million pounds in 1992, increasing to 6.2 million pounds in 1998. MeBr use declined after 1998 in Florida with use declining to 4.15 million pounds in 2006 - no estimate for MeBr use was reported after 2006 (USDA-NASS 2014b; Figure 2).

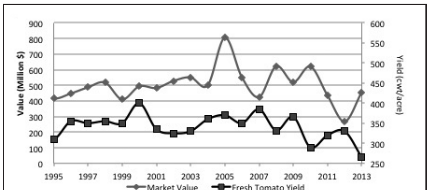

Figure 1. Fresh tomato market value and yield for Florida's fresh tomatoes, 1995-2013 (USDA-NASS 2014a).

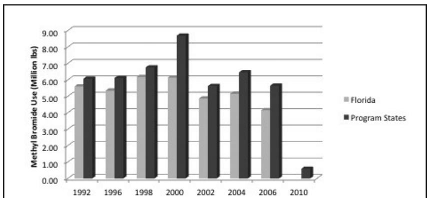

Figure 2. Methyl Bromide use estimates for fresh tomatoes in Florida and program states, 1992-2010 (USDA NASS, 2014b)

Producers have been forced to seek alternatives to adapt to the phaseout of MeBr. Finding and implementing cost effective alternatives that offer MeBr's efficacy, ease of use and worker safety has proven difficult. As of now there is no known single substitute for MeBr and research has been tasked with finding a feasible cocktail of chemicals as an alternative (Sydorovych et al., 2006).

In order to identify the best MeBr alternatives for tomatoes, strawberry and floriculture production, extensive studies were conducted by examining and/or re-examining new and existing soil fumigants such as 1,3-Dichloropropene, methyl isothiocyanate (MITC) generators and chloropicrin (Rosskopf et al. 2005). Based on the research results, Environmental Protection Agency (EPA) published a list of chemical and non-chemical alternatives and relevant studies for each crop. In this list, the registered chemicals for tomatoes include 1,3-Dichloropropene, Chloropicrin, Dazomet (only for California), Dimethyl Disulfide, Fosthiazate, Glyphosate, Metam Sodium, Paraquat, Halosulfuron-methyl, s-Metolachlor, Trifloxysulfuron-methyl, Rimsulfuron, Metam Sodium + Chloropicrin, 1,3-Dichloropropene + Metam Sodium, and 1,3-Dichloropropene + Chloropicrin (EPA, 2014). Most of the research on these products has been presented at the Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions since 1994, sponsored by Methyl Bromide Alternatives Outreach, EPA and U.S. Department of Agriculture. The research on alternatives shows that none of the alternatives perfectly substitute for MeBr but some alternatives result in relatively similar pesticidal activity compared to MeBr (Table 1).

Table 1. The relative effectiveness of various soil fumigant alternatives to methyl bromide (MBr) for nematode, soilborne disease, and weed control in Florida.

	Relative pesticidal activity		
Fumigant	**Nematode**	**Disease**	**Weed**
1) Methyl Bromide 50/50	Good to excellent	Excellent	Fair to excellent
2) Chloropicrin2	None to poor	Excellent	Poor
3) Methyl Iodide	Good to excellent	Good to excellent	Good to excellent
4) Metam Sodium	Erratic	Erratic	Erratic
5) Telone® II	Good to excellent	None to poor	Poor
6) Telone® C17	Good to excellent	Good	Poor
7) Telone® C35	Good to excellent	Good to excellent	Poor to fair
8) Pic-Clor 60	Good to excellent	Good to excellent	Poor to fair
9) Metam Potassium (Kpam)	Erratic	Erratic	Erratic
10) Dimethyl Disulfide	Good to excellent	Good to excellent	Poor to excellent

Notes: The table is adjusted from the University of Florida extension study on MBr alternatives (Noling et al. 2012).

Table 2. Summary yield results of field studies for 2011-2012 and 2012-2013 seasons.

Treatment	Plastic	Season	Marketable yield (Mean) (lbs/Plant)	Standard deviation	Marketable yield (Median) (lbs/Plant)
Methyl Bromide (MeBr) trials					
350 lb 50:50 MeBr:Pic*	VIF	2011-12	8.23	1.18	8.41
400 lb 50:50 MeBr:Pic	TIF	2012-13	8.37	2.38	8.61
Telone C35 trials					
Full C35 + N2	VIF	2011-12	6.42	1.36	6.33
0.5 C35 + N2	VIF	2011-12	4.94	1.71	4.84
0.3 C35 + N2	VIF	2011-12	3.38	1.84	3.35
0.3 C35 + N2*	TIF	2011-12	8.00	2.27	7.44
0.5 C35 + CO2	VIF	2011-12	5.39	1.85	5.37
0.3 C35 + CO2	VIF	2011-12	4.15	1.65	3.63
0.3 C35 + CO2*	TIF	2011-12	8.74	2.18	8.91
Dimethyl Disulfide (DMDS) trials					
15 GPA 79:21 DMDS:Pic + CO2	TIF	2012-13	7.77	1.73	8.09
25 GPA 79:21 DMDS:Pic + CO2	TIF	2012-13	7.17	1.61	7.12
40 GPA 79:21 DMDS:Pic + CO2*	TIF	2012-13	7.83	1.28	7.69
15 GPA 79:21 DMDS:Pic + N2	TIF	2012-13	6.98	2.18	7.22
25 GPA 79:21 DMDS:Pic + N2	TIF	2012-13	7.46	1.85	7.69
40 GPA 79:21 DMDS:Pic + N2*	TIF	2012-13	8.82	2.24	9.32
Control trials					
Untreated	VIF	2011-12	1.24	0.57	1.16
Untreated	TIF	2011-12	3.66	1.23	3.50
Untreated	TIF	2012-13	5.24	2.78	6.14

Notes: *represents the top yield performances from trials used in risk analysis.

Table 1 shows that the alternatives having relatively similar pesticidal activity compared to MeBr are Methyl Iodide, Telone C35, and Dimethyl Disulfide. In this study, we analyzed the yield risk of the later two chemicals and compared those results with MeBr.

EVALUATING ALTERNATIVES

In this study, we used data collected from field trials conducted at the Plant Science Research and Education Unit, University of Florida. The original field studies intended to analyze the efficacy of Telone C35 (C35) for the 2011-2012 season and Dimethyl Disulfide (DMDS) combined with chloropicrin (Pic) for the 2012-2013 season with carbonation and low permeable films. The films used in these studies were virtually impermeable film (VIF) and totally impermeable film (TIF) in the 2011-2012 season and only totally impermeable film (TIF) in the 2012-2013 season. The study field site was located at the Plant Science Research and Education Unit of the University of Florida in Citra about 35 km south of Gainesville, Florida. The soil at the site was classified as Arredondo fine sand, a good representative of Florida soil (Thomas et al. 2012).

These studies compared the marketable yields of tomatoes from various chemical applications. In the 2011-2012 season, trials were also conducted for carbonation of Telone C35 and for Telone C35 dispersed by N_2 in different rates (full, 0.5, 0.3) and two different films (VIF and TIF). The results of these trials were later compared with marketable yield from a MeBr (50:50) plot and an untreated production plot produced under similar conditions. In the 2012-2013 season, a similar procedure was repeated for DMDS: Pic with carbonation and N_2 dispersion. However, in this case only TIF was used as a permeable film. The marketable yields obtained from various application rates of DMDS:Pic (15 GPA, 25 GPA, and 40 GPA) were again compared with MeBr and untreated production. The results are summarized in Table 2. The results show that MeBr consistently gave higher yield performance in both seasons while yield from C35 and DMDS:Pic vary based on the application rates and plastics.

The top two yield performances for each alternative and the top yield performance for methyl bromide trial were selected to determine the impact of risk on alternative selection. Yields and net present values (NPVs) were simulated using Monte Carlo simulation in Simetar© software (Richardson 2008; Richardson et al. 2000). Risk parameters in the simulation were the yield from trial data and the sales prices correlated with the tomato yield for the financial statement analysis. Historical price and yield data were collected from U.S. Department of Agriculture, Economic Research Service (USDA-ERS) annual field-grown price and yield from 1990 to 2013 for Florida (USDA-ERS, 2014).

RESULTS

Comparison of MeBr with TeloneC35

Stochastic NPVs were computed for each fumigant separately for ten-year periods. The probability distribution function (PDF) of NPV values for alternative fumigants are illustrated in Figure 3. NPV distributions suggest that production technologies using Telone C35 have larger NPV means than the tomato production using MeBr. Therefore, production with Telone C35 would be preferred. However, tomato yield trails using MeBr show lower standard deviations which indicates that the shift away from MeBr may be driven by cost and the late adopters of alternatives to MeBr may be driven by MeBr having lower risk.

Figure 4 shows the distributions for yield using alternative fumigants. The mean values suggest that production with carbonated Telone C35 (C35-CO2) gives the highest yield followed by production with Telone C35 with nitrogen (C35-N2) and then MeBr. The graphs also indicate that production with MeBr is less risky than the alternative production technologies. Thus, risk aversion appears important to the decisions made by decision makers.

Selection of alternatives by producers with the low (RAC = 0, risk neutral) and high risk aversion coefficients (RAC = 0.005, risk averse) are listed in Table 3. The results show a risk neutral producer would prefer Telone C35 with CO2 as the first preferred alternative to MeBr, followed by Telone C35 with N2. However, the preference among the alternative options changes for the extremely risk-averse producers. Extremely risk-averse producers prefer the field-grown tomato production with MeBr over both Telone C35 alternatives.

Comparison of MeBr with DMDS

The comparison of field-grown tomato production using MeBr with production using DMDS gave similar results. Figure 5 shows the PDFs of yield for alternative fumigants including MeBr and DMDS production technologies. The mean values suggest that production with carbonated DMDS with nitrogen (DMDS-N2) gave the highest yield followed by production with MeBr and then carbonated DMDS (DMDS-CO2). When risk aversion of the decision maker is factored into consideration, we witness the shift in preference of extremely risk-averse producer into production using MeBr (Table 4).

CONCLUSION

NPV distributions suggest that production technology using Telone C35 alternatives have larger mean values than the tomato production with MeBr use.

The PDFs of yield for alternative fumigants show that the production with MeBr is less risky than the alternative production technologies.

When we include risk aversion of the decision maker into consideration, we witness the shift in preference of extremely risk-averse producer into production using MeBr.

Lastly, to understand whether the shift away from MeBr is driven by cost, we repeated the analysis using MeBr with a unit price of $2.5 per pound which is the average chemical price before reduction began in 1999 (Osteen, 2003). Previously, the recent MeBr price was taken as $7 per pound for NPV analysis. The results show that, in 1999 prices, MeBr becomes the most attractive fumigant even to risk neutral producers compared to the Telone C35 alternatives which indicates that the recent shift away from MeBr is influenced by cost since the late adopters are using riskier alternatives in terms of yield.

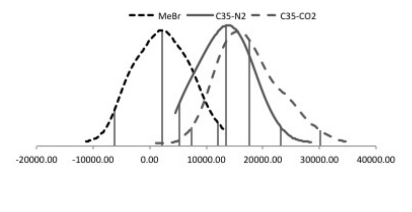

Figure 3. Probability distribution function approximations of net present values for a 1-acre tomato farm with Methyl Bromide (MeBr) and Telone C35.

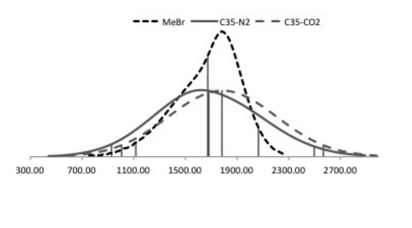

Figure 4. Probability distribution function approximations of tomato yield with methyl bromide (MeBr) and Telone C35.

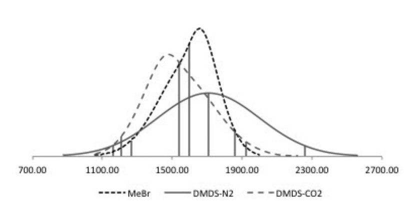

Figure 5. Probability distribution function approximations of tomato yield with methyl bromide (MeBr) and Dimethyl Disulfide:Pic (DMDS:Pic).

Table 3. Analysis of tomato yield with Methyl Bromide (MeBr) and Telone C35 using stochastic dominance with respect to a function (SDRF).

Low risk aversion coefficient: 0			Upper RAC	0.005	
	Name	Level of preference		Name	Level of preference
1	C35-CO2	Most Preferred	1	MeBr	Most preferred
2	C35-N2	2nd Most Preferred	2	C35-CO2	2nd most preferred
3	MeBr	3rd Most Preferred	3	C35-N2	3rd most preferred

Table 4. Analysis of tomato yield with Methyl Bromide (MeBr) and dimethyl disulfide (DMDS:Pic) using stochastic dominance with respect to a function (SDRF).

Efficient set based on SDRF at			Efficient set based on SDRF at		
lower RAC	0		upper RAC	0.005	
	Name	Level of Preference		Name	Level of Preference
1	DMDS-N2	Most Preferred	1	MeBr	Most Preferred
2	MeBr	2nd Most Preferred	2	DMDS-N2	2nd Most Preferred
3	DMDS-CO2	3rd Most Preferred	3	DMDS-CO2	3rd Most Preferred

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Evaluation of the Usefulness of a Late Blight Decision Support System in Florida Tomato

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INTRODUCTION

Effective management of late blight, caused by *Phytophthora infestans*, continues to challenge tomato growers through lost yields and increased production costs, mainly due to costly applications of fungicides. Environmental conditions during the growing season, particularly during wet and cool periods, can severely limit the effectiveness of late blight management even when employing an intensive management regime of frequent fungicide applications.

Decision Support System (DSS) is the term used for programs (mostly computer based) developed to assist growers in making disease management decisions. The most typical DSS is used to assist in timing of fungicide applications in relation to weather conditions. A DSS may use inputs such as information on the disease/pathogen (such as genotype), weather, cultivar resistance, past fungicide applications and other inputs to advise growers when conditions are favorable for disease development and trigger a fungicide application (Cooke et al., 2011).

A DSS for late blight on tomato and potato, named the BlightPro Decision Support System (formerly named the Cornell DSS and USABlight DSS), is a web-based late blight management DSS that uses disease predictions based upon local weather (hourly data points on rain, relative humidity, and temperature), crop, and fungicide sprays to provide its users with a detailed report risk of a late blight outbreak (Small et al. 2015). BlightPro has the convenient feature sending users notifications of upcoming critical thresholds via e-mail or text message. Users can register and access the DSS on the website: http://blight.eas.cornell.edu/blight/

We tested the usefulness of the BlightPro DSS for late blight management on tomato in Florida in two seasons, 2014 and 2015. The susceptible tomato cultivar ‘Charger’ (2015) or highly susceptible ‘FL 47’ (2015) and a moderately resistant cultivar ‘Legend’ (2014 and 2015) were used in these trials. Each cultivar received one of three treatments: an untreated control, weekly fungicide spray program, and fungicide spray program triggered using the BlightPro DSS. The trials were intended to evaluate the effectiveness of BlightPro DSS to manage late blight on tomato in Florida.

EXPERIMENTAL DESIGN

Both experiments were conducted at the Southwest Florida Research and Education Center in Immokalee, FL. Guidelines established by the University of Florida/IFAS were followed for land preparation, fertility, irrigation, weed management and insect control. Beds were 32 in wide with 6 ft. centers covered with black polyethylene film. In 2014, tomato seedlings ‘FL 47” and ‘Legend’ were transplanted on 17 Feb 2014 and in 2015, ‘Charger’ and ‘Legend’ were transplanted on 22 Jan 2015 in a complete randomized block treatment design with four replicates. Each plot consisted of ten plants spaced 18 in. apart within a 15 ft. row with 10 ft. between each plot.

FUNGICIDE REGIMES

Sprays were applied with a high clearance sprayer designed specifically for applications in staked tomato at 2 mph and at 200 psi. A double drop boom equipped with six nozzles delivered a spray volume of 80 gal/A. The spray program began prior to the first onset of disease. Three fungicide regimes were evaluated on both the susceptible and moderately resistant tomato varieties: 1) no fungicides; 2) calendar based spray applications at 7 day intervals (weekly); and 3) BlightPro DSS recommended. Fungicides used are all labeled for late blight on tomato.

LATE BLIGHT EVALUATION

Disease severity ratings as a percentage (0-100%) of foliage exhibiting symptoms were collected at 3 to 5 day intervals following detection of late blight symptoms and used to calculate the Area under the disease progress curve (AUDPC). Data was entered into ARM 9.0 and analyzed with ANOVA with LSD means separation.

RESULTS

Results for both trials are presented in Table 1.

In 2014, the susceptible cultivar ‘Florida 47’ without any fungicide applications had high disease severity (AUDPC=742) compared to the greatly reduced late blight severity on plants that received weekly fungicide applications (AUDPC=33) and plants that received fungicide applications based upon the DSS (AUDPC=27). The moderately resistant cultivar ‘Legend’ not receiving fungicides had about 50% reduction in late blight (AUDPC=377) compared to ‘FL 47’. Both the weekly fungicide applications and the DSS significantly reduced late blight on ‘Legend’. The number of fungicides applications using Blight Pro DSS was reduced from 9 to 7 (33%) on ‘Florida 47’ and from 9 to 4 (55%) on ‘Legend’ in 2014 while achieving the same level of late blight control.

Table 1. Evaluation of BlightPro decision support system (DSS) on susceptible and moderately resistant tomato cultivars in 2014 and 2015 to manage late blight (LB).

Season	Cultivar	LB susceptibility	Fungicide	Number of fungicide sprays	AUDPC* of late blight
2014					
	‘FL 47’	Susceptible	None	0	742 a **
			Calendar	9	33 c
			DSS	7	27 c
	‘Legend’	Moderately Resistant	None	0	377 b
			Calendar	9	4 c
			DSS	4	16 c
2015					
	‘Charger’	Susceptible	None	0	944 x
			Calendar	11	179 y
			DSS	13	27 z
	‘Legend’	Moderately Resistant	None	0	546 x
			Calendar	11	74 Y
			DSS	7	128 Y

* Area under the disease progress curve
** Means followed by same letter do not significantly differ (P=.05, LSD)

In 2015, results for the untreated tomato cultivars were similar in that late blight severity was highest on the susceptible 'Charger' but was more than 50% reduced on 'Legend' as compared by AUDPC values. In contrast, use of the BlightPro DSS in 2015 increased the number of fungicide applications on 'Charger' by two applications, however, late blight control was also increased. The number of spray applications using BlightPro DSS was decreased by four applications on 'Legend' compared to the calendar spray (36% reduction in number of sprays) with no reduction in late blight control.

CONCLUSIONS

The results from these two preliminary trials demonstrate the potential of BlightPro DSS to manage late blight on tomato in Florida. Similar levels of late blight control were achieved using the BlightPro DSS compared to weekly spray intervals, however, in three of the four regimes, the number of fungicide applications were reduced by 30% to 50%. In these limited trials, in one regime, BlightPro DSS increased the number of fungicide applications, but the level of late blight control was also increased compared to the weekly applications thus demonstrating that timing of fungicide applications coinciding with weather events can increase disease control.

In summary, when weather conditions were unfavorable, BlightPro DSS recommended fewer fungicide applications while achieving the same level of late blight control. However, when weather conditions were favorable for late blight, BlightPro DSS recommended more fungicide applications on the susceptible cultivar with improved late blight control.

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Recruiting H-2A Workers into Florida Vegetable Operations

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Florida vegetable growers are dependent on a large number of seasonal and migrant farm workers to grow and harvest high quality crops. Most of these workers are recent immigrants from Mexico and Central America. Unfortunately, a high percentage of these workers do not have legal authorization to work in the United States. Until the U.S. Congress passes legislation to comprehensively reform immigration policies, an estimated 70% of these "domestic" farm workers are at risk of being deported. Furthermore, there is no evidence to suggest that a sufficient number of legal domestic workers are willing to work for Florida's vegetable operations. The only legal option by which Florida growers can recruit agricultural workers from outside the U.S. is through the H-2A, or the foreign agricultural guest worker program. This paper outlines the bureaucratic requirements and process by which a Florida vegetable grower can participate in the H-2A program.

Historically, the H-2A program has been opposed by farm worker advocates and by some officials within the U.S. Department of Labor. Worker advocates argue that the employment of foreign workers keeps farm wages low for domestic workers and the U.S. Department of Labor, which is charged with enhancing employment opportunities for U.S. citizens, does not want to see U.S. workers supplanted by foreign workers. With these concerns in mind, federal law stipulates that any employer who wants to recruit H-2A workers must satisfy two conditions: 1) the applicant must document a shortage of domestic workers to meet their work load demand; and 2) that employment of H-2A workers will not adversely affect the wages of domestic workers performing similar jobs.

Once a grower/employer decides to enter the H-2A program, he/she needs to be prepared to deal with a considerable amount of government bureaucracy. At least three federal agencies, one state agency, and the local/county health department will be involved in the petition, recruitment, and management of H-2A workers. The petition process starts between 60 and 75 days prior to the date when the workers are needed. The employer-applicant completes and submits Form ETA-790 to the state workforce agency[1]. Included in this form is a request for a specific number of workers. The state work force agency reviews the application for completeness and enters the information into its job-service system which initiates recruitment of domestic workers. At 45 days before workers are needed, the employer completes and submits Form ETA-9142A (H-2A Application for Temporary Employment Certification) along with the ETA-790 to the U.S. Department of Labor (DOL). After all "deficiencies" are corrected, the DOL "accepts the petition for processing" and notifies the employer as to the geographic areas where he/she needs to advertise for domestic workers. By 30 days prior to the workers' start date, the employer has submitted a domestic recruitment report to the DOL and DOL, in turn, "certifies" the number of H-2A workers to be the difference between the requested number of workers

[1] The state work force agency in Florida is the Florida Department of Economic Opportunity (FDEO)

on the ETA-790 and the number of domestic workers actually recruited. Together Forms ETA-790 and ETA 9142A make up the foreign labor certification process and thereby satisfy Condition #1: that there are not enough domestic workers to meet the grower/employer's work load demand. Once the labor certification is complete, a petition for non-immigrant worker visas (Form I-129) is submitted to the Department of Homeland Security's Citizenship and Immigration Services (USCIS). Worker recruitment, which may have been ongoing for some time, is finalized and the Department of State processes individual visas for the H-2A workers. The actual number of visas can be less than, but not greater than what the DOL certified.

Employers pay for all costs associated with the H-2A application and the recruitment process including visa fees, bond expenses, and any filing charges. In addition, an H-2A employer must pay for any fees charged to workers by third-party recruiters whether the recruiter was authorized by the employer or not. It is strongly recommended that an employer-applicant either be directly engaged with worker recruitment or work with a trusted in-country agent to ensure that no inappropriate fees are paid by the workers. All in-bound travel expenses from the workers' home town are paid for by the employer. Some employers choose to pay these costs up-front, others wait until the worker has completed 50% of the contract period before reimbursing any travel and/or visa costs the worker may have paid. If the worker completes the contract, the employer pays for all travel costs for the workers' return trip home. The employer is obligated to pay only for the least expensive means of in-bound and return home travel. For example, bus fare is typically the most cost-effective means of traveling between Florida and most states in Mexico.

Form ETA-790 is also known as the "job-order" and is the fundamental document to the H-2A process. Along with the requested number of foreign workers, the job order specifies the start and end dates of the contract period. As mentioned previously, the number of "certified" H-2A workers is reduced one-for-one for each domestic worker hired during the recruitment process. Even after H-2A workers arrive in Florida, the positive recruitment of domestic workers continues through the half-way point of the contract period. For example, if a 6-month contract starts November 1 and ends April 30, the H-2A employer must actively recruit and hire domestic workers through January 30th.

Employers are required to provide transportation and housing to all H-2A workers during the contract period at no cost to the workers. The job-order enumerates the number of housing units under the employer's control and that number must be equal or greater than the number of H-2A workers certified by the DOL. The local county health department inspects leased/rental housing and the state workforce agency inspects employer-owned housing. Housing facilities built after 1980 must meet local as well as OSHA health and safety standards. Renting motel units without kitchens is acceptable so long as the employer makes the provisions to cater three meals a day for all workers. Housing with full kitchens allows workers to prepare their own meals, but the employer must provide the necessary transportation for workers to secure their individual food supplies.

The job-order specifies the minimum hourly rate of pay and the minimum number of hours for the contract period. The hourly pay rate, typically, is the federally set Adverse Effect Wage Rate (AEWR)[2], but if a higher state minimum wage or a locally agreed-upon collective bargaining rate was in effect, then that higher hourly rate is what would be paid during the contract period. In this way, Condition #2 will be satisfied, that hiring H-2A workers will not adversely affect the wages of domestic workers.

The job-order promises a minimum number of hours on a weekly basis. Multiplying weekly hours by the number of weeks in the contract period and by the AEWR, the job-order establishes a minimum income level that an H-2A worker will earn. The job-order further guarantees that each worker will earn at least 75% of the minimum earnings set forth during the contract period. An "act-of-God," which prematurely destroys a crop, will exempt an H-2A employer form the three-quarter guarantee, but the employer is not immune from any in-season changes in the business climate which negates his/her overall demand for guest workers. More importantly, it is difficult, if not impossible to send a worker home early simply because they are deemed to be a "slow" worker. Worker productivity standards usually are based on the current state minimum wage and workers must be allowed a "sufficient" training period to attain this productivity threshold. In many cases, H-2A employers have to tolerate "slow" workers during the first year. For subsequent years, however, they do not have to invite these workers back and instead encourage their more productive workers to return with similarly skilled friends and family.

To further ensure that domestic workers are not adversely affected by the H-2A program, any legal domestic worker applying for an H-2A position must be hired and receive all the same benefits being given to the foreign guest workers. For instance, if your 21-year old nephew in Chicago, IL, wants to pick tomatoes for an Immokalee grower who has recruited H-2A workers, his bus ticket to Southwest Florida and transportation costs during the contract period will be paid for by the grower. Your nephew will be housed at no cost to him. His hourly rate will be $10.19, or whatever the current AEWR happens to be, and his contract period will be defined by the same job-order which brought in the foreign guest workers. If he completes the contract, the grower will pay for his return trip back to Chicago.

The H-2A program is a costly endeavor both in terms of bureaucratic red-tape and hard cash. At the present time, however, it may be a grower's only legal labor option. A substantial percentage of "domestic" farm workers do not have the legal authorization to work in the U.S. and there does not seem to be a sufficient number of legal domestic workers willing to work for Florida's vegetable and other specialty crop operations.

[2] As of January 1, 2015 the AEWR in Florida was $10.19 per hour.

Western Flower Thrips and Tospoviruses Emerging as Serious Threats to Tomato in Central and Southern Florida

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INTRODUCTION

The western flower thrips, *Frankliniella occidentalis* (Order Thysanoptera: Family Thripidae) and *Tomato spotted wilt virus* (Family Bunyaviridae: Genus Tospovirus), have been serious pests of tomato in northern Florida for several decades. More recently, western flower thrips has emerged as a serious threat in central and southern Florida (Funderburk 2009). *Tomato spotted wilt virus* and several other tospoviruses, including *Tomato chlorotic spot virus* and *Groundnut ringspot virus*, have emerged as threats to tomato in southern and central Florida (Webster et al. 2015). The emergence of these thrips and disease problems at the same time is probably not coincidental as the western flower thrips is a demonstrated vector of each of these tospoviruses in Florida.

Western flower thrips adults inhabit the flowers where they lay eggs in the small tomato fruits resulting in small cosmetic 'dimples.' The adults and larvae feed on the developing fruits resulting in another form of cosmetic injury called 'flecking.' Images of these injuries are contained in the internet publication by Funderburk et al. (2014) and Ghidiu et al. (2006). Tomato flowers are inhabited by a number of other thrips species, both native and introduced, that have little if any pest status. The eastern flower thrips, *F. tritici*, is the most common in northern Florida. It is neither injurious to tomato nor is it a vector of tospoviruses. The Florida flower thrips, *F. bispinosa*, does not injure tomatoes and it is not an important vector of tospoviruses in tomato. The tobacco thrips, *F. fusca*, is not injurious in tomato although it is an efficient vector of tospoviruses. The common blossom thrips, *F. schultzei*, has been shown to be a vector of tospoviruses in Florida under laboratory conditions (Webster et al. 2015). Melon thrips, *Thrips palmi*, is sometimes found in tomato flowers in extreme southern Florida, but it is not a pest of tomato.

Viruses in general and tospoviruses in particular can cause very similar symptoms. Tospoviruses can be diagnosed using commercially available serological and molecular tests. Refer to Adkins et al. (2013) for a full description of symptoms with images. Leaf symptoms on tomato caused by most tospoviruses consist of brown necrotic or yellow chlorotic rings or ring patterns. The lesions may also form on stems. Wilting and purpling of leaves is typical. Young leaves frequently turn bronze and develop small, dark brown lesions. Plants infected at a young age are often stunted and have drooping leaves. Once a plant is infected, there is no cure.

Research has been conducted on the ecology and management of western flower thrips and tospoviruses in Florida for 30 years. Most of the research was focused in northern Florida where they became the key pest problems of tomato and other crops. Much was learned and technologies were developed that have greatly alleviated losses. More recently, these problems have shifted to central and southern Florida where they have emerged as economically important pests. Here we focus on the ecology and management of thrips and tospoviruses in tomato with an emphasis on the situation in central and southern Florida. Management of these problems should be considered simultaneously as thrips and tospoviruses are economic pests in all regions of Florida, and effective, sustainable management involves numerous tactics that reduce damage from both.

THRIPS AND TOSPOVIRUS BIOLOGY

Flower thrips develop rapidly (about 15 days from egg to adult in warm temperatures), have a high reproductive rate, are rapidly mobile, and are capable of reproducing without mating. The adults quickly invade tomato fields once flowering begins (Salguero-Navas et al. 1991). Populations aggregate in flowers. Florida flower thrips and eastern flower thrips are highly mobile and are randomly distributed in the flowers throughout the field. Western flower thrips are not as mobile and they may, at times, be aggregated along a field edge. High populations of all flower thrips species are typical in the spring in all regions of Florida.

The genus tospovirus is named after *Tomato spotted wilt virus*. Members of the tospovirus genus cause significant worldwide crop losses. Tospoviruses have a unique shape, genome and transmission strategy among plant viruses. All tospoviruses are transmitted by one or more species of thrips. In all known cases, thrips must acquire the tospovirus as larvae to be able to transmit it as adults. The distribution of tospovirus-infected plants in a field is frequently random (Puche et al. 1995). At other times, however, disease is aggregated along a field edge.

HOST RANGE OF THRIPS AND TOSPOVIRUSES

Western flower thrips, eastern flower thrips, Florida flower thrips, and common blossom thrips inhabit the flowers of a wide range of plant species in numerous plant families (Paini et al. 2007). Some of these plants are hosts in which thrips breed, and others are non-hosts that are utilized as resources for food and shelter. In all regions of Florida, western flower thrips occurs in very low numbers on non-crop plants as it is outcompeted by the native species of thrips and it is more preferred by natural enemies; however, western flower thrips thrives in disturbed habitats such as crop fields where insecticides and fertilizers are applied (Funderburk et al. 2015).

At the present time, *Tomato chlorotic spot virus*, *Groundnut ringspot virus* and *Tomato spotted wilt virus* are all established in southern Florida. In addition to tomato, these viruses may be found infecting pepper, tomatillo and eggplant. Solanaceous weeds including American black nightshade (*Solanum americanum*), cutleaf groundcherry (*Physalis angulata*) and jimsonweed (*Datura stramonium*) have also been identified as natural hosts for one or more of these tospoviruses. Lettuce and impatiens have been identified as experimental hosts for *Tomato chlorotic spot virus* and/or *Groundnut ringspot virus* (Webster et al. 2015). Recently, natural infection of lettuce in Puerto Rico and several ornamental crops in Florida with *Tomato chlorotic spot virus* has been reported (e.g. Estévez de Jensen and Adkins, 2014; Baker and Adkins, 2015).

Acquisition of tospoviruses takes place when the larva of a thrips vector species (i.e., western flower thrips or common blossom thrips) feeds on an infected plant host. Transmission to a new plant can occur after the thrips completes development to an adult. Plants that are not hosts for thrips may become infected with tospovirus when fed on by a viruliferous thrips adult, but non-host plants where thrips do not breed are dead-ends for subsequent cycles of disease. Crop and non-crop plant hosts for thrips vector species can serve as sources of viruliferous adult thrips.

SCOUTING AND ECONOMIC THRESHOLDS

Because eastern flower thrips and Florida flower thrips occur in large numbers in the flowers of fruiting vegetables where they outcompete the damaging western flower thrips, it is necessary to accurately identify the species to make informed management decisions. Refer to Funderburk et al. (2014) for specific details of appropriate scouting procedures. Adults of eastern flower thrips and Florida flower thrips are non-damaging and should be considered beneficial. Tomato is not a host for melon thrips and the adults are not injurious to the fruit. The adults of western flower thrips lay eggs in the small fruit of the flower, and this results in an injury called 'dimpling.' Although purely cosmetic, dimpling can be unsightly and cause downgrading. The economic threshold for western flower thrips adults is one per flower.

Flowers and small fruits should be scouted for thrips larvae. The larvae cannot be identified to species, but larvae in tomato will usually be the western flower thrips. Feeding on the fruits results in an injury called 'flecking.' The economic threshold for thrips larvae of any species is two per flower or fruit.

Scouting for tospoviruses relies on the visual inspection of tomato plants displaying characteristic tospovirus symptoms. Solanaceous weed species within and around a field should also be monitored as they can act as reservoirs of tospoviruses. Typical tospovirus symptoms in tomato and other hosts include ringspots and necrotic and chlorotic lesions in stems, petioles, leaves, and fruits. Due to the similarity of symptoms caused by *Tomato spotted wilt virus*, *Groundnut ringspot virus* and *Tomato chlorotic spot virus*, definitive identification of the tospovirus species present in a field must be confirmed using nucleic acid-based techniques such as reverse transcriptase-PCR to identify one or more genome segments of these three tospoviruses.

Because there is no cure for a tomato plant infected with tospoviruses and because insecticides targeted at killing adult thrips do not prevent primary spread, preventive tactics need to be employed based on the risk of disease incidence. Risk assessments on individual farms should be based on the historical incidence of tospovirus infection and known presence of thrips vectors throughout the geographic area. Preventive management tactics are justified even if the risk of incidence is 10% or less.

MANAGEMENT TACTICS

Insecticides. Labeled insecticides have been evaluated against flower thrips in tomato and pepper in Florida on an almost annual basis since 1985. Srivastava et al. (2014) shows the results from several years of recent experiments. Currently labeled products for tomato were included in these trials. The broad-spectrum insecticides acetamiprid and methomyl demonstrated activity against western flower thrips but also reduced populations of minute pirate bugs, *Orius insidiosus* (Hemiptera: Anthocoridae), a key predator of thrips. A number of insecticides showed moderate (significant) activity against western flower thrips while conserving minute pirate bug populations, including cyantraniliprole, flonicamid, spirotetramat, and terpenes. Spinetoram has consistently shown the highest activity against the western flower thrips since its labeling in Florida in 1997. A resistance monitoring program was begun in 2007 to determine the susceptibility of Florida populations of western flower thrips and other thrips species to spinetoram. Results from the monitoring program showed widespread spinetoram resistance of Florida populations of western flower thrips. A resistance monitoring program was begun in 2015 to determine the susceptibilities of flower thrips to acetamiprid.

Very few insecticides are available with activity against western flower thrips. Further, western flower thrips has developed resistance to many of the newer insecticides. The best way to slow or even prevent the development of resistance is to follow integrated pest management practices in which insecticides are used only when western flower thrips adults or larvae reach their respective economic thresholds. Rotating between insecticides of different chemical classes can be employed when multiple applications of insecticides are needed. Reitz and Funderburk (2012) discuss in greater detail the role of insecticides in the management of western flower thrips.

Killing adult thrips with insecticides does not reduce the spread of tospoviruses in tomato (Momol et al. 2004). The reason is that insecticides do not kill adult thrips quickly enough to prevent them from feeding and transmitting tospoviruses. Other tactics are necessary to prevent primary spread of tospoviruses. Insecticides targeted at the larvae feeding on infected plants will prevent additional secondary spread to other healthy plants in a field.

Funderburk et al. (2014) provides an updated list of insecticides labeled for tomato that have various levels of activity against western flower thrips.

UV-reflective mulches and other technologies. Ultraviolet-reflective mulch repels the migrating adults of western flower thrips and this reduces the primary and secondary spread of tomato spotted wilt. The use of ultraviolet-reflective mulch also reduces the influx of eastern flower thrips and Florida flower thrips (Momol et al. 2004). This cultural tactic is most effective from early to midseason before the plants grow to cover the mulch.

Kaolin is a clay particle film with multiple modes of action that include repellency. It has been shown to reduce the numbers of thrips (Tyler-Julian et al. 2014) and to reduce the incidence of tomato spotted wilt in tomato (Tyler-Julian et al. 2015).

Acibenzolar-S-methyl. Acibenzolar-S-methyl is a systemic acquired resistance inducer that influences the salicylic acid pathway in the plant. It is effective against bacteria and viruses. This product has been shown to reduce the incidence of infection of *Tomato spotted wilt virus* (Momol et al. 2004). Its use has minimal impacts on populations of flower thrips.

Fertility. Extra nitrogen fertilization above the recommended optimal level increases densities of western flower thrips. As vector populations expand with increasing fertilization, there is an upsurge in the incidence of tospoviruses. Growers can improve overall crop production by maintaining recommended fertilization levels. Refer to Demirozer et al. (2012) for further information.

Tospovirus-resistant cultivars. Numerous cultivars of tomato resistant to *Tomato spotted wilt virus* are commercially available. However, these cultivars are not resistant to thrips feeding or egg-laying. All of the commercially available cultivars of tomato share a single source of resistance from the Sw-5 gene. This is a single-gene dominant trait, and thus could potentially be compromised by resistance-breaking strains of the virus. Therefore, an integrated approach is needed to prevent/minimize the development of resistance-breaking strains of tospoviruses (Demirozer et al. 2012). Cultivars with resistance through the Sw-5 gene include large round determinate types, plum or roma types, large round indeterminate types, large round heritage type, and grape type. Refer to Funderburk et al. (2014) for a listing of each cultivar by type.

Recent damaging outbreaks of two emerging tospoviruses, *Tomato chlorotic spot virus* and *Groundnut ringspot virus*, have significantly impacted the south Florida tomato industry in the Homestead growing region. Fruit from infected plants are not marketable. Because infected fruit can develop symptoms well after harvest due to latent infections, even a low incidence of disease in a field can ultimately result in serious, if not total economic loss because packers are not willing to accept the risk of their fruit developing symptoms after they have been harvested and packed. Current management strategies for these viruses and their thrips vectors have proven ineffective. Development of effective strategies requires a multi-pronged approach beginning with the evaluation of commercial cultivars and inbred lines possessing virus resistance genes for suitability for production in the Homestead growing region. The Sw-5 gene for resistance to *Tomato spotted wilt virus*, a related tospovirus, is known to also confer resistance to *Tomato chlorotic spot virus* and *Groundnut ringspot virus* although its field effectiveness needs to be validated.

CONCLUSIONS AND FUTURE DIRECTIONS

Unfortunately, western flower thrips has developed resistance to the insecticides that traditionally provided the greatest control. Simply rotating insecticides from different chemical classes is not the best plan of action to prevent development of resistance in the few remaining products. The following resistance management protocol serves as the foundation for a sound IPM program: apply insecticides only when required; make accurate and precise insecticide applications; diversify management methods that are used; and conserve natural enemies. Integrated pest management programs are knowledge-based systems that require regular updating as new research findings become available. Refer to Funderburk et al. (2014) for the most recent updated information.

Outbreaks of *Tomato chlorotic spot virus* and/or *Groundnut ringspot virus* have occurred in every season since their introduction in the Homestead growing region, and with each subsequent season disease severity has increased. In addition, these emerging viruses are widely present in southeast and southwest Florida production areas. Under current circumstances, an outbreak of *Tomato chlorotic spot virus* in the greater Florida production regions could be problematic for the tomato industry. The use of insecticides for management of the thrips vector has proven ineffective in preventing recent outbreaks, and resistant cultivars, which are the only effective control, have not been fully tested under field conditions and are not widely grown in southern Florida. Horticulturally acceptable virus-resistant tomato cultivars will provide the foundation for the long term solution to this problem. Alteration of grower practices, such as adjustments to planting dates for specific varieties or targeted management of reservoir host plants and weeds, are possible management strategies that might show promise following collection and analysis of epidemiological data from current outbreaks.

ACKNOWLEDGEMENTS

We thank numerous growers and scouts, especially Glades Crop Care, for help with sample collection. Research reported here was supported in part by the Florida Tomato Committee, Florida Fruit and Vegetable Association, Florida Specialty Crop Foundation, USDA-AFRI-CAP, USDA-NIFA-Critical Issues and FDACS-Specialty Crop Block Grants.

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Evaluation of Tomato Cultivars and Insecticides for Management of *Tomato Chlorotic Spot Virus* (TCSV) and Thrips Species Recorded in Virus-Infected Tomato Fields

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INTRODUCTION

South Florida tomato growers experienced a severe outbreak of *Tomato chlorotic spot virus* (TCSV), an emerging tospovirus, during the growing season from the fall of 2014 into the spring of 2015 (Zhang et al. 2015a, b). TCSV caused significant yield losses to tomato growers in this area as its infection incited necrosis of leaves, stunted plant growth, and rendered the fruit unmarketable. Initial symptoms of TCSV occurred as chlorotic spots and necrotic lesions on the upper leaves only about three weeks after transplanting. If the plants survived then symptoms of stunting, bronzing, necrosis, and deformation appeared. Early infection of TCSV in young plants resulted in stunting of the plants with few or no flowers or fruit developed, and eventual death of the plant. Fruit from infected plants, if any, showed necrotic rings rendering them unmarketable. In December 2014, more than 30% tomato plants in a field of Homestead, FL were infected with TCSV and the infected plants had to be rogued out from the field attempting to reduce the spread of the virus. The worst case was seen in a 50-acre field that was completely abandoned due to severe infection of TCSV. Losses could reach as high as 100% based on observations in field trials conducted at TREC during the spring of 2015 in Homestead, FL.

TCSV was first detected in the USA and reported in tomato and pepper from South Florida in 2012 by Polston and Zhang (Londoño et al. 2012; Polston et al, 2013). TCSV is analogous to *Tomato spotted wilt virus* (TSWV), *Groundnut ring spot virus* (GRSV), and other known tospoviruses (Whitfield et al., 2005). The genome of TCSV consists of large (L), medium (M) and small (S) RNA segments. The L RNA segment is negative sense that encodes a multifunction protein (L) including a domain of RNA-dependent RNA polymerase. The M RNA is ambisense encoding a precursor for two glycoproteins (GN and GC) and a nonstructural movement protein (NSm). The S RNA is also ambisense but encodes a nucleocapsid (N) protein and a nonstructural silencing suppressor protein (NSs). Tomato plants in South Florida can be infected with TCSV as well as two other known tospoviruses TSWV and GRSV. However, the biggest problem in the growing season 2014-2015 of South Florida appeared to be TCSV. Testing of samples of symptomatic tomato plants has confirmed that all of them were unexclusively infected with TCSV. Clearly, TCSV is established in South Florida and is now a major threat to commercial tomato production in this area.

Similar to other tospoviruses, TCSV is known to be transmitted exclusively by thrips. To date, western flower thrips (*Frankliniella occidentalis*) and common blossom thrips (*F. schultzei*) are confirmed to be the major vectors of TCSV in South Florida (Polston et al., 2013; Webster et al. 2015). It is unknown if other species of thrips also transmit TCSV in Florida. *F. occidentalis* is a major vector of several tospoviruses including TCSV, and is widespread in the USA and worldwide. *F. schultzei* is not commonly present in Florida and the USA. Recently, however, *F. schultzei* has been reported in vegetable production areas of South Florida where TCSV was detected (Kakkar et al., 2012a, b). The potential of other thrips species to transmit TCSV in Florida has not yet been determined. Vegetable fields in Florida and the southeastern US are commonly inhabited by a number of species of thrips including Florida flower thrips (*F. bispinosa*), eastern flower thrips (*F. tritici*), melon thrips (*Thrips palmi*), and tobacco thrips (*F. fusca*) that are all reported to transmit tospoviruses (Riley et al., 2011). It is important to understand the role of these commonly present species of thrips in transmitting TCSV in Florida.

The known hosts of TCSV are primarily in the family *Solanaceae* and include vegetables (tomato, pepper, eggplant, tomatillo), ornamentals (tobacco, petunia) and jimson weed. Non-solanaceous hosts of TCSV that are known, to date, are lettuce and impatiens. Most recently reported in 2015, TCSV was detected from more non-solanaceous plants such as the annual vinca, also known as Madagascar periwinkle, *Catharanthus roseus* (family *Apocynaceae*) in Miami-Dade County in 2014 (Warfield et al., 2015), and porcelainflower or waxflower, *Hoya wayetii* (in *Apocynaceae*) and false Christmas cactus, *Schlumbergera truncate* (in *Cactaceae*) in Central Florida in 2014 (Baker and Adkins, 2015). The recent identification of these plant species as hosts of TCSV in Florida implies that TCSV exists both in vegetables and ornamental crops. Studies of the epidemiology and management of TCSV must be conducted on both groups of crops as they often share production space in Florida. Considering the establishment and spread of TCSV in South Florida, where vegetable fields, ornamental plant nurseries, tropical and subtropical fruit groves, and transplant producers are in close proximity, many crops and weeds may be potential reservoirs or hosts of TCSV.

There is great concern that TCSV may spread beyond South/Central Florida to other areas due to the widespread presence of thrips vectors and transplant producers in this area. TCSV was recently reported from Ohio infecting tomatoes in a commercial high tunnel in the summer of 2013 (Baysal-Gurel et al. 2015). This is the second report of TCSV in the USA, highlighting the great potential of this virus spreading to other U.S. states. Appropriate management measures must be taken in vegetable and ornamental fields to not only reduce losses to those crops, but to restrict the movement of TCSV to other states in the USA. In the spring of 2015, we initiated field studies under commercial production conditions to evaluate tomato cultivars for resistance to TCSV in South Florida, and to investigate insecticides for their efficacy against thrips and TCSV disease.

MATERIALS AND METHODS

Evaluating tomato cultivars for resistance to TCSV. Tomato seed of fourteen cultivars including thirteen large fruited types and one Roma type were provided by seed companies, and were evaluated for their resistance against TCSV on the research farm of UF/IFAS TREC in Homestead, FL in the spring of 2015. The large fruited cultivars were Skyway (Enza), BHN 602, BHN 640, BHN 1064 (BHN Seed), Volante, XTM8135 (Sakata), Dixie Red, SV 7631TD, SV 7101TD, Quincy (Seminis), Brickyard, Richmond, Summerpick (Syngenta), and the Roma type was Monticello (Syngenta) which are all known to be resistant/tolerant to *Tomato spotted wilt virus* (TSWV). A susceptible cultivar FL47 was included as a commercial standard. All tomato seedlings were grown from seed in a greenhouse by a grower in Immokalee, FL. On February 3, 2015, tomato seedlings were transplanted into the beds 2 feet apart within rows. The beds were prepared for vegetable cultivation that were 30-inch-wide and centered 6 feet apart and covered with white plastic mulch. The trial was designed as a randomized complete block (RCB) with four replications for each cultivar. Each plot consisted of a single row of 28-foot section with a 4-foot buffer zone between adjacent plots. Fourteen plants were transplanted in each plot, and a total of fifty six plants were tested for each tomato cultivar. Irrigation, fertilization were applied as needed to promote plant growth, and a foliar spray program with fungicides and insecticides (ineffective for thrips) was designed for weekly applications to maintain the plots and promote plant health. After initial symptoms of TCSV appeared, incidence of TCSV was rated every 3-4 days until all plants of FL47 were infected with TCSV. On April 21, 2015, tomato fruits were harvested, graded and yields were recorded. Postharvest fruit quality including parameters such as firmness, Brix, and pH which drives grower selection of cultivars were also investigated after harvest.

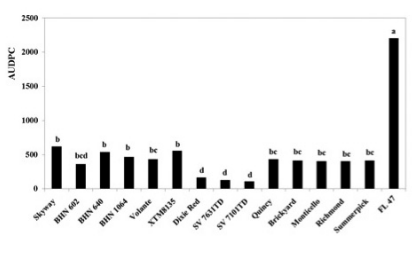

Figure 1. Disease of *Tomato Chlorotic Spot Virus* on tomato cultivars in the spring of 2015. AUDPC = the area under the disease progress curve.

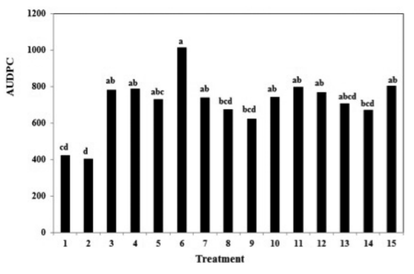

Figure 2. Efficacy of insecticides against Tomato Chlorotic Spot Virus on tomato cultivars. Tygress in the spring of 2015. AUDPC = the area under the disease progress curve. Treatment list: 1. Radiant (8 fl oz), 2. Exirel (13.5 fl oz), 3. Agrimek (3.5 fl oz), 4. Malathion (32 fl oz), 5. Brigade 2SC (2.5 fl oz), 6. Requiem (2.5 qt), 7. Movento (5 fl oz), 8. Venom (4 oz), 9. Lannate (32 fl oz) alt. Requiem (2.5 qt), 10. Agrimek (3.5 fl oz) alt. Exirel (13.5 fl oz), 11. Malathion (32 fl oz) alt. Radiant (8 fl oz), 12. Radiant (8 fl oz) alt. Lannate (32 fl oz) alt. Marathon (32 fl oz) + Radiant (8 fl oz), 13. Hero (6 fl oz) alt. Rimon 0.83 EC (12 fl oz), 14. Trilogy (1.0%) alt. Entrust (8 fl oz), and 15. Untreated Control.

Evaluating insecticides for thrips and TCSV. Selective insecticides that are recommended on fruiting vegetables for management of thrips with low toxicity to natural enemies were evaluated separately, in alternation or combination on tomato for their efficacy in reducing TCSV disease and thrips. To avoid *Tomato yellow leaf curl virus* (TYLCV), a common virus that seriously damage tomato during the spring season in Homestead, FL, a TYLCV resistant cultivar ‘Tygress’ was used in this insecticide trial. This trial was setup at the same time as the cultivar trial described above, and all other information relevant to the trial were identical, except that each plot was a 20-foot section with nine plants, and a total of thirty six plants were planted for each treatment. A total of fourteen treatments with insecticides were applied weekly as foliar sprays beginning February 12, 2015 until March 19, 2015, and plants not receiving treatment were included as an untreated control. Populations of thrips species were monitored weekly using yellow sticky cards set in the field, and TCSV incidence was rated every 3-4 days until most plants in untreated plots showed symptoms of TCSV.

In order to understand general distribution of thrips species in TCSV infected tomato fields, eight commercial tomato fields in Homestead, FL with significant incidence of TCSV were also weekly monitored during the fall of 2014 to spring 2015 by collecting leaf and flower samples. All samples were washed with 70% alcohol to separate thrips which were then identified by using a binocular microscope.

RESULTS AND DISCUSSION

All cultivars of tomato tested in this trial showed varied levels of resistance to TCSV during the spring of 2015 (Fig. 1). The highest resistance was found in the cultivars Dixie Red, SV 7631TD, and SV 7101TD. At the last disease rating on April 3, 2015, i.e. 59 days after transplanting (DAT), disease incidence of TCSV on these three cultivars was 10.7%, 16.1%, and 10.7%, respectively. The other eleven cultivars showed intermediate resistance to TCSV with 30-42% plants infected, whereas 100% of the FL47 plants displayed TCSV symptoms.

Initial symptoms of TCSV were observed on plants of FL47 on February 27, 2015, i.e. 24 DAT. Most new symptoms of TCSV on FL47 occurred during the 5th - 6th weeks after transplanting (WAT). On tested cultivars with resistance, new symptoms still occurred by the 9th WAT. However, most new disease was observed during the 6th - 8th WAT (data not shown).

In the insecticide trial, first symptoms of TCSV were observed on February 25, 2015, i.e. 22 DAT. At the last rating on March 20, 2015 (45 DAT), 95% of the plants showed TCSV symptoms in the untreated plots. Among all treatments, only Radiant (8 fl oz/acre) and Exirel (13.5 fl oz/acre) significantly (P<0.05) reduced overall disease (AUDPC) of TCSV compared to the untreated control (Fig. 2). Regardless of insecticide treatment, most new symptoms of TCSV occurred during the 5th – 6th WAT, and nearly 100% of tomato plants from the untreated plots showed TCSV symptoms by the 7th WAT.

Tomato plants in the cultivar trial were heavily infected with TYLCV after 7 WAT, the growth of many plants was severely stunted. Many fruits showed symptoms of TYLCV, therefore tomatoes were only harvested one time on April 21, 2015. In the insecticide trial, TCSV incidence reached as high as 95% in untreated plots and 64% in plots with the best treatment after 6 WAT. No marketable fruit was harvested due to high disease incidence in this trial. Further repeated trials need to be conducted under regular production season of South Florida, i. e. the fall of 2015 to confirm the results of these trials, and to obtain data such as yield, horticultural traits, and postharvest quality.

On the yellow sticky traps, we commonly observed thrips species at variable densities in the insecticide trial on three sampling dates. Radiant and Exirel had fewer adults of common blossom thrips (CBT) on the second sampling date (2 Mar 2015) than the untreated control (Table 1). The number of adult CBT on the other sampling dates (27 Feb and 9 Mar) did not differ from the untreated control. In the instance of western flower thrips (WFT), the number of adult WFT on yellow sticky traps was very low on the first two sampling dates (27 Feb and 2 Mar). Population abundance of WFT increased thereafter, one or more than one WFT adults were recorded in most treated plots on yellow sticky traps. Mean numbers of WFT adults were significantly fewer in Radiant, Exirel, Malathion, Brigade, Lannate alt. Requiem, Agrimek alt. Exirel, and Malathion alt. Radiant treated plots than the untreated control. None of the treatments in the present study, either applied solo, in rotation or combination, significantly reduced melon thrips compared to the untreated control (data not shown).

In monitoring eight TCSV infected commercial tomato fields in Miami-Dade County, six species of thrips were observed including common blossom thrips, western flower thrips, melon thrips, Florida flower thrips, chilli thrips (*Scirtothrips dorsalis*), and onion thrips (*Thrips tabaci*) (data not shown). Common blossom thrips, western flower thrips, melon thrips, and Florida flower thrips were observed in all fields during the tomato growing season 2014-2015. Only five adults of chilli thrips were collected in samples from two tomato fields, and onion thrips were observed only on one sampling date.

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Table 1. Effect of insecticide treatments on western flower thrips and common blossom thrips in tomato in 2015 (Number of thrips adults/yellow sticky trap)

Treatment	Chemical name/ common name	Rate (oz/A)	IRAC Group	Western flower thrips 27 Feb	Western flower thrips 2 Mar	Western flower thrips 9 Mar	Common blossom thrips 27 Feb	Common blossom thrips 2 Mar	Common blossom thrips 9 Mar
Radiant	Spinetoram	8.0	5	0	0.25	0.50 c	0.50	0.50 b	0.25
Exirel	Cyantraniliprole	13.5	28	0	0.0	1.00 bc	0.50	0.75 b	0.50
Agrimek	Abamectin	3.5	6	0.25	0.75	2.25 ab	0.75	1.50 ab	0.50
Malathion	Malathion	32.0	1B	0	0.25	1.00 bc	0.50	1.00 ab	0.50
Brigade 2SC	Bifenthrin	2.5	3	0	0.0	1.00 bc	0.75	1.25 ab	0.50
Requiem	Extract of *Chenopodium ambrosioides* near *ambrosioides*	2.5 qt	?	0	0.0	2.25 ab	0.75	2.25 a	0.75
Movento	Spirotetramat	5.0	23	0	0.0	1.75 abc	0.50	1.75 ab	0.25
Venom	Dinotefuran	4.0	4A	0	0.0	1.25 abc	1.0	1.00 ab	0.25
Lannate alt. Requiem	Methomyl *Chenopodium*	32.0 2.5 qt	1A ?	0	0.50	1.00 bc	1.0	1.75 ab	0.75
Agrimek alt. Exirel	Abamectin Cyantraniliprole	3.5 13.5	5 28	0	0.25	1.00 bc	0.75	1.25 ab	0.50
Malathion alt. Radiant	Malathion Spinetoram	32.0 8.0	1B 5	0	0.50	0.75 bc	0.50	0.75 ab	0.50
Radiant alt. Lannate alt. Malathion + Radiant	Spinetoram Methomyl Malathion Spinetoram	8.0 32.0 32.0 8.0	5 1A 1B 5	0	0.25	1.50 abc	1.0	1.25 ab	0.50
Hero alt. Rimon 0.83EC	Foot note Novaluron	6.0 12.0	3 15	0	0.0	1.50 abc	0.75	1.50 ab	0.50
Trilogy alt. Entrust	Neem derivative Spinosad	1.0% 8.0	? 5	0.25	0.50	1.50 abc	1.0	2.00 ab	0.50
Untreated Control				0	0.25	2.75 a	0.75	2.25 a	1.00

Data were collected using yellow sticky traps. Data were analyzed by using repeated measure factor in PROC MIXED. Means within a column followed by a same letter do not differ statistically ($P > 0.05$; Tukey-Kramer test).

Managing Pests and Insecticide Resistance in Florida Tomato

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SYSTEMIC INSECTICIDES FOR WHITEFLY CONTROL

Prior to 1994, Florida tomato growers depended largely on frequent sprays of tank-mixed pyrethroid and organophosate insecticides for whitefly control. That all changed when imidacloprid (Admire 2F) became available late that year. With widespread use of Admire drenches throughout the industry, whiteflies virtually disappeared from the spring 1995 crop, as did the then virus plague, *Tomato mottle virus* (ToMoV). Unfortunately, the much worse *Tomato yellow leaf curl virus* (TYLCV) soon took its place. TYLCV steadily gained ground as it spread through the industry while imidacloprid gradually lost effectiveness due to resistance. Fast forward 20 years we find ourselves in a continuing battle against whiteflies and virus although with a few more systemic tools in the tool box. These include additional group 4A neonicotinoids, two mode of action (MoA) group 4 products in different subgroups: Closer (sulfoxaflor - 4C) and Sivanto (flupyradifurone – 4D), and a group 28 active ingredient, cyantraniliprole. (Verimark/Exirel).

Repetition of any MoA within a crop is generally not recommended in the interest of preventing or delaying resistance. The active ingredient of Verimark (soil applied) and Exirel (foliar) is very similar to Coragen (chlorantraniliprole). The different subgroup classifications for Closer and Sivanto indicate they share the same target site with the neonicotinoids but are sufficiently different to so that chance of selection for either metabolic or target-site cross resistance is reduced. What is the best way to use these products to achieve and maintain effective control over the short term and the long haul?

Early on we learned that the transplant drench was the most effective way to apply imidacloprid and most other 4A products that subsequently became available (thiamethoxam, dinotefuran). Acetamiprid (Assail) and sulfoxaflor (Closer) are exceptions that do not lend themselves to soil application and are therefore used only as foliar sprays. In the interest of resistance management, the longstanding recommendation has been that neonicotinoids only be applied within the first 6 weeks after transplanting. A neonicotinoid drench at planting has become standard practice since young plants are most vulnerable to TYLCV. However, the availability of Verimark and non-neonicotinoid group 4 products creates the possibility of prolonging systemic control of whiteflies further into the crop cycle. So how can these recently available additional products be best integrated into the system?

The Stansly lab has done extensive field testing of cyantraniliprole (Verimark, Exirel) and flupyradifurone (Sivanto) as drenches, drip injection and sprays. In 2009 we evaluated Verimark (soil) and Exirel (foliar). Seedlings were transplanted 6 Mar and evaluations for nymphs made at 33, 47, 61 and 75 days after transplanting DAT (Table 1).

The Admire drench provided least control of all treatments (Figure 1). Verimark drenches aided by 2 sprays of Fulfill provided significant suppression of large SWF nymphs through 75 DAT with no significant difference between the two rates. The drip applications provided best control, although they used twice as much product. The foliar applications of Exirel were the least effective way to apply cyantraniliprole.

In another trial conducted in 2011, two rates of Venom and four of Sivanto were applied by drench or by drip (Table 2).

Fewer nymphs and adults were seen with drenches of Venom and Sivanto than the respective drip applications (Figures 2 and 3). Furthermore, the 21 oz/ac Sivanto drench was the only treatment that resulted in a lower incidence of TYLCV, even though it contained 7 oz/ac less product compared to the highest drip application (Figure 4).

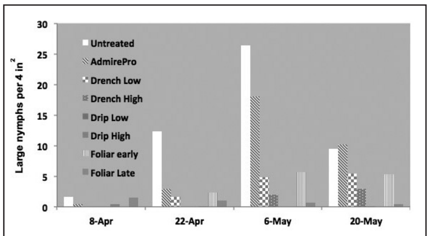

Figure 1. Efficacy of imidacloprid (AdmirePro) and cyantraniliprole (Verimark drench and drip, Exirel spray) against silverleaf whitefly in tomato, SWFREC spring 2009 .

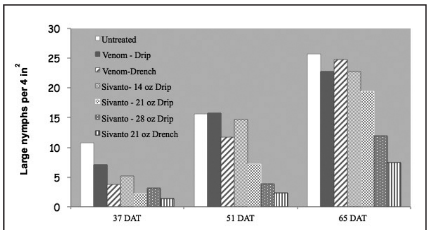

Figure 2. Whitefly nymphs on tomato in 2011 trial at SWFREC.

Table 1. Product, method, rate and timing of application and total active ingredient of imidacloprid or cyantraniliprole.

Product	Method	Rate (oz/ac)	Days after transplant			Total AI (lb/ac)	Fulfill
AdmirePro	Drench	10.5	0			0.386	2x2.75 oz
Verimark	Drench	1.64 3.3	0			0.107 0.214	2x2.75 oz 3 &10 Apr
Verimark	Drip		10	20	33	0.268 0.401	
Exirel	Spray (Early)		14	21	27	0.267	
Exirel	Spray (Late)		34	41	48	0.267	2.75 oz 3 Apr

Table 2. Application rates, dates and methods for 2011 trial at SWFREC on tomato.

Treatment	Active ingredient	Rate (oz/ac)	Method	Application date	
				7-Mar	8 Mar
Untreated					
Venom	dinotefuron	6.0	Drip	X	
Venom		6.0	Drench	X	
Sivanto	flupyradifurone	14	Drip		X
Sivanto		21	Drip		X
Sivanto		28	Drip		X
Sivanto		21	Drench	X	

These results show that you get most bang for the buck with an early drench application of any of the tested systemics. However, drip applications of systemic insecticides are better than foliars. Therefore a drench application followed by a drip injection of a different mode of action would be the best combination. Verimark is presently the most effective product available for whitefly control, although it is also the most expensive, but with the additional advantages of worm and leafminer control similar to Coragen. Therefore, the most efficient use of Verimark would be the drench application at planting. In that case, a 4A neonicotinoid or Sivanto could be used as a follow-up through the drip once the drench wears out and the root system is developed enough to uptake the product efficiently. Additional sprays of other modes of action could be made later in the crop as necessary. Another option would be to start with the neonicotinoid or Sivanto drench and then go to a Verimark drip injection or a rotation of sprays. We would further recommend that 4A neonicotinoids not be used in the same crop as Sivanto or Closer, preferably alternating crop cycles to reduce pressure on these important insecticides.

GROWER SURVEY

Florida tomato growers provided information on pest management priorities and practices at meetings held between August 2013 and August 2014 in Immokalee, Naples and Parrish. About 26 growers contributed answers to a series of questions designed to provide baseline information on pest management practices in Florida tomato production. The respondents represented a cross section of small, medium and large farms. Twenty percent were associated with farms growing either 4-8 or 36-60 acres of tomato annually; 35% worked for farms 145-800 acres in size, and 25% were associated with operations ranging from 1500-4000 acres.

Sixty percent said that whiteflies were the pest requiring the most frequent applications of insecticides. The remaining growers mentioned other pests in addition to whiteflies, including leafminers, mites (15%), thrips, aphids, caterpillars (10%) and stink bugs (5%). All growers indicated that they treat tomatoes at-plant with a neonicotinoid insecticide. Sixty-two percent listed Admire or another formulation of imidacloprid; 37% listed Venom (dinotefuran) and 8% listed Platinum (thiamethoxam). (Some growers listed more than one material in response to this and subsequent questions, hence totals are sometimes greater than 100 percent.) When asked which materials they routinely applied through the drip irrigation system, fifty-four percent listed Coragen (chlorantraniliprole/rynaxypyr), thirty-three percent listed Admire or a generic imidacloprid, twenty-five percent listed Venom and 4% listed Vydate (oxamyl).

Table 3 lists the products that growers apply foliarly for control of whiteflies. Twenty-five percent apply neonicotinoids, and 67% apply pyrethroids. Over half listed endosulfan, also sold as Thionex and Thiodan, which as of 2015 is not registered for use on tomato in Florida. Ten modes of action and two materials without an assigned mode of action number were listed in total.

Twenty-five growers listed the foliar materials they apply for control of caterpillars (Figure 5). Seventy-two percent apply diamide insecticides: 63% listed Coragen and 10% listed Belt/Synapse (flubendiamide). (The Belt label has replaced the Synapse label for use on vegetables).

Eighteen growers provided information on the insecticides they apply for management of leafminers (*Liriomyza* spp.). The majority (78%) apply Coragen. Thirty-nine percent apply Agri-Mek (abamectin, IRAC # 6), 28% apply Trigard (cyromazine, IRAC # 17) and 22% apply Radiant (spinetoram, IRAC # 5).

Six growers indicated that they routinely apply acaricides for management of spider mites. The products listed included Agri-Mek, Oberon and Portal (fenpyroximate, IRAC # 21A). Two growers mentioned using Rimon and pyrethroids for management of stink bugs, and one grower listed Radiant for thrips control.

FREQUENCY OF INSECTICIDE APPLICATIONS

Forty-four percent spray twice a week during the spring crop; 40% spray once or twice a week for the spring crop, and 16% spray once a week in the spring. Thirty-eight percent spray the fall crop twice a week; 31% spray once or twice a week in the fall and 31% indicated that their fall spray frequency depended on the rain. These responses referred to applications of both insecticides and fungicides. Eighty-eight percent of respondents indicated that they practice insecticide resistance management by rotating modes of action.

Eighteen modes of action in total were reported in the growers' responses, as well as botanical products and soaps that are not assigned a mode of action number. Since this information was collected, new insecticides have become available and others have been withdrawn. Endosulfan can no longer be used on tomatoes in Florida. In 2014, a new diamide insecticide, cyantraniliprole/cyazypyr, has become available, and in 2015, Sivanto became available.. With the availability of cyazypyr, growers can now treat tomatoes with diamide insecticides from planting till the initiation of harvest, raising concerns regarding the development of resistance to diamides in tomato. Although not a recommended practice, a grower could treat tomatoes at-plant with Verimark, through the drip a few weeks later with Coragen (or Durivo, which contains chlorantraniliprole and thiamethoxam), then foliarly with Coragen, Belt or Exirel. The high percentage of growers already reporting use of diamides for control of caterpillar and leafminer lends credence to concerns regarding the overuse of diamide insecticides.

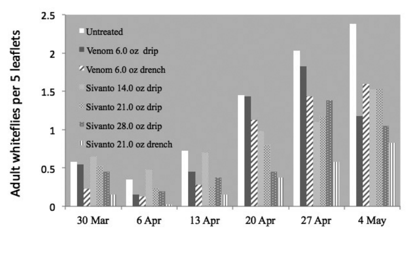

Figure 3. Whitefly adults on tomato in 2011 trial at SWFREC.

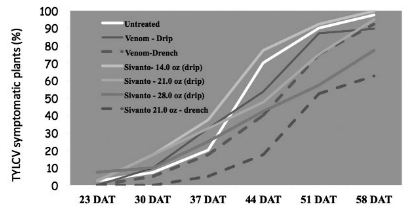

Figure 4. Incidence of TYLCV symptomatic plants in 2011 tomato trial at SWFREC.

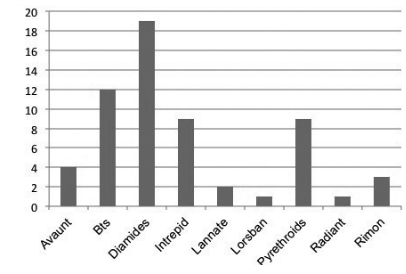

Figure 5. Number of growers using specific insecticides for caterpillar management on tomato (25 respondents).

Table 3. Foliar materials listed by 24 tomato growers for control of whitefly. Active ingredient, IRAC mode of action number in parentheses; ---indicates that no mode of action number has been assigned.

Insecticide	Number of times product was listed
Actara (thiamethoxam, 4A), Coragen (28), Neem oil (---), Requiem (extract of *Chenopodium ambrosioides;* --), Rimon (novaluron, 15)	1
Provado (imidacloprid, 4A)	2
Courier (buprofezin, 16), Knack (pyriproxifen, 7C), Venom (dinotefuran, 4A)	3
Malathion (1B)	4
Insecticidal soap (---)	5
Oberon (spiromesifen) or Movento (spirotetramat) (23)	7
Fulfill (pymetrozine, 9B)	10
Endosulfan (2A)	13
Pyrethroids (various, 3A)	16

Effect of Acibenzolar-S-Methyl on Bacterial Wilt Incidence of Grafted Tomatoes

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ABSTRACT

The study was conducted to assess the effect of Acibenzolar-S-Methyl (ASM), a systemic acquired resistance inducer, on bacterial wilt incidence and marketable yield of grafted tomatoes in 2013-2014. Grafting alone or in combination with drip application of ASM (0.5 oz/A) significantly reduced disease incidence relative to non-grafted BHN 602 control and also significantly improved total marketable yield relative to all non-grafted treatments ($P \leq 0.05$). Drip applications of ASM on grafted plants was statistically similar to non-treated grafted control in terms of bacterial wilt incidence or total marketable yield ($P \leq 0.05$). Foliar applications of ASM, however, had a negative effect on grafted plants and significantly reduced the total marketable yield relative to non-treated grafted control and grafted plants treated with ASM through drip ($P \leq 0.05$).

INTRODUCTION

Field tomato production in the southeastern United States is highly affected by bacterial wilt disease caused by *Ralstonia solanacearum* (Ji et al. 2005). In Florida, race 1 (biovar I, phylotype II) has been reported to cause more than 80% yield loss in field tomato production under disease favorable conditions (Hong et al. 2012). Although a lot of cultural and chemical methods have been applied in the past, effective management is difficult because of the wide host range of the pathogen. Although, use of resistant cultivars has been universally identified as the most effective method for managing the disease (Lebeau et al. 2011), the currently available commercial varieties in Florida do not have resistance to bacterial wilt. A recent study in Florida and Virginia has demonstrated the effectiveness of grafting to manage bacterial wilt disease in field tomato production with significant improvement in marketable yield (McAvoy et al. 2012). Also, foliar applications of the systemic acquired resistance (SAR) inducer, Acibenzolar-S-Methyl (ASM; Syngenta Crop Protection, Inc. Greensboro, NC. U.S.A), has been shown to provide effective bacterial wilt disease control in moderately resistant tomato genotypes with significant improvement in marketable yield compared to susceptible control in Florida (Pradhanang et al. 2005). This study was conducted to investigate the effect of ASM, applied as foliar or drip on grafted plants and impact on bacterial wilt incidence.

MATERIAL AND METHODS

Two weeks old seedlings of a bacterial wilt susceptible variety BHN 602 and resistant rootstock BHN 998 were grafted using a modified Japanese tube graft technique (Kunwar et al. 2015). Ten to fifteen days after removing the grafted transplants out from the grafting chamber, the transplants were treated with a single application of 50 ml of ASM (50 mg/l) in the greenhouse, applied as foliar or as drench, followed by weekly applications in the field (0.5 oz/A) following supplemental label application guidelines for ASM. Field inoculations were conducted one to two weeks before transplantation by pouring 50 ml of 10^5 CFU/ml of Rs5 strain of *Ralstonia solanacearum* suspended in field irrigation water in each planting hole. Each treatment in the 2013 trial consisted of four replications with 17 plants in each replication and each treatment in 2014 trial consisted of five replications with 14 plants in each replication. Bacterial wilt incidence data for each of the plots were recorded at weekly intervals as the percentage of plants wilted. Marketable yield of tomato fruits for each plot was recorded at harvest and graded according to USDA specifications. Two way ANOVA was conducted separately on percentage disease incidence and marketable yield data of 2013 and 2014 field trials using 'year' and 'treatment' as two independent factors. The effect of interaction of 'year' and 'treatment' on disease incidence or marketable yield was not significant at P = 0.05 and thus the data from the two trails were combined for analysis and presented in Table1.

DISCUSSION AND CONCLUSION

This study demonstrated the negative impact of foliar applications of ASM on grafted plants (Table 1). The reduction in fruit yield associated with foliar applications of ASM could be attributed to the physiological compensation against excessive and constitutive induction of plant defense response as reported in various other studies (van Loon et al. 2006; Walters and Fountaine 2009). This study further validates the usefulness of grafting to effectively control bacterial wilt disease of tomato with significant improvement in total marketable yield compared to non-grafted control (Table 1). Grafting has been shown to manage root-knot nematode (*Meloidogyne* spp.) (Kunwar et al. 2015; Rivard et al. 2010), southern blight (*Sclerotium rolfsii*) (Rivard et al. 2010), Fusarium wilt (*Fusarium oxysporum f.sp. lycopersici*) and Verticillium wilt (*Verticillium dahlia*) (Louws et al. 2010; Rivard et al. 2006) in the U.S. Also, drip applications of ASM (0.25-0.50 oz/A) was reported to effectively control bacterial spot of tomato (*Xanthomonas perforans*) with increase in marketable yield by 27.3 % compared to foliar ASM applications (applied at different rates and frequencies) (Huang et al. 2011). In this scenario, an integrated approach including grafting and drip applications of ASM is expected to provide profitable production in the fields infected with multiple pathogens if use of grafted plants would become commercial in Florida open field tomato production system in the future.

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Table 1. Yield and bacterial wilt (BW) incidence of susceptible tomato cultivar 'BHN 602' grafted onto resistant rootstock 'BHN 998' integrated with foliar and drip applications of ASM (0.5 oz/A). The trial was conducted in fall season of 2013 and 2014 in Quincy, FL.

	Marketable yield (kg/ha)				BW incidence
Treatment	Medium	Large	Extra Large	Total	(%)
Grafted (non-treated)	8049 az	11,779 a	23581 a	43,408 a	20.9 b
Grafted + ASM (drip)	8,024 a	11,769 a	22,535 a	42,330 a	14.2 b
Grafted + ASM (foliar)	6,074 ab	75,69 b	13,118 b	26,761 b	22.6 b
BHN 602 (non-treated)	3,913 bc	4,288 bc	7,112 bc	15,314 bc	67.8 a
BHN 602 + ASM (drip)	3,887 bc	4,708 bc	7,671 bc	16,266 bc	44.5 b
BHN 602 + ASM (foliar)	2,138 c	2,592 c	3,747 c	8,478 c	57.8 ab

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Eliminating Transplant Shock by Hormonal Control to Improve Growth and Yield of Tomato

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INTRODUCTION

Transplanting causes various stress responses in vegetable seedlings, transiently slowing down the field establishment (Agehara and Leskovar, 2012; Vavrina, 2002). In particular, a high degree of mechanical stress occurs as seedlings are shaken, moved, pulled from trays, and planted into the soil (Cantliffe, 1993). The most common consequences of mechanical stress are stem thickening and reductions in stem height and leaf area, resulting in plants which are smaller and more compact than unstressed plants (Biddington, 1986).

Some mechanical stress responses are known to be induced by ethylene (Druege, 2006). Ethylene is a strong antagonist of gibberellic acid, another plant hormone that promotes plant growth by stimulating both cell division and cell elongation (Zarembinski and Theologis, 1994). The biosynthesis of ethylene increases in response to various types of mechanical stimulation, inhibiting cell elongation and promoting stem thickening (Druege, 2006).

If ethylene is a primary hormone responsible for the slow field establishment of vegetable seedlings, inhibiting the ethylene action prior to transplanting may promote post-plating growth without "transplant shock", and thus improve early production of vegetable crops. In this study, 1-Methylcyclopropene (1-MCP) was used to inhibit ethylene signaling by blocking ethylene receptors. The objective is to examine the effect of pre-planting 1-MCP application on post-planting growth and yield of tomato.

MATERIALS AND METHODS

A field experiment was conducted at the Gulf Coast Research and Education Center in Wimauma, FL. Treatments were 0, 12.5, or 50 mg/L 1-MCP applied to tomato (cv. Florida 47) seedlings at 2 liters per tray (67 x 34 cm, 128 cells) 1 day before transplanting. The powder formulation of 1-MCP, AF-XRD-038 (AgroFresh, Spring House, PA), was used to prepare the test solutions.

Raised beds (8-inch high and 32-inch wide at the base) were fumigated with Pic-Clor 60 at 300 lb/acre and covered with black VIF plastic mulch. Pre-plant fertilization includes the soil incorporation at 200N–162P_2O_5–200K_2O_5 lb/acre and the band application at 150N lb/acre. Seedlings were transplanted on the raised beds at 12-inch in-row spacing on September 26, 2014. Each bed was irrigated through two drip tapes, each of which was placed 4 inches from the bed center at 1-inch depth. The drip tapes had emitters spaced 12 inches apart with a flow rate per emitter of 0.25 gal/h. Tomatoes were harvested on December 9, 2014.

The experiment was set up using a randomized complete block design with three blocks. Each plot consisted of 10 plants. All data were analyzed in SAS with the MIXED procedure.

RESULTS AND DISCUSSION

A single pre-plant spray of 1-MCP accelerated shoot elongation of tomato seedlings after transplanting (Table 1). The increase in plant height by 1-MCP ranged from 7% to 12%, and it was statistically significant for the 12.5 mg/L treatment measured at 33 DAP. Plant width was unaffected by1-MCP (Table 1), suggesting that 1-MCP promoted mainly upright growth. This upright growth

Table 1. Tomato (cv. Florida 47) post-planting early growth as affected by 1-MCP applied 1 day before transplanting.

1 -MCP (mg/L)	Plant height (cm)		Plant width (cm)		Stem diameter (mm)	
	17 DAP[1]	33 DAP	17 DAP	33 DAP	17 DAP	33 DAP
0	23.1	55.5 b[2]	37.6	78.6	4.5	14.5 a
12.5	25.8	62.4 a	37.2	80.7	4.1	13.4 ab
50	25.5	59.5 ab	36.4	78.4	4.3	11.8 b

[1] DAP = day after planting.
[2] Means in a column with the same letter are not significantly different (Fisher's protected LSD, $P < 0.05$).

promotion, however, resulted in thinner stem growth. At 33 DAP, stem diameter decreased proportionally to 1-MCP concentration by up to 19% compared with the control. Under mechanical stress, plants increase ethylene biosynthesis to promote more compact growth by stimulating stem thickening and inhibiting stem elongation (Druege, 2006). Therefore, the observed morphological changes in this study suggest that 1-MCP effectively inhibited ethylene signaling to promote unstressed, more upright growth.

Both extra-large fruit and marketable fruit yields were significantly increased by 1-MCP by up to 51% and 25%, respectively. At the time of harvest, the 1-MCP-treated plants had 17%–19% larger shoot biomass and 10%–14% more flowers than the control plants (data not shown). Therefore, the yield increase by 1-MCP was due likely to the promotion of vegetative growth that enabled increased flower production and photosynthesis to support more fruit set and fruit expansion.

The mode of action of 1-MCP involves its binding to ethylene receptors in plant tissue and preventing ethylene-dependent responses, rather than directly inhibiting ethylene synthesis (Blankenship and Dole, 2003). This mechanism allows newly produced plant tissue to be responsive to ethylene. Although the 1-MCP effect is limited to the treated tissue, the results of this study suggest that the early growth promotion by 1-MCP can be translated in improved yield potential in tomato. In addition, when 1-MCP is applied only at the young seedling stage, the effect of 1-MCP appears to have no side effect on important fruit developing processes regulated by ethylene.

Table 2. Tomato (cv. Florida 47) yield as affected by 1-MCP applied 1 day before transplanting.

1-MCP (mg/L)	Fruit yield (t/ha)	
	Extra large	Marketable
0	7.7 b1	24.5 b
12.5	11.5 a	30.0 ab
50	9.3 ab	30.7 a

[1] Means in a column with the same letter are not significantly different (Fisher's protected LSD, $P < 0.05$).

ACKNOWLEDGMENT

This work was supported by the financial support of AgroFresh and the technical assistance of Elizabeth Golden and Victor Alifonso.

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Tomato Varieties for Florida

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Variety selections, often made several months before planting, are one of the most important management decisions may by the grower. Failure to select the most suitable variety or varieties may lead to loss of yield or market acceptability.

The following characteristics should be considered in selection of tomato varieties for use in Florida:

Yield – The variety selected should have the potential to produce crops at least equivalent to varieties already grown. The average yield in Florida is currently about 1400 25-pound cartons per acre. The potential yield of varieties in use should be much higher than average.

Disease Resistance – Varieties selected for use in Florida must have resistance to Fusarium wilt, race 1, race 2, and in some areas race 3; Verticillium wilt (race 1); Gray leaf spot; and some tolerance to Bacterial soft rot. Available resistance to other diseases may be important in certain situations, such as Tomato yellow leaf curl virus in south and central Florida and Tomato spotted wilt virus and Bacterial wilt resistance in northwest Florida.

Horticultural Quality – Plant habit, stem type and fruit size, shape, color, smoothness, and resistance to defects should all be considered in variety selection.

Adaptability – Successful tomato varieties must perform well under the range of environmental conditions usually encountered in the district or on the individual farm.

Market acceptability – The tomato produced must have characteristics acceptable to the packer, shipper, wholesaler, retailer, and consumer. Included among these qualities are pack out, fruit shape, ripening ability, firmness, and flavor.

CURRENT VARIETY SITUATION

Many tomato varieties are grown commercially in Florida, but only a few represent most of the acreage. In years past, we were able to give a breakdown of which varieties are used and predominantly where they were being used but this information is no longer available through the USDA Crop Reporting Service.

TOMATO VARIETIES FOR COMMERCIAL PRODUCTION

The following varieties are currently popular with Florida growers or have done well in university trials. It is by no means a comprehensive list of all varieties that may be adapted to Florida conditions. Growers should try new varieties on a limited basis to see how they perform for them.

LARGE FRUITED TOMATO VARIETIES

1. LARGE FRUITED ROUND AND BEEFSTAKE TYPES

BHN 602. Early midseason. Determinate. Fruit are globe shaped but larger than BHN 640, and green shouldered. Resistance: Fusarium wilt (races 1, 2, and 3), Verticillium wilt (race 1), and Tomato spotted wilt.

BHN 730. Fall through winter. Determinate. Intended for mature green production. Strong bush that produces well even on poor soils and smooth fruit. Resistance: Fusarium wilt (races 1 and 2), Fusarium crown rot, Verticillium wilt (race 1), and Bacterial speck.

BHN 975. Early fall. Hot set tomato for early fall mature green production in Florida. Strong vine and smooth large fruit. Resistance: Fusarium wilt (races 1 and 2), Fusarium crown rot, and Verticillium wilt (race 1).

Brickyard - Best suited for the early winter growing season in south FL and the Nov/Dec plantings in Homestead. High marketable yield of large to extra-large firm, smooth, uniform fruit. Wide adaptability and performance in mature green and vine ripe markets. Resistance: Fusarium wilt (races 1, 2, and 3), Gray Leaf spot, Verticillium wilt (race 1), and Tomato spotted wilt.

Charger. Midseason. Determinate. Suited for fall and early summer production. Vigorous plant with good vine cover. Extra-large, smooth, deep oblate fruit with excellent firmness, color and good flavor. Resistance: Alternaria stem canker, Fusarium wilt (races 1, 2, and 3), and Verticillium wilt (race 1). Intermediate resistance: Gray leaf spot and Tomato yellow leaf curl virus.

Dixie Red. Determinate, early-main season. Round tomato with good plant habit. Fruit set ability in high temperatures. Good fruit cover deep, smooth, globe-shaped fruit with high yield potential and excellent size, color, and firmness. Resistance: Fusarium wilt (races 1, 2 and 3), Tomato Spotted Wilt Virus, Southern root-knot nematode, Alternaria Stem Canker and Verticillium wilt. Gray leaf spot.

Fletcher. Midseason. Determinate. Large, globe to deep oblate shaped fruit with compact plants. Does best with moderate pruning and high fertility. Good flavor, color and shelf-life. For vine ripe use only due to nipple characteristic on green fruit. Resistance: Fusarium wilt (races 1 and 2), Verticillium wilt (race 1), Root-knot nematode, Tomato spotted wilt, and Gray leaf spot.

Florida 47. Late midseason. Determinate, jointed hybrid. Uniform green, globe shaped fruit. Resistance: Alternaria stem canker, Fusarium wilt (races 1 and 2), Verticillium wilt (race 1), and Gray leaf spot. (Note growers are moving away from Florida 47 as improved varieties become available, and it is no longer the predominate variety in the industry).

Florida 91. Midseason. Determinate. Uniform green fruit borne on jointed pedicels. Good fruit setting ability in high temperatures. Resistance: Alternaria stem canker, Fusarium wilt (races 1 and 2), Verticillium wilt (race 1), and Gray leaf spot.

HM 1823 . Early season. Determinate. Round tomato with strong plant habit. Good fruit cover deep, smooth, globe-shaped fruit with high yield potential and excellent size, color, and firmness. Resistance: Fusarium wilt (races 1 and 2), Fusarium crown rot, and Verticillium wilt (race 1). Intermediate resistance: Gray leaf spot.

HM 8849 CR. Early season. Determinate. Strong plant and good leaf cover. Fruit extra-large, smooth and slightly flattened globe shape. Resistance: Fusarium wilt (races 1 and 2), Fusarium crown and root rot, Verticillium wilt (race 1), and Gray leaf spot.

Phoenix. Early midseason. Determinate. Vigorous vine with good leaf cover for fruit protection. "Hot-set" variety with large to extra-large fruit, high quality, firm, globe shaped, and uniformly-colored. Resistance: Alternaria stem canker, Fusarium wilt (races 1 and 2), Verticillium wilt (race 1), and Gray leaf spot.

Quincy. Full season for North Florida. Determinate. Large to extra-large, excellent quality, firm, deep oblate shaped fruit, and uniformly colored. Resistance: Alternaria stem canker, Fusarium wilt (races 1 and 2), Verticillium wilt (race 1), Tomato spotted wilt, and Gray leaf spot.

Raceway (STM9203). Main season. Determinate. Vigorous with good vine cover, suited for light pruning. Mostly extra-large, smooth, deep oblate fruit with great firmness and color. Gassing and vine ripe. Resistance: Alternaria stem canker, Fusarium crown and root rot, Fusarium wilt (races 1 and 2), Verticillium wilt (race 1). Intermediate resistance: Gray leaf spot.

Red Bounty. Medium maturity. Vigorous with good vine cover. Good heat set, high yield with extra-large, uniform, smooth fruit. Resistance: Gray leaf spot, Fusarium wilt (races 1 and 2), Verticillium wilt (race 1) and root knot. Intermediate resistance: Tomato spotted wilt.

Red Defender. Medium. Determinate. Vigorous vine with smooth, large deep red fruit with excellent firmness and shelf life. Resistance: Alternaria stem canker, Fusarium wilt (races 1 and 2), Verticillium wilt (race 1), and Gray leaf spot. Intermediate resistance: Tomato spotted wilt.

Red Rave. Main season. Determinate. Large plants with fruit that have good eating quality and fancy appearance in a large sturdy shipping tomato and firm enough for vine-ripe. Resistance: Fusarium wilt (races 1 and 2), Verticillium wilt (race 1), and Gray leaf spot.

RidgeRunner. Medium. Determinate. Bush for the mature green market. Tall plant that performs best in warm season conditions. Resistance: Fusarium wilt (races 1 and 2), Fusarium Crown Rot, Verticillium (Race 1), and Tomato yellow leaf curl virus.

Rocky Top. Midseason. Determinate. Mostly extra-large and large firm fruit. Great eating quality and is well adapted for vine ripe production as well as high tunnel production. Resistance: Fusarium wilt (races 1, 2, and 3), Verticillium wilt (race 1), and Gray leaf spot.

Sanibel. Main season. Determinate. Large, firm, smooth fruit with light green shoulder and a tight blossom end. Use widely in Homestead. Resistance: Alternaria stem canker, Fusarium wilt (races 1 and 2), Verticillium wilt (race 1), Root knot nematodes, and Gray leaf spot.

Sebring. Main season. Determinate, jointed hybrid. Plant with smooth, deep oblate shaped, firm, thick walled fruit. Resistance: Fusarium wilt (races 1, 2, and 3) Fusarium crown rot, Verticillium wilt (race 1), and Gray leaf spot.

SevenTY III. Midseason. Determinate. Variety is best for spring production. Vigorous bush with good plant cover. It has good gray wall tolerance. Resistance: Fusarium wilt (races 1, 2, and 3) and Verticillium wilt (Race 1). Intermediate resistance: Tomato yellow leaf curl virus.

Skyway687. Vigorous determinate variety for the whole season widely adapted throughout the Southeast U.S. with extra-large to jumbo fruits suited for gas green or vine ripe production. Resistance: TYLCV, TSWV, Nematode, and Fusarium wilt (races 1-3) and strong bacterial tolerance.

Soraya. Full season. Determinate. Continuous set. Strong, large bush. Fruit are high quality, smooth, and tend toward large to extra-large. Resistance: Fusarium wilt (races 1, 2, and 3), Fusarium crown rot, Verticillium wilt (race 1), and Gray leaf spot.

Southern Ripe. Determinate, main season. Winter variety for Central and South Florida.. Round tomato with good plant habit. Good fruit cover with deep, smooth, globe-shaped fruit and high yield potential and excellent size, color, and firmness. Resistance: Fusarium wilt (races 1, 2 and 3), Fusarium crown rot, Tomato Spotted Wilt Virus, Southern root-knot nematode, Alternaria Stem Canker and Verticillium wilt. Gray leaf spot.

Tasti-Lee. Midseason. Determinate, jointed hybrid. Fruit are uniform green with a high lycopene content and deep red interior color due to the crimson gene. Targeted at the premium tomato market with moderate heat-tolerance. Resistance: Fusarium wilt (races 1, 2, and 3), Verticillium wilt (race 1), and Gray leaf spot. (Note: only available to select growers by arrangement with Bejo Seed.

2. ROMA TOMATO VARIETIES

BHN 685. Midseason. Determinate. Vigorous bush with no pruning recommended.

Large to extra-large, deep blocky fruit. Resistance: Fusarium wilt (races 1, 2, and 3), Verticillium wilt (race 1), and Tomato spotted wilt.

Mariana. Midseason. Determinate. Small to medium sized plant with good fruit set. Fruit are predominately extra-large and extremely uniform in shape. Fruit wall is thick and external. Fruit internal color is very good with excellent firmness and shelf life. Resistance: Alternaria stem canker, Fusarium wilt (races 1 and 2), Verticillium wilt (race 1), Root-knot nematode. Intermediate resistance: Gray leaf spot.

Monica - Midseason. Determinate. Tall, vigorous plants with good canopy cover, has high yield potential. Fruit are extra-large, smooth, have good color and flavor. Resistance: Alternaria stem canker, Fusarium wilt (races 1 and 2), Bacterial speck (race 0), Verticillium wilt (race 1). Intermediate resistance: Gray leaf spot.

Monticello. Early-medium. Determinate. Uniform fruit size and a unique blocky shape with an improved disease resistance package for North Florida. Large firm fruit with good interior quality and small blossom end scar. Resistance: Fusarium wilt (races 1 and 2), Bacterial speck, Verticillum wilt (race 1), Root know nematode, Tomato spotted wilt virus, and Gray leaf spot.

Picus. Main season. Determinate. Medium to large, vigorous plant that provides good fruit cover and sets well in hot temperatures. Fruits are large, uniform and blocky, maturing to a deep-red color with great firmness at the red stage. Resistance: Alternaria stem canker, Fusarium wilt (race 1), Verticillium wilt (race 1), Tomato spotted wilt, and Gray leaf spot.

Regidor. Main season. Determinate. Medium tall plant with short internodes 6-8 sets with great fruit quality. Open field production. Resistance: Fusarium wilt (races 1 and 2), Verticillium wilt (race 1), and Tomato yellow leaf curl.

Sunoma. Main season. Determinate. Plant maintains fruit size through multiple harvests and has good fruit cover. Fruit are medium-large, elongated and cylindrical. Resistance: Fusarium wilt (races 1 and 2), Verticillium wilt (race 1), Root-knot nematodes, Tomato mosaic, and Gray leaf spot. Intermediate resistance: Bacterial speck (race 0).

Supremo. Midseason. Determinate. Mid compact plant with early maturity. Uniform predominately extra-large fruit. Suited for concentrated harvests for vine ripe and mature green markets. Resistance: Fusarium wilt (races 1, 2 and 3), Bacterial speck (race 0), Verticillium wilt (race 1), and Root-knot nematode. Intermediate resistance: Tomato spotted wilt.

Tachi. Midseason. Determinate. Mid compact plant with classic saladette shape. Uniform predominately extra-large fruit. Wide adaptability and suited for concentrated harvests for vine ripe and mature green markets. Resistance: Alternaria stem canker, Fusarium wilt (races 1 and 2), Verticillium wilt (race 1), and Root-knot nematode. Intermediate resistance: Tomato spotted wilt.

3. CHERRY TOMATO VARIETIES

BHN 268. Early to midseason. Determinate. Medium to tall bush with high yields an extra firm cherry tomato that holds, packs and ships well. Resistance: Fusarium wilt (race 1) and Verticillium wilt (race 1).

Camelia. Midseason. Indeterminate. Deep globe, cocktail-cherry size with excellent firmness and long shelf life. Outdoor or greenhouse production. Resistance: Fusarium wilt (race 1), Verticillium wilt (race 1), and Tobacco mosaic.

Shiren. Midseason. Compact plant with high yield potential and nice cluster. Resistance: Fusarium wilt (races 1 and 2) and Tomato mosaic. Intermediate resistance: Root-knot nematodes.

Sweet Treats. Early main season. Indeterminate. Strong, vigorous plant with wide adaptability. Deep pink, firm, globe shaped fruit with outstanding flavor potential. Strong against cracking. Resistance: Fusarium wilt (race 1 and 2), Leaf mold (races A-E), and Tomato mosaic (races 0 and 1). Intermediate resistance: Fusarium crown and root rot and Gray leaf spot.

4. GRAPE TOMATO VARIETIES

Amai. Early main season. Indeterminate. Smooth uniform fruit, 1-2 gr more than Sweet Hearts. Uniform sizing. Dark red, firm, elongated grape-shaped fruit. High yield potential. Resistance: Fusarium wilt (race 1), Leaf mold (races A-E), and Tomato mosaic (races 0, 1, and 2). Intermediate resistance: Root-knot nematode and Gray leaf spot.

BHN 784 - Determinate plant with capability to set fruit in hot conditions. Excellent size, shape and attractive red color. Resistance: Fusarium wilt (race 1).

BHN 785. Midseason. Determinate. Hybrid with a strong set of very uniform size and shape fruit on a vigorous bush with good cover. Resistance: Fusarium wilt (race 1).

BHN 1022. Fall and spring. Determinate. Very firm fruit with heat tolerance and great shelf life. Resistance: Fusarium wilt (race 3) and Tomato spotted wilt.

Cupid. Early season. Indeterminate. Vigorous bush with oval shaped fruit that have an excellent red color and a sweet flavor. Resistance: Alternaria stem canker, Fusarium wilt (race 1), and Gray leaf spot. Intermediate resistance: Bacterial speck (race 0).

Jolly Girl. Early season. Determinate. Extended market life with firm, flavorful grape shaped fruits which resist green shoulders. High brix. Resistance: Verticillium wilt (race 1) and cracking. Intermediate resistance to Fusarium wilt (race 1 and 2).

Santa. 75 days. Indeterminate. Vigorous bush with firm elongated grape-shaped fruit that has outstanding flavor and up to 50 fruits per truss. Resistance: Fusarium wilt (races 1, 2, and 3), Verticillium wilt (race 1), Root-knot nematodes, and Tobacco mosaic.

St. Nick. Mid-early season. Indeterminate. Oblong, grape shaped fruit with brilliant red color and good flavor. High brix with brilliant red color and good flavor. Resistance: unknown.

Smarty. 69 days. Indeterminate. Vigorous bush with short internodes. Plants are 25% shorter than Santa. Good flavor, sweet and excellent flavor. Resistance: Fusarium wilt (races 1 and 2) and Verticillium wilt (race 1).

Sweet Hearts. Early to main season. Indeterminate. Bush with intermediate internodes, high yield potential, and wide adaptability. Brilliant red, firm, elongated grape-shaped fruit with good flavor and shelf life. Crack resistance and high brix. Resistance: Fusarium wilt (race 1), Leaf mold (A-E), Tobacco mosaic (races 0, 1, and 2). Intermediate resistance: Gray leaf spot.

Tami G. Early season. Indeterminate. Medium tall bush with mall fruits with nice shape. Resistance: unknown.

Note: some of these varieties are used by only a few producers. In reality, a much smaller subset of varieties dominates the market.

Fertilizer and Nutrient Management for Tomato

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Fertilizer and nutrient management are essential components of successful commercial tomato production. This article presents the basics of nutrient management for the different production systems used for tomato in Florida.

CALIBRATED SOIL TEST: TAKING THE GUESSWORK OUT OF FERTILIZATION

Prior to each cropping season, soil tests should be conducted to determine fertilizer needs and eventual pH adjustments. Obtain a UF/IFAS soil sample kit from the local agricultural Extension agent or from a reputable commercial laboratory for this purpose. If a commercial soil testing laboratory is used, be sure the laboratory uses methodologies calibrated and extractants suitable for Florida soils. When used with the percent sufficiency philosophy, routine soil testing helps adjust fertilizer applications to plant needs and target yields. In addition, the use of routine calibrated soil tests reduces the risk of over-fertilization. Over fertilization reduces fertilizer efficiency and increases the risk of groundwater pollution. Systematic use of fertilizer without a soil test may also result in crop damage from salt injury.

The crop nutrient requirements of nitrogen, phosphorus, and potassium (designated in fertilizers as N, P_2O_5, and K_2O, respectively) represent the optimum amounts of these nutrients needed for maximum tomato production (Table 1). Fertilizer rates are provided on a per-acre basis for tomato grown on 6-ft centers. Under these conditions, there are 7,260 linear feet of tomato row in a planted acre. When different row spacings are used, it is necessary to adjust fertilizer application accordingly. For example, a 200 lbs/acre N rate on 6-ft centers is the same as 240 lbs/acre N rate on 5-ft centers and a 170 lbs/acre N rate on 7-ft centers. This example is for illustration purposes, and only 5 and 6 ft centers are commonly used for tomato production in Florida.

Fertilizer rates can be simply and accurately adjusted to row spacings other than the standard spacing (6-ft centers) by expressing the recommended rates on a 100 linear bed feet (lbf) basis, rather than on a real-estate acre basis. For example, in a tomato field planted on 7-ft centers with one drive row every six rows, there are only 5,333 lbf/acre (6/7 x 43,560 /7). If the recommendation is to inject 10 lbs/acre of N (standard spacing), this becomes 10 lbs of N/7,260 lbf or 0.14lbs N/100 lbf. Since there are 5,333 lbf/acre in this example, then the adjusted rate for this situation is 7.46 lbs N/acre (0.14 x 53.33). In other words, an injection of 10 lbs of N to 7,260 lbf is accomplished by injecting 7.46 lbs of N to 5,333 lbf.

LIMING

The optimum pH range for tomato is 6.0-6.5. This is the range at which the availability of all the essential nutrients is highest. Fusarium wilt problems are reduced by liming within this range, but it is not advisable to raise the pH above 6.5 because of reduced micronutrient availability. In areas where soil pH is basic (>7.0), micronutrient deficiencies may be corrected by foliar sprays.

Calcium (Ca) and magnesium (Mg) levels should be also corrected according to the soil test. If both elements are "low", and lime is needed, then broadcast and incorporate dolomitic limestone ($CaCO_3$, $MgCO_3$). Where calcium alone is deficient, "hi-cal" ($CaCO_3$) limestone should be used. Adequate Ca is important for reducing the severity of blossom-end rot. Research shows that a Mehlich-I (double-acid) index of 300 to 350 ppm Ca would be indicative of adequate soil-Ca. On limestone soils, add 30-40 lbs/acre of Mg in the basic fertilizer mix. It is best to apply lime several months prior to planting. However, if time is short, it is better to apply lime any time before planting than not to apply it at all. Where the pH does not need modification, but Mg is low (below 15 ppm, Mehlich-3 soil test index), apply magnesium sulfate or potassium-magnesium sulfate.

Changes in soil pH may take several weeks to occur when carbonate-based lim-

TABLE 1. Fertilization recommendations for tomato grown in Florida on sandy soils testing low in Mehlich-3 potassium (K_2O).

		Recommended base fertilization[z]									
				Injected[x] (lbs/acre/day)						
				Weeks after transplanting[w]				Recommended supplemental fertilization[z]		
Production system	Nutrient	Total (lbs/acre)	Preplant[y] (lbs/acre)	1-2	3-4	5-10	11-13	Leaching rain[r,s]	Measured > low = plant nutrient content[u,s]	Extended harvest season[s]
Drip irrigation, raised beds, and polyethylene Mulch	N	200	0-70	1.5	2.0	2.5	2.0	n/a	1.5 to 2 lbs/acre/day for 7days[t]	1.5-2 lbs/acre/day[p]
	K_2O	150-225	0-55	1.0	1.5	2.5	1.5	n/a	1.5-2 lbs/acre/day for 7days[t]	1.5-2 lbs/acre/day[p]
Seepage irrigation, raised beds, and polyethylene Mulch	N	200	200[v]	0	0	0	0	30 lbs/A[q]	30 lbs/acre[t]	30 lbs/acre[p]
	K_2O	150- 225	225[v]	0	0	0	0	20 lbs/A[q]	20 lbs/acre[t]	20 lbs/acre[p]

[z] 1 A = 7,260 linear bed feet per acre (6-ft bed spacing); for soils testing "low" in Mehlich 3 potassium (K_2O).

[y] applied using the modified broadcast method (fertilizer is broadcast where the beds will be formed only, and not over the entire field). Pre-plant fertilizer cannot be applied to double/triple crops because of the plastic mulch; hence, in these cases, all the fertilizer has to be injected.

[x] This fertigation schedule is applicable when no N and K_2O are applied preplant. Reduce schedule proportionally to the amount of N and K_2O applied pre-plant. Fertilizer injections may be done daily or weekly. Inject fertilizer at the end of the irrigation event and allow enough time for proper flushing afterwards.

[w] For a standard 13 week-long, transplanted tomato crop grown in the Spring.

[v] Some of the fertilizer may be applied with a fertilizer wheel though the plastic mulch during the tomato crop when only part of the recommended base rate is applied pre-plant. Rate may be reduced when a controlled-release fertilizer source is used.

[u] Plant nutritional status may be determined with tissue analysis or fresh petiole-sap testing, or any other calibrated method. The "low" diagnosis needs to be based on UF/IFAS interpretative thresholds.

[t] Plant nutritional status must be diagnosed every week to repeat supplemental application.

[s] Supplemental fertilizer applications are allowed when irrigation is scheduled following a recommended method. Supplemental fertilization is to be applied in addition to base fertilization when appropriate. Supplemental fertilization is not to be applied >in advance= with the pre-plant fertilizer.

[r] A leaching rain is defined as a rainfall amount of 3 inches in 3 days or 4 inches in 7 days.

[q] Supplemental amount for each leaching rain

[p] Plant nutritional status must be diagnosed after each harvest before repeating supplemental fertilizer application.

ing materials are used (calcitic or dolomitic limestone). Oxide-based liming materials (quick lime -CaO- or dolomitic quick lime -CaO, MgO-) are fast reacting and rapidly increase soil pH. Yet, despite these advantages, oxide-based liming materials are more expensive than the traditional liming materials, and therefore are not routinely used. The increase in pH induced by liming materials is not due to the presence of Ca or Mg. Instead, it is the carbonate (CO_3) and oxide (O) part of $CaCO_3$ and CaO, respectively, that raises the pH. Through several chemical reactions that occur in the soil, carbonates and oxides release OH- ions that combine with H^+ to produce water. As large amounts of H^+ react, the pH rises. A large fraction of the Ca and/or Mg in the liming materials gets into solution and binds to the sites that are freed by H^+ that have reacted with OH^-.

FERTILIZER-RELATED PHYSIOLOGICAL DISORDERS

Blossom-End Rot. Growers may have problems with blossom-end-rot, especially on the first or second fruit clusters. Blossom-end rot (BER) is a Ca deficiency in the fruit, but is often more related to plant water stress than to Ca concentrations in the soil. This is because Ca movement into the plant occurs with the water stream (transpiration). Thus, Ca moves preferentially to the leaves. As a maturing fruit is not a transpiring organ, most of the Ca is deposited during early fruit growth.

Once BER symptoms develop on a tomato fruit, they cannot be alleviated on this fruit. Because of the physiological role of Ca in the middle lamella of cell walls, BER is a structural and irreversible disorder. Yet, the Ca nutrition of the plant can be altered so that the new fruits are not affected. BER is most effectively controlled by attention to irrigation and fertilization, or by using a calcium source such as calcium nitrate when soil Ca is low. Maintaining adequate and uniform amounts of moisture in the soil are also keys to reducing BER potential.

Factors that impair the ability of tomato plants to obtain water will increase the risk of BER. These factors include damaged roots from flooding, mechanical damage or nematodes, clogged drip emitters, inadequate water applications, alternating dry-wet periods, and even prolonged overcast periods. Other causes for BER include high fertilizer rates, especially potassium and nitrogen. Calcium levels in the soil should be adequate when the Mehlich-3 index is 300 to 350 ppm, or above. In these cases, added gypsum (calcium sulfate) is unlikely to reduce BER. Foliar sprays of Ca are unlikely to reduce BER because Ca does not move out of the leaves to the fruit.

Gray Wall. Blotchy ripening (also called gray wall) of tomatoes is characterized by white or yellow blotches that appear on the surface of ripening tomato fruits, while the tissue inside remains hard. The affected area is usually on the upper portion of the fruit. The etiology of this disorder has not been fully established, but it is often associated with high N and/or low K, and aggravated by excessive amount of N. This disorder may be at times confused with symptoms produced by the tobacco mosaic virus. Gray wall is cultivar specific and appears more frequently on older cultivars. The incidence of gray wall is less with drip irrigation where small amounts of nutrients are injected frequently, than with systems where all the fertilizer is applied pre-plant.

Micronutrients. For acidic sandy soils cultivated for the first time ("new ground"), or sandy soils where a proven need exists, a general guide for fertilization is the addition of micronutrients (in elemental lbs/acre) manganese -3, copper -2, iron -5, zinc -2, boron -2, and molybdenum -0.02. Micronutrients may be supplied from oxides or sulfates. Growers using micronutrient-containing fungicides need to consider these sources when calculating fertilizer micronutrient needs.

Properly diagnosed micronutrient deficiencies can often be corrected by foliar applications of the specific micronutrient. For most micronutrients, a very fine line exists between sufficiency and toxicity. Foliar application of major nutrients (N, P, or K) has not been shown to be beneficial where proper soil fertility is present.

FERTILIZER APPLICATION

Mulch Production with Seepage Irrigation. Under this system, the crop may be supplied with all of its soil requirements before the mulch is applied (Table 1). It is difficult to correct a deficiency after mulch application, although a liquid fertilizer injection wheel can facilitate sidedressing through the mulch. The injection wheel will also be useful for replacing fertilizer under the used plastic mulch for double-cropping systems. A general sequence of operations for the full-bed plastic mulch system is:

1. Land preparation, including development of irrigation and drainage systems, and liming of the soil, if needed.
2. Application of "cold" mix comprised of 10% to 20% of the total N and potassium seasonal requirements and all of the needed P and micronutrients. The cold mix can be broadcast over the entire area prior to bedding and then incorporated. During bedding, the fertilizer will be gathered into the bed area. An alternative is to use the "modified broadcast" technique for systems with wide bed spacings. Use of modified broadcast or banding techniques can increase P and micronutrient efficiencies, especially on alkaline (basic) soils.
3. Formation of beds, incorporation of herbicide, and application of mole cricket bait.
4. The remaining 80% to 90% of the N and K is placed in one or two narrow bands 9 to 10 inches to each side of the plant row in furrows. This "hot mix" fertilizer should be placed deep enough in the grooves for it to be in contact with moist bed soil. Bed presses are modified to provide the groove. Only water-soluble nutrient sources should be used for the banded fertilizer. A mixture of potassium nitrate (or potassium sulfate or potassium chloride), calcium nitrate, and ammonium nitrate has proven successful. Research has shown that it is best to broadcast incorporate controlled-release fertilizers (CRF) in the bed with bottom mix than in the hot bands.
5. Fumigation, pressing of beds, and mulching. This should be done in one operation, if possible. Be sure that the mulching machine seals the edges of the mulch adequately with soil to prevent fumigant escape.

Water management with the seep irrigation system is critical to successful crops. Use water-table monitoring devices and tensiometers or TDRs in the root zone to help provide an adequate water table but no higher than required for optimum moisture. It is recommended to limit fluctuations in water table depth since this can lead to increased leaching losses of plant nutrients. An in-depth description of soil moisture devices may be found in Munoz-Carpena (2004).

Mulched Production with Drip Irrigation. Where drip irrigation is used, drip tape or tubes should be laid 1 to 2 inches below the bed soil surface prior to mulching. This placement helps protect tubes from mice and cricket damage. The drip system is an excellent tool with which to fertilize tomato. Where drip irrigation is used, apply all phosphorus and micronutrients, and 20 % to 40 % of total N and K pre-plant in the bed. Apply the remaining N and K through the drip system in increments as the crop develops.

Successful crops have resulted where the total amounts of N and K were applied through the drip system. Some growers find this method helpful where they have had problems with soluble-salt burn. This approach would be most likely to work on soils with relatively high organic matter and some residual potassium. However, it is important to begin with rather high rates of N and K to ensure young transplants are established quickly. In most situations, some pre-plant N and K fertilizers are needed.

Suggested schedules for nutrient injections have been successful in both research and commercial situations, but might need slight modifications based on potassium soil-test indices and grower experience (Table 1).

SOURCES OF N-P_2O_5-K_2O.

About 30% to 50% of the total applied N should be in the nitrate form for soil treated with multi-purpose fumigants and for plantings in cool soil. Controlled-release N sources may be used to supply a portion of the N requirement. One-third of the total required nitrogen can be supplied from sulfur-coated urea (SCU), isobutylidene diurea (IBDU), or polymer-coated urea (PCU) fertilizers incorporated in the bed. Nitrogen from natural organics and most controlled-release materials is initially in the ammoniacal form, but is rapidly converted into nitrate by soil microorganisms.

Normal superphosphate and triple superphosphate are recommended for phosphorus needs. Both contribute calcium and normal superphosphate contributes sulfur.

All sources of potassium can be used for tomato. Potassium sulfate, sodium-potassium nitrate, potassium nitrate, potassium chloride, monopotassium phosphate, and potassium-magnesium sulfate are all good K sources. If the soil test predicted amounts of K_2O are applied, then there should be no concern for the K source or its associated salt index.

SAP TESTING AND TISSUE ANALYSIS

While routine soil testing is essential in designing a fertilizer program, sap tests and/or tissue analyses reveal the actual nutritional status of the plant. Therefore these tools complement each other, rather than replace one another.

When drip irrigation is used, analysis of tomato leaves for mineral nutrient content (Table 2) or quick sap test (Table 3) can help guide a fertilizer management program during the growing season or assist in diagnosis of a suspected nutrient deficiency.

For both nutrient monitoring tools, the quality and reliability of the measurements are directly related with the quality of the sample. A leaf sample should contain at least 20 most recently, fully developed, healthy leaves. Select representative plants, from representative areas in the field.

SUPPLEMENTAL FERTILIZER APPLICATIONS

In practice, supplemental fertilizer applications allow vegetable growers to numerically apply fertilizer rates higher than the standard UF/IFAS recommended rates when growing conditions require doing so. Applying additional fertilizer under the three circumstances described in Table 1 (leaching rain, 'low' foliar content, and extended harvest season) is part of the current UF/IFAS fertilizer recommendations and nutrient BMPs.

LEVELS OF NUTRIENT MANAGEMENT FOR TOMATO PRODUCTION

Based on the growing situation and the level of adoption of the tools and techniques described above, different levels of nutrient management exist for tomato production in Florida. Successful production and nutrient BMPs requires management levels of 3 or above (Table 4).

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Table 2. Deficient, adequate, and excessive nutrient content-rations for tomato [most-recently-matured (MRM) leaf (blade plus petiole)].

				N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu	Mo
				(%)						(ppm)					
Tomato	MRM[z] leaf	5-leaf stage	Deficient	<3.0	0.3	3.0	1.0	0.3	0.3	40	30	25	20	5	0.2
			Adequate range	3.0 5.0	0.3 0.6	3.0 5.0	1.0 2.0	0.3 0.5	0.3 0.8	40 100	30 100	25 40	20 40	5 15	0.2 0.6
			High	>5.0	0.6	5.0	2.0	0.5	0.8	100	100	40	40	15	0.6
	MRM leaf	First flower	Deficient	<2.8	0.2	2.5	1.0	0.3	0.3	40	30	25	20	5	0.2
			Adequate range	2.8 4.0	0.2 0.4	2.5 4.0	1.0 2.0	0.3 0.5	0.3 0.8	40 100	30 100	25 40	20 40	5 15	0.2 0.6
			High	>4.0	0.4	4.0	2.0	0.5	0.8	100	100	40	40	15	0.6
			Toxic (>)								1500	300	250		
	MRM leaf	Early fruit set	Deficient	<2.5	0.2	2.5	1.0	0.25	0.3	40	30	20	20	5	0.2
			Adequate range	2.5 4.0	0.2 0.4	2.5 4.0	1.0 2.0	0.25 0.5	0.3 0.6	40 100	30 100	20 40	20 40	5 10	0.2 0.6
			High	>4.0	0.4	4.0	2.0	0.5	0.6	100	100	40	40	10	0.6
			Toxic (>)										250		
Tomato	MRM leaf	First ripe fruit	Deficient	<2.0	0.2	2.0	1.0	0.25	0.3	40	30	20	20	5	0.2
			Adequate range	2.0 3.5	0.2 0.4	2.0 4.0	1.0 2.0	0.25 0.5	0.3 0.6	40 100	30 100	20 40	20 40	5 10	0.2 0.6
			High	>3.5	0.4	4.0	2.0	0.5	0.6	100	100	40	40	10	0.6
	MRM leaf	During harvest period	Deficient	<2.0	0.2	1.5	1.0	0.25	0.3	40	30	20	20	5	0.2
			Adequate range	2.0 3.0	0.2 0.4	1.5 2.5	1.0 2.0	0.25 0.5	0.3 0.6	40 100	30 100	20 40	20 40	5 10	0.2 0.6
			High	>3.0	0.4	2.5	2.0	0.5	0.6	100	100	40	40	10	0.6

[z]MRM=Most recently matured leaf.

Table 3. Recommended nitrate-N and K concentrations in fresh petiole sap for round tomato.

	Sap concentration (ppm)	
Stage of growth	NO_3-N	K
First buds	1,000-1,200	3,500-4,000
First open flowers	600-800	3,500-4,000
Fruits one-inch diameter	400-600	3,000-3,500
Fruits two-inch diameter	400-600	3,000-3,500
First harvest	300-400	2,500-3,000
Second harvest	200-400	2,000-2,500

Table 4. Progressive levels of nutrient management for tomato production.[z]

Nutrient Management		
Level	Rating	Description
0	None	Guessing
1	Very low	Soil testing and still guessing
2	Low	Soil testing and implementing > a = recommendation
3	Intermediate	Soil testing, understanding IFAS recommendations, and correctly implementing them
4	Advanced	Soil testing, understanding IFAS recommendations, correctly implementing them, and monitoring crop nutritional status
5	Recommended	Soil testing, understanding IFAS recommendations, correctly implementing them, monitoring crop nutritional status, and practice year-round nutrient management and/or following BMPs (including one of the recommended irrigation scheduling methods).

[z] These levels should be used together with the highest possible level of irrigation management

Water Management For Tomato

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Water and nutrient management are two important aspects of tomato production in all production systems. Water is used for wetting the fields before land preparation, transplant establishment, and irrigation. The objective of this article is to provide an overview of recommendations for tomato irrigation management in Florida. Irrigation management recommendations should be considered together with those for fertilizer and nutrient management.

Irrigation is used to replace the amount of water lost by transpiration and evaporation. This amount is also called crop evapotranspiration (ETc). Irrigation scheduling is used to apply the proper amount of water to a tomato crop at the proper time. The characteristics of the irrigation system, tomato crop needs, soil properties, and atmospheric conditions must all be considered to properly schedule irrigations. Poor timing or insufficient water application can result in crop stress and reduced yields from inappropriate amounts of available water and/or nutrients. Excessive water applications may reduce yield and quality, are a waste of water, and increase the risk of nutrient leaching.

A wide range of irrigation scheduling methods is used in Florida, which correspond to different levels of water management (Table 1). The recommend method to schedule irrigation for tomato is to use together an estimate of the tomato crop water requirement that is based on plant growth, a measurement of soil water status and a guideline for splitting irrigation (water management level 5 in Table 1; Table 2). The estimated water use is a guideline for irrigating tomatoes. The measurement of soil water tension is useful for fine tuning irrigation. Splitting irrigation events is necessary when the amount of water to be applied is larger than the water holding capacity of the root zone.

TOMATO WATER REQUIREMENT

Tomato water requirement (ETc) depends on stage of growth, and evaporative demand. ETc can be estimated by adjusting reference evapotranspiration (ETo) with a correction factor call crop factor (Kc; equation [1]). Because different methods exist for estimating ETo, it is very important to use Kc coefficients which were derived using the same ETo estimation method as will be used to determine ETc. Also, Kc values for the appropriate stage of growth and production system (Table 3) must be used.

By definition, ETo represents the water use from a uniform green cover surface, actively growing, and well watered (such as a turf or grass covered area). ETo can be measured on-farm using a small weather station. When daily ETo data are not available, historical daily averages of Penman-method ETo can be used (Table 4). However, these long-term averages are provided as guidelines since actual values may fluctuate by as much as 25%, either above the average on hotter and drier than normal days, or below the average on cooler or more overcast days than normal. As a result, SWT or soil moisture should be monitored in the field.

Eq. [1] Crop water requirement = Crop coefficient x Reference evapotranspiration
ETc = Kc x ETo

Tomato crop water requirement may also be estimated from Class A pan evaporation using:

Eq. [2] Crop water requirement = Crop factor x Class A pan evaporation
ETc = CF x Ep

Typical CF values for fully-grown tomato should not exceed 0.75 (Locascio and Smajstrla, 1996). A third method for estimated tomato crop water requirement is to use modified Bellani plates also known as atmometers. A common model of atmometer used in Florida is the $ET_{gage.}$ This device consists of a canvas-covered ceramic evapo-

TABLE 1. Levels of water management and corresponding irrigation scheduling methods for tomato.

Water Management Level	Rating	Irrigation scheduling method
0	None	Guessing (no specific rule is followed to irrigate)
1	Very low	Using the "feel and see" method
2	Low	Using systematic irrigation (example: 2 hrs every day from transplanting to harvest)
3	Intermediate	Using a soil moisture measuring tool to start irrigation
4	Advanced	Using a soil moisture measuring tool to schedule irrigation and apply amounts based on a budgeting procedure
5	Recommended	Using together a water use estimate based on tomato plant stage of growth, a measurement of soil moisture, determining rainfall contribution to soil moisture, having a guideline for splitting irrigation and keeping irrigation records.

TABLE 2. Summary of irrigation management guidelines for tomato.

Irrigation management component	Irrigation system[z] Seepage[y]	Drip[x]
1- Target water application rate	Keep water table between 18 and 24 inch depth	Historical weather data or crop evapotranspiration (ETc) calculated from reference ET or Class A pan evaporation
2- Fine tune application with soil moisture measurement	Monitor water table depth with observation wells	Maintain soil water tension in the root zone between 8 and 15 cbar
3- Determine the contribution of rainfall	Typically, 1 inch rainfall raises the water table by 1 foot	Poor lateral water movement on sandy and rocky soils limits the contribution of rainfall to crop water needs to (1) foliar absorption and cooling of foliage and (2) water funneled by the canopy through the plan hole.
4- Rule for splitting irrigation	Not applicable	Irrigations greater than 12 and 50 gal/100ft (or 30 min and 2 hrs for medium flow rate) when plants are small and fully grown, respectively are likely to push the water front being below the root zone
5-Record keeping	Irrigation amount applied and total rainfall received[w] Days of system operation	Irrigation amount applied and total rainfall received[w] Daily irrigation schedule

[z] Efficient irrigation scheduling also requires a properly designed and maintained irrigation systems
[y] Practical only when a spodic layer is present in the field
[x] On deep sandy soils
[w] Required by the BMPs

ration plate mounted on a water reservoir. The green fabric creates a diffusion barrier that controls evaporation at a rate similar to that of well water plants. Water loss through evaporation can be read on a clear sight tube mounted on the side of the device. Evaporation from the ET_{gage} (ETg) was well correlated to ETo except on rainy days, but overall, the ET_{gage} tended to underestimate ETo (Irmak et al., 2005). On days with rainfall less than 0.2 inch/day, ETo can be estimated from ETg as: ETo = 1.19 ETg. When rainfall exceeds 0.2 inch/day, rain water wets the canvas which interferes with the flow of water out of the atmometers, and decreases the reliability of the measurement.

TOMATO IRRIGATION REQUIREMENT

Irrigation systems are generally rated with respect to application efficiency (Ea), which is the fraction of the water that has been applied by the irrigation system and that is available to the plant for use. In general, Ea is 20% to 70% for seepage irrigation and 90% to 95% for drip irrigation. Applied water that is not available to the plant may have been lost from the crop root zone through evaporation, leaks in the pipe system, surface runoff, subsurface runoff, or deep percolation within the irrigated area. When dual drip/seepage irrigation systems are used, the contribution of the seepage system needs to be subtracted from the tomato irrigation requirement to calculate the drip irrigation need. Otherwise, excessive water volume will be systematically applied. Tomato irrigation requirement are determined by dividing the desired amount of water to provide to the plant (ETc), by Ea as a decimal fraction (Eq. [3]).

Eq. [3] Irrigation requirement = Crop water requirement / Application efficiency
IR = ETc/Ea

IRRIGATION SCHEDULING FOR TOMATO

For seepage-irrigated crops, irrigation scheduling recommendations consist of maintaining the water table near the 18-inch depth shortly after transplanting and near the 24- inch depth thereafter (Stanley and Clark, 2003). The actual depth of the water table may be monitored with shallow observation wells (Smajstrla, 1997).

Irrigation scheduling for drip irrigated tomato typically consists in daily applications of ETc, estimated from Eq. [1] or [2] above. In areas where real-time weather information is not available, growers use the "1,000 gal/acre/day/string" rule for drip-irrigated tomato production. As the tomato plants grow from 1 to 4 strings, the daily irrigation volumes increase from 1,000 gal/acre/day to 4,000 gal/acre/day. On 6-ft centers, this corresponds to 15 gal/100lbf/day and 60 gal/100lbf/day for 1 and 4 strings, respectively.

SOILS MOISTURE MEASUREMENT

Soil water tension (SWT) represents the magnitude of the suction (negative pressure) the plant roots have to create to free soil water from the attraction of the soil particles, and move it into its root cells. The dryer the soil, the higher the suction needed, hence, the higher SWT. SWT is commonly expressed in centibars (cb) or kiloPascals (kPa; 1cb = 1kPa). For tomatoes grown on the sandy soils of Florida, SWT in the rooting zone should be maintained between 6 (field capacity) and 15 cb.

The two most common tools available to measure SWT in the field are tensiometers and time domain reflectometry (TDR) probes, although other types of probes are now available (Muñoz-Carpena, 2004). Tensiometers have been used for several years in tomato production. A porous cup is saturated with water, and placed under vacuum. As the soil water content changes, water comes in or out of the porous cup, and affects the amount of vacuum inside the tensiometer. Tensiometer readings have been successfully used to monitor SWT and schedule irrigation for tomatoes. However, because they are fragile and easily broken by field equipment, many growers have renounced to use them. In addition, readings are not reliable when the tensiometer dries, or when the contact between the cup and the soil is lost. Depending on the length of the access tube, tensiometers cost between $40 and $80 each. Tensiometers can be reused as long as they are maintained properly and remain undamaged.

It is necessary to monitor SWT at two soil depths when tensiometers are used. A shallow 6-inch depth is useful at the beginning of the season when tomato roots are near that depth. A deeper 12-inch depth is used to monitor SWT during the rest of the season. Comparing SWT at both depths is useful to understand the dynamics of soil moisture. When both SWT are within the 4-8 cb range (close to field capacity), this means that moisture is plentiful in the rooting zone. This may happen after a large rain, or when tomato water use is less than the irrigation applied. When the 6-inch-depth SWT increases (from 4-8 cb to 10-15cb) while SWT at 12-inch-depth remains within 4-8 cb, the upper part of the soil is drying, and it is time to irrigate. If the 6-inch-depth SWT continues to rise above 25cb, a water stress will result; plants will wilt, and yields will be reduced. This should not happen under adequate water management.

A SWT at the 6-inch depth remaining with the 4-8 cb range, but the 12-inch-depth reading showing a SWT of 20-25cb suggest that deficit irrigation has been made: irrigation has been applied to re-wet the

TABLE 3. Crop coefficient estimates (Kc) for tomato [z].

Tomato Growth Stage	Corresponding weeks after transplanting [y]	Kc for drip-irrigated crops
1	1-2	0.30
2	3-4	0.40
3	5-11	0.90
4	12	0.90
5	13	0.75

[z] Actual values will vary with time of planting, length of growing season and other site-specific factors. Kc values should be used with ETo values in Table 2 to estimated crop evapotranspiration (ETc)
[y] For a typical 13-week-long growing season.

TABLE 4. Historical Penman-method reference ET (ETo) for four Florida locations (gallons/acre/day).

Month	Tallahassee	Tampa	West Palm Beach	Miami
January	1,630	2,440	2,720	2,720
February	2,440	3,260	3,530	3,530
March	3,260	3,800	4,340	4,340
April	4,340	5,160	5,160	5,160
May	4,890	5,430	5,160	5,160
June	4,890	5,430	4,890	4,890
July	4,620	4,890	4,890	4,890
August	4,340	4,620	4,890	4,620
September	3,800	4,340	4,340	4,070
October	2,990	3,800	3,800	3,800
November	2,170	2,990	3,260	2,990
December	1,630	2,170	2,720	2,720

[z] Assuming water application over the entire area with 100% efficiency

TABLE 5. Estimated maximum water application (in gallons per acre and in gallons/100 lft) in one irrigation event for tomato grown on 6-ft centers (7,260 linear bed feet per acre) on sandy soil (available water holding capacity 0.75 in/ft and 50% soil water depletion). Split irrigations may be required during peak water requirement.

Wetting width (ft)	Gal/100 ft to wet depth (ft)			Gal/acre to wet depth (ft)		
	1	1.5	2	1	1.5	2
1.0	24	36	48	1,700	2,600	3,500
1.5	36	54	72	2,600	3,900	5,200

upper part of the profile only. The amount of water applied was not enough to wet the entire profile. If SWT at the 12-inch depth continues to increase, then water stress will become more severe and it will become increasingly difficult to re-wet the soil profile. The sandy soils of Florida have a low water holding capacity. Therefore, SWT should be monitored daily and irrigation applied at least once daily. Scheduling irrigation with SWT only can be difficult at times. Therefore, SWT data should be used together with an estimate of tomato water requirement.

Times domain reflectometry (TDR) is another method for measuring soil moisture. The availability of inexpensive equipment ($400 to $550/unit) has recently increased the potential of this method to become practical for tomato growers. A TDR unit is comprised of three parts: a display unit, a sensor, and two rods. Rods may be 4 inches or 8 inches in length based on the depth of the soil. Long rods may be used in all the sandy soils of Florida, while the short rods may be used with the shallow soils of Miami-Dade county.

The advantage of TDR is that probes need not being buried permanently, and readings are available instantaneously. This means that, unlike tensiometers, TDR can be used as a hand-held, portable tool.

TDR actually determines percent soil moisture (volume of water per volume of soil). In theory, a soil water release curve has to be used to convert soil moisture in to SWT. However, because TDR provides an average soil moisture reading over the entire length of the rod (as opposed to the specific depth used for tensiometers), it is not practical to simply convert SWT into soil moisture to compare readings from both methods. Tests with TDR probes have shown that best soil monitoring may be achieved by placing the probe vertically, approximately 6 inches away from the drip tape on the opposite side of the tomato plants. For fine sandy soils, 9% to 15% appears to be the adequate moisture range. Tomato plants are exposed to water stress when soil moisture is below 8%. Excessive irrigation may result in soil moisture above 16%.

GUIDELINES FOR SPLITTING IRRIGATION

For sandy soils, a one square foot vertical section of a 100-ft long raised bed can hold approximately 24 to 30 gallons of water (Table 5). When drip irrigation is used, lateral water movement seldom exceeds 6 to 8 inches on each side of the drip tape (12 to 16 inches wetted width). When the irrigation volume exceeds the values in Table 5, irrigation should be split into 2 or 3 applications. Splitting will not only reduce nutrient leaching, but it will also increase tomato quality by ensuring a more continuous water supply. Uneven water supply may result in fruit cracking.

UNITS FOR MEASURING IRRIGATION WATER

When overhead and seepage irrigation were the dominant methods of irrigation, acre-inches or vertical amounts of water were used as units for irrigations recommendations. There are 27,150 gallons in 1 acre-inch; thus, total volume was calculated by multiplying the recommendation expressed in acre-inch by 27,150. This unit reflected quite well the fact that the entire field surface was wetted.

Acre-inches are still used for drip irrigation, although the entire field is not wetted. This section is intended to clarify the conventions used in measuring water amounts for drip irrigation. In short, water amounts are handled similarly to fertilizer amounts, i.e., on an acre basis. When an irrigation amount expressed in acre-inch is recommended for plasticulture, it means that the recommended volume of water needs to be delivered to the row length present in a one-acre field planted at the standard bed spacing. So in this case, it is necessary to know the bed spacing to determine the exact amount of water to apply. In addition, drip tape flow rates are reported in gallons/hour/emitter or in gallons/hour/100 ft of row. Consequently, tomato growers tend to think in terms of multiples of 100 linear feet of bed, and ultimately convert irrigation amounts into duration of irrigation. It is important to correctly understand the units of the irrigation recommendation in order to implement it correctly.

EXAMPLE

How long does an irrigation event need to last if a tomato grower needs to apply 0.20 acre-inch to a 2-acre tomato field? Rows are on 6-ft centers and a 12-ft spray alley is left unplanted every six rows; the drip tape flow rate is 0.30 gallons/hour/emitter and emitters are spaced 1 foot apart.

1. In the 2-acre field, there are 14,520 feet of bed (2 x 43,560/6). Because of the alleys, only 6/8 of the field is actually planted. So, the field actually contains 10,890 feet of bed (14,520x 6/8).
2. A 0.20 acre-inch irrigation corresponds to 5,430 gallons applied to 7,260 feet of row, which is equivalent to 75gallons/100feet (5,430/72.6).
3. The drip tape flow rate is 0.30 gallons/hr/emitter which is equivalent to 30 gallons/hr/100feet. It will take 1 hour to apply 30 gallons/100ft, 2 hours to apply 60gallons/100ft, and 2½ hours to apply 75 gallons. The total volume applied will be 8,168 gallons/2-acre (75 x 108.9).

IRRIGATION AND BEST MANAGEMENT PRACTICES

As an effort to clean impaired water bodies, federal legislation in the 70’s, followed by state legislation in the 90’s and state rules since 2000 have progressively shaped the Best Management Practices (BMP) program for vegetable production in Florida. Section 303(d) of the Federal Clean Water Act of 1972 required states to identify impaired water bodies and establish Total Maximum Daily Loads (TMDL) for pollutants entering these water bodies. In 1987, the Florida legislature passed the Surface Water Improvement and Management Act requiring the five Florida water management districts to develop plans to clean up and preserve Florida lakes, bays, estuaries, and rivers. In 1999, the Florida Watershed Restoration Act defined a process for the development of TMDLs. The “*Water Quality/quantity Best Management Practices for Florida Vegetable and Agronomic Crops”* manual was adopted by reference and by rule 5M-8 in the Florida Administrative Code on Feb. 8, 2006 (FDACS, 2005). The manual (available at www.floridaagwaterpolicy.com) provides background on the state-wide BMP program for vegetables, lists all the possible BMPs, provides a selection mechanism for building a customized BMP plan, outlines record-keeping requirements, and explains how to participate in the BMP program. By definition, BMPs are specific cultural practices that aim at reducing nutrient load while maintaining or increasing productivity. Hence, BMPs are tools to achieve the TMDL. Vegetable growers who elect to participate in the BMP program receive three statutory benefits: (1) a waiver of liability from reimbursement of cost and damages associated with the evaluation, assessment, or remediation of contamination of ground water (Florida Statutes 376.307); (2) a presumption of compliance with water quality standards (F.S. 403.067 (7)(d)), and (3); an eligibility for cost-share programs (F.S. 570.085 (1)).

BMPs cover all aspects of tomato production: pesticide management, conservation practices and buffers, erosion control and sediment management, nutrient and irrigation management, water resources management, and seasonal or temporary farming operations. The main water quality parameters of importance to tomato and pepper production and targeted by the BMPs are nitrate, phosphate and total dissolved solids concentration in surface or ground water. All BMPs have some effect on water quality, but nutrient and irrigation management BMPs have a direct effect on it.

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Weed Control in Tomato

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Labels change frequently. Be sure to read a current product label before applying any chemical.

Active ingredient lb. a.i./A	Trade name product/A	MOA Code	Weeds controlled / remarks
			*** **PREPLANT / PREEMERGENCE** ***
Carfentrazone **up to 0.031**	(Aim) 1.9 EW or (Aim) 2.0 EC up to 2 fl. oz.	14	Apply as a pre-plant burndown for emerged broadleaves upto 4 inches tall or rosettes less than 3 inches across. Good coverage is essential. A nonionic surfactant, methylated seed oil, or crop oil concentrate is recommended. No pre-transplant interval.
EPTC **2.6**	(Eptam) 7 E 3 pt.	8	Annual broadleaves, annual grasses and suppression of yellow/purple nutsedge. Labeled for transplanted tomatoes grown on low density mulch. Do not use under high density, VIF, TIF, or metalized mulches. A 24(c) special local needs label in Florida. 14 day pre-transplant interval.
Flumioxazin	(Chateau) 51 WDG up to 4 oz.	14	Annual broadleaves and grasses. Apply to row middles of raised plastic mulched beds that are at least 4 in. higher than the treated row middle and 24 in. bed width. Label is a Third-Party registration (TPR, Inc.). Use without a signed authorization and waiver of liability is a misuse of the product. Tank mix with a burndown herbicide to control emerged weeds. 0 day pre-transplant interval.
Fomesafen **0.25 - 0.38**	(Reflex) 2 EC 1.0 - 1.5 pt.	14	Broadleaves and suppression of yellow/purple nutsedge. Suppression of some annual and perennial grasses. Label is a 24(C) local indemnified label and a waiver of liability must be signed for use. Transplanted crop only. May be applied to bareground production or to plastic mulched beds following bed formation but prior to laying plastic. Use shields or hooded sprayers if applying to row middles and prevent contact with the plastic mulch. 7 and 0 day pre-transplant interval on bare ground and plastic mulch, respectively. 70 day PHI.
Glyphosate	(various formulations) consult labels	9	Emerged broadleaves, grasses, and nutsedge. Apply as a preplant burndown. Consult label for individual product directions.
Halosulfuron **0.024 - 0.05**	(Sandea, Profine) 75 DF 0.5 - 1.0 oz.	2	Broadleaf weeds and yellow/purple nutsedge. Do not exceed 2 applications of halosulfuron per 12 month period. 7 day pre-transplant interval. 30 day PHI.
Imazosulfuron **0.19-0.3**	(League) 4.0-6.4 oz	2	Broadleaves and suppression of yellow/purple nutsedge. Apply pre-transplant just prior to installation of plastic mulch. 1 day pre-transplant interval. 21 day PHI.
Lactofen **0.25 - 0.5**	(Cobra) 2 EC 16 - 32 fl. oz.	14	Broadleaves. Label is a Third-Party registration (TPR, Inc.). Use without a signed authorization and waiver of liability is a misuse of the product. Apply to row middles only with shielded or hooded sprayers. Contact with green foliage or fruit may cause excessive injury. Drift of Cobra treated soil particles onto plant can cause contact injury. Limit of 1 PRE and 1 POST application per growing season. 30 day PHI.
***S*-metolachlor** **1.0 - 1.3**	(Brawl, Dual Magnum, Medal) 7.62 EC 1.0 - 1.33 pt. if organic matter less then 3%	15	Annual broadleaves and grasses. Suppression of yellow/purple nutsedge. Apply to bed tops pre-transplant just prior to laying the plastic. May also be used in row middles. Research has shown that the 1.33 pt. may be too high in some Florida soils except in row middles. 30 day PHI. 90 day PHI if rate exceeds 1.33 pt./A.
Metribuzin **0.25 - 0.5**	(Sencor DF, TriCor DF) 75 WDG 0.33 - 0.67 lb. (Sencor 4, Metri) 4 F 0.5 - 1.0 pt.	5	Small emerged weeds less than 1 in. tall. Apply preplant in transplanted tomatoes only. Incorporate to a depth of 2-4 inches. Maximum of 1.0 lb. a.i./A within a season. Avoid application for 3 days following cool, wet, or cloudy weather to reduce possible crop injury. 7 day PHI.

Labels change frequently. Be sure to read a current product label before applying any chemical.			
Active ingredient lb. a.i./A	**Trade name product/A**	**MOA Code**	**Weeds controlled / remarks**
Napropamide 1.0 - 2.0	(Devrinol DF XT) 50 DF 2.0 - 4.0 lb.	15	Annual broadleaves and grasses. For direct-seed or transplanted tomatoes. Apply to well worked soil that is moist enough to permit thorough incorporation to a depth of 2 in. Incorporate same day as applied.
Oxyfluorfen 0.25 - 0.5	(Goal 2 XL) 2 EC 1.0 - 2.0 pt. (GoalTender) 4 E	14	Broadleaves. Apply pre-transplant just prior to installation of plastic mulch. 30 day pre-transplant interval. Mulch may be applied any time during the 30-day interval.
Paraquat 0.5 - 1.0	(Gramoxone) 2 SL 2.0 - 4.0 pt. (Firestorm) 3 SL 1.3 - 2.7 pt.	22	Emerged broadleaves and grasses. Apply as a preplant burndown treatment. Surfactant recommended.
Pelargonic acid	(Scythe) 4.2 EC 3 - 10% v/v		Emerged broadleaves and grasses. Apply as a preplant burndown treatment or post transplant with shielded or hooded sprayers. Product is a contact, nonselective, foliar applied herbicide with no residual control.
Pendimethalin 0.48 - 0.72	(Prowl H_20) 3.8 1.0 - 1.5 pt.	3	May be applied pretransplant to bed tops just prior to laying the plastic mulch or to row middles. Do not exceed 3.0 pt./A per year. 70 day PHI.
Pyraflufen 0.001 - 0.003	(ETX Herbicide) 0.208 EC 0.3 - 1.25 fl. oz.	14	Emerged broadleaves less than 4 in. tall or rosttes less than 3 in. diameter. Apply as a preplant burndown treatment. Nonionic surfactant or crop oil concentrate recommended.
Rimsulfuron 0.03 - 0.06	(Matrix FNV, Matrix SG, Pruvin) 25 WDG 2.0 - 4.0 oz.	2	Annual broadleaves and grasses. Suppression of yellow nutsedge. Requires 0.5-1 in. of rainfall or irrigation within 5 days of application for activation. May be applied as a sequential treatment with a PRE and POST application not exceeding 0.06 lb. a.i./A in a single season. 45 day PHI
Tifluralin 0.5	(Treflan, Trifluralin) 4 EC 1 pt. (Treflan, Trifluralin) 10 G 5 lb.	3	Annual broadleaves and grasses. Do not apply in Dade County. Incorporate 4 in. or less within 8 hr. of application. Results in Florida are erratic on soils with low organic matter and clay contents. Note label precautions against planting noncrop within 5 months. Do not apply after transplanting.
			***** POSTTRANSPLANT *****
Carfentrazone **up to 0.031**	(Aim) 1.9 EW or (Aim) 2.0 EC up to 2 fl. oz.	14	Emerged broadleaf weeds. Apply as a hooded application to row middles only. Good coverage is essential. May be tank mixed with other herbicides. A nonionic surfactant, methylated seed oil, or crop oil concentrate is recommended. 0 day PHI.
Clethodim 0.09 - 0.25 / 0.07 - 0.25	(Arrow, Select) 2 EC 6 - 16 fl. oz. (Select Max) 1 EC 9 - 32 fl. oz.	1	Perennial and annual grasses. Use higher rates under heavy grass pressure or larger weeds. Surfactant or crop oil concentrate recommended. Consult label. 20 day PHI.
DCPA 6.0 - 7.5	(Dacthal) W-75 8 - 10 lb. (Dacthal) 6 F 8 - 10 pt.	3	Annual grasses and select broadleaves. Apply to weed-free soil 6-8 wk. after crop is established and growing rapidly or to moist soil in row middles after crop establishment. Note label precautions against replanting non-registered crops within 8 months.
Diquat 0.5	(Reglone Dessiccant) 1 qt.	22	Broadleaves and grasses. Apply to row middles only. Maximum of 2 applications per season. Prevent drift to crop. Nonionic surfactant recommended. 30 day PHI.
Halosulfuron 0.024 - 0.05	(Sandea, Profine) 75 DF 0.5 - 1.0 oz.	2	Broadleaf weeds and yellow/purple nutsedge. Apply 14 days after transplant but before first bloom. Following first bloom apply with shielded or hooded applicator. May be applied to row middles with shielded or hooded sprayer. Do not exceed 2 oz per 12 month period. Surfactant recommended. 30 day PHI.
Imazosulfuron 0.19-0.3	(League) 4.0-6.4 oz	2	Apply post emergence 3 to 5 days after transplant through early bloom. Only apply if no pre-transplant application was made. Surfactant recommended. PHI 21 days.
Lactofen 0.25 - 0.5	(Cobra) 2 EC 16 - 32 fl. oz.	14	Broadleaf weeds. Apply to row middles only with shielded or hooded sprayers. Contact with green foliage or fruit can cause excessive injury. Drift of Cobra treated soil particles onto plants can cause contact injury. Limit of 1 PRE and 1 POST application per growing season. Do not apply within 18 days of transplant. Surfactant recommended. PHI 30 days.
***S*-metolachlor** 1.0 - 1.3	(Brawl, Dual Magnum, Medal) 7.62 EC 1.0 - 1.33 pt.	15	Annual broadleaf, grasses, and yellow/purple nutsedge. Apply to row middles. Label rates are 1.0-1.33 pt./A if organic matter is less than 3%. Use on a trial basis. Surfactant not recommended. 90 day PHI for rates above 1.33 pt./A. 30 day PHI for rates 1.33 pt./acre or less.
Metribuzin 0.25 - 0.5	(Sencor DF, TriCor DF) 75 WDG 0.33 - 0.67 lb. (Sencor 4, Metri) 4 F 0.5 - 1.0 pt.	5	Small emerged weeds. Apply after transplants or seedlings are well established. Apply in single or multiple applications with a minimum of 14 days between treatments. Maximum of 1.0 lb. a.i./A within a season. Avoid application for 3 days following cool, wet, or cloudy weather to reduce possible crop injury. 7 day PHI.
Paraquat 0.5	(Gramoxone) 2 SL 2 pt. (Firestorm) 3 SL 1.3 pt.	22	Emerged broadleaf and grass weeds. Direct spray over emerged weeds 1-6 in. tall in row middles between mulched beds. Use low pressure and shields to control drift. Do not apply more than 3 times per season. Nonionic surfactant recommended. 30 day PHI.
Pelargonic acid	(Scythe) 4.2 EC 3 - 10% v/v		Emerged broadleaf and grass weeds. Direct spray to row middles. Product is a contact, nonselective, foliar applied herbicide with no residual control. May be tank mixed with several soil residual compounds.
Pendimethalin 0.48 - 0.72	(Prowl H_20) 3.8 1.0 - 1.5 pt.	3	Broadleaf and grass weeds. May be applied post transplant to row middles if previously untreated. Do not exceed 3.0 pt./A per year. 70 day PHI.

Labels change frequently. Be sure to read a current product label before applying any chemical.			
Active ingredient lb. a.i./A	**Trade name product/A**	**MOA Code**	**Weeds controlled / remarks**
Rimsulfuron **0.02 - 0.03**	(Matrix FNV, Matrix SG, Pruvin) 25 WDG 1.0 - 2.0 oz.	2	Broadleaves and grasses. May be applied as a sequential treatment with a PRE and POST application not exceeding 0.06 lb. a.i./A in a single season. Requires 0.5-1.0 in. of rainfall or irrigation within 5 days of application for activation. Nonionic surfactant or crop oil concentrate recommended. PHI 45 days.
Sethoxydim **0.19 - 0.28**	(Poast) 1.5 EC 1.0 - 1.5 pt.	1	Actively growing grasses. A total of 4.5 pt./A applied in one season. Unsatisfactory results may occur if applied to grasses under stress. Crop oil concentrate recommended. 20 day PHI.
Trifloxysulfuron **0.005 - 0.009**	(Envoke) 75 DG 0.1 - 0.2 oz.	2	Broadleaves and yellow/purple nutsedge. Direct spray solution to the base of transplanted tomato plants. Apply at least 14 days after transplanting and before fruit set. 45 day PHI.
			***** POSTHARVEST *****
Diquat **0.5**	(Reglone Dessiccant) 2.0 pt.	22	Minimum of 35 gal./A. Thorough coverage is required. Nonionic surfactant recommended.
Paraquat **0.62 - 0.94**	(Gramoxone) 2 SL 2.4 - 3.75 pt. (Firestorm) 3 SL 1.6 - 2.5 pt.	22	Broadcast spray over the top of the plants after the last harvest. Thorough coverage is required to ensure maximum herbicide burndown. Do not use treated crop for human or animal consumption. Nonionic surfactant recommended.

Tomato Fungicides

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TOMATO FUNGICIDES

Products Sorted byDisease and then in Order by FRAC Group Corresponding to the Mode of Action.
Biopesticides and other alternative products labeled for disease management are listed in a separate table for convenience. (Updated June 2014).

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BE SURE TO READ A CURRENT PRODUCT LABEL BEFORE APPLYING ANY PRODUCT.

Labels change frequently. Be sure to read a current product label before applying any chemical. Refer to Table XX for biopesticide and other alternative products labeled for disease management.

Pertinent Diseases or Pathogens	Fungicide Group [1]	Chemical (active ingredients)	Max. Rate/Acre		Min. Days to		Remarks [2]
			Applic.	Season	Harvest	Reentry	
Anthracnose	M1	**(copper compounds)** **Many brands available:** Badge SC, Badge X2, Basic Copper 50W HB, Basic Copper 53, C-O-C-S WDG, Champ DP, Champ F2 FL, Champ WG, Champion WP, C-O-C DF, C-O-C WP, Copper Count N, Cuprofix Ultra 40D, Cueva, Kentan DF, Kocide 3000, Kocide 2000, Kocide DF, Nordox, Nordox 75WG, Nu Cop 50WP, Nu Cop 3L, Nu Cop 50DF, Nu Cop HB	**SEE INDIVIDUAL LABELS**		1	Varies from 4 hr to 2 days.	Mancozeb enhances bactericidal effect of fix copper compounds.
	M3	**(mancozeb)** **Many brands available:** Dithane DF, Dithane F45, Dithane M45, Koverall, Manzate FL, Manzate Pro-Stik, Penncozeb 4FL, Penncozeb 75DF, Penncozeb 80WP	**SEE INDIVIDUAL LABELS**		5	1	
	M3	Ziram 76DF (ziram)	4 lb	23.7 lb	7	2	Do not use on cherry tomatoes.
	M3 & M1	ManKocide (mancozeb + copper hydroxide)	5 lb	112 lb	5	2	
	M5	**(chlorothalonil)** **Many brands available:** Bravo Ultrex, Bravo Weather Stik, Bravo Zn, Chloronil 720, Echo 720, Echo 90 DF, Echo Zn, Equus 500 Zn, Equus 720 SST, Equus DF, Initiate 720	**SEE INDIVIDUAL LABELS**		0	0.5	Use higher rates at fruit set and lower rates before fruit set.

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Pertinent Diseases or Pathogens	Fungicide Group [1]	Chemical (active ingredients)	Max. Rate/Acre		Min. Days to		Remarks [2]
			Applic.	Season	Harvest	Reentry	
(suppression)	7	Fontelis (penthiopyrad)	24 fl oz	72 fl oz	0	0.5	For Disease suppression only. No more than 2 sequential applications before rotating with another effective fungicide from a different FRAC group. See label for additional instructions pertaining to greenhouse useage.
	9 & 3	Inspire Super (cyprodinil + difenoconazole)	20 fl oz	47 fl oz	0	0.5	Limit is 5 apps per season with no more than 2 sequential apps. Must tank mix or alternate with another effective fungicide from another FRAC group. Has up to a 8 month plant back restriction with off label crops.
	11	Equation Heritage Quadris FL (azoxystrobin)	6.2 fl oz 3.2 oz 6.2 fl oz	37 fl oz 1.6 lb 37 fl oz	0 0 0	 4 hr 4 hr	Must alternate or tank mix with a fungicide from a different FRAC group; use of an adjuvant or tank mixing with EC products may cause phytotoxicity.
	11 & M5	Quadris Opti (azoxystrobin + chlorothalonil)	1.6 pt	8 pt	0	0.5	Must alternate with a non-FRAC code 11 fungicide; use of an adjuvant may cause phytotoxicity.
	11 & 3	Quadris Top (azoxystrobin + difenoconazole)	8 fl oz	47 fl oz	0	0.5	Limit is 4 apps per season with no more than 2 sequential apps. Must tank mix or alternate with another effective fungicide from another FRAC group.
	11 & 7	Priaxor (pyraclostrobin + fluxapyroxad)	8 fl oz	24 fl oz	0	0.5	Limit is 3 apps per season; no more than 2 sequential apps. See label about compatibility with other formulated products and adjuvants.
	11 & 27	Tanos (famoxadone + cymoxanil)	8 oz	72 oz	3	0.5	Do not alternate or tank mix with other FRAC group 11 fungicides.
(suppression)	19	Ph-D WDG Oso 5% SC (polyoxin D zinc salt)	6.2 oz 13 fl oz	31.0 oz 78 fl oz	0 0	4 hr 4 hr	Alternate with a non-FRAC code 19 fungicide.
	40 & 3	Revus Top (mandipropamid + difenoconazole)	7 fl oz	28 fl oz	1	0.5	Limit is 4 apps per season; no more than 2 sequential apps. Not labeled for transplants.
Bacterial canker	M1	**(copper compounds)** **Many brands available:** Badge SC, Badge X2, Basic Copper 50W HB, Basic Copper 53, C-O-C-S WDG, Champ DP, Champ F2 FL, Champ WG, Champion WP, C-O-C DF, C-O-C WP, Copper Count N, Cuprofix Ultra 40D, Cueva, Kentan DF, Kocide 3000, Kocide 2000, Kocide DF, Nordox, Nordox 75WG, Nu Cop 50WP, Nu Cop 3L, Nu Cop 50DF, Nu Cop HB	**SEE INDIVIDUAL LABELS**		1	Varies by product from 4 hr to 2 days.	Mancozeb enhances the bactericidal effect of fix copper compounds.
(suppression)	11 & 27	Tanos (famoxadone + cymoxanil)	8 oz	72 oz	3	0.5	Do not alternate or tank mix with other FRAC group 11 fungicides.
Bacterial spot and Bacterial speck	M1	**(copper compounds)** **Many brands available:** Badge SC, Badge X2, Basic Copper 50W HB, Basic Copper 53, C-O-C-S WDG, Champ DP, Champ F2 FL, Champ WG, Champion WP, C-O-C DF, C-O-C WP, Copper Count N, Cuprofix Ultra 40D, Cueva, Kentan DF, Kocide 3000, Kocide 2000, Kocide DF, Nordox, Nordox 75WG, Nu Cop 50WP, Nu Cop 3L, Nu Cop 50DF, Nu Cop HB	**SEE INDIVIDUAL LABELS**		1	Varies by product from 4 hr to 2 days.	Mancozeb enhances the bactericidal effect of fix copper compounds.
	M3	**(mancozeb)** **Many brands available:** Dithane DF, Dithane F45, Dithane M45, Koverall, Manzate FL, Manzate Pro-Stik, Penncozeb 4FL, Penncozeb 75DF, Penncozeb 80WP	**SEE INDIVIDUAL LABELS**		5	1	Bacterial spot control only when tank mixed with a copper fungicide.
	M3 & M1	ManKocide (mancozeb + copper hydroxide)	5 lb	112 lb	5	2	
(suppression)	11 & 27	Tanos (famoxadone + cymoxanil)	8 oz	72 oz	3	0.5	Do not alternate or tank mix with other FRAC group 11 fungicides.

TOMATO FUNGICIDES (continued)

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			Applic.	Season	Harvest	Reentry	
	25	Agri-mycin 17 Ag Streptomycin Bac-Master (streptomycin sulfate)	200 ppm	-	-	0.5	See label for details. For transplant production only. Many isolates are resistant to streptomycin.
	P	Actigard (acibenzolar-S-methyl)	0.75 oz	4.75 oz	14	0.5	Begin applications within one week of transplanting or emergence. Make up to 8 weekly, sequential applications.
Black mold (*Alternaria* spp.)	3	Mentor (propiconazole)	8 oz /100 gal or /50,000 lb of fruit	-	-	-	Apply as a post-harvest dip, drench, or high-volume spray for the post-harvest control of certain rots. See label for details.
	7	Endura (boscalid)	12.5 oz	25 oz	0	0.5	Alternate with non-FRAC code 7 fungicides, see label
	7	Fontelis (penthiopyrad)	24 fl oz	72 fl oz	0	0.5	No more than 2 sequential applications before rotating with another effective fungicide from a different FRAC group. See label for additional instructions pertaining to greenhouse useage.
	9 & 3	Inspire Super (cyprodinil + difenoconazole)	20 fl oz	47 fl oz	0	0.5	Limit is 5 apps per season with no more than 2 sequential apps. Must tank mix or alternate with another effective fungicide from another FRAC group. Has up to a 8 month plant back restriction with off label crops.
	11	Heritage Quadris FL (azoxystrobin)	3.2 oz 6.2 fl oz	1.6 lb 37 fl oz	0	4 hr	Must alternate or tank mix with a fungicide from a different FRAC group; use of an adjuvant or tank mixing with EC products may cause phytotoxicity.
	11 & M5	Quadris Opti (azoxystrobin + chlorothalonil)	1.6 pt	8 pt	0	0.5	Must alternate with a non-FRAC code 11 fungicide; use of an adjuvant may cause phytotoxicity.
	11 & 3	Quadris Top (azoxystrobin + difenoconazole)	8 fl oz	47 fl oz	0	0.5	Limit is 4 apps per season with no more than 2 sequential apps. Must tank mix or alternate with another effective fungicide from another FRAC group. Has up to a 1 year plant back restriction for certain off label crops.
	11 & 7	Priaxor (pyraclostrobin + fluxapyroxad)	8 fl oz	24 fl oz	0	0.5	Limit is 3 apps per season; no more than 2 sequential apps. See label about compatibility with other formulated products and adjuvants.
	40 & 3	Revus Top (mandipropamid + difenoconazole)	7 fl oz	28 fl oz	1	0.5	4 apps per season; no more than 2 sequential apps. Not labeled for transplants.
Botrytis, Gray Mold	M5	**(chlorothalonil)** Many brands available: Bravo Ultrex, Bravo Weather Stik, Bravo Zn, Chloronil 720, Echo 720, Echo 90 DF, Echo Zn, Equus 500 Zn, Equus 720 SST, Equus DF, Initiate 720	**SEE INDIVIDUAL LABELS**		0	0.5	Use higher rates at fruit set and lower rates before fruit set.
	7	Fontelis (penthiopyrad)	24 fl oz	72 fl oz	0	0.5	No more than 2 sequential applications before switching to another effective fungicide with a different mode of action. See label for additional instructions pertaining to greenhouse useage.
(*suppression*)	7	Endura (boscalid)	12.5 oz	25 oz	0	0.5	Alternate with non-FRAC code 7 fungicides.
	9	Scala SC (pyrimethanil)	7 fl oz	35 fl oz	1	0.5	Use only in a tank mix with another effective non-FRAC code 9 fungicide; Has a 30 day plant back with off label crops.
	9 & 12	Switch 62.5WG (cyprodinil + fludioxonil)	14 oz	56 oz per year	0	0.5	After 2 appl. Alternate with non-FRAC code 9 or 12 fungicides for next 2 applications. Has a 30 day plant back with off label crops.
(suppression)	11	Cabrio 2.09 F (pyraclostrobin)	16 fl oz	96 fl oz	0	0.5	Only 2 sequential appl. Allowed. Limit is 6 appl/crop. Must alternate or tank mix with a fungicide from a different FRAC group.

TOMATO FUNGICIDES (continued)

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			Applic.	Season	Harvest	Reentry	
(suppression)	11 & 7	Priaxor (pyraclostrobin + fluxapyroxad)	8 fl oz	24 fl oz	0	0.5	Limit is 3 apps per season; no more than 2 sequential apps. See label about compatibility with other formulated products and adjuvants.
	14	Botran 75 W (dichloran)	1 lbs per 100 gal.	5.33 lb	10	0.5	Greenhouse use only. Limit is 4 applications. Seedlings or newly set transplants may be injured.
	19	Ph-D WDG Oso 5% SC (polyoxin D zinc salt)	6.2 oz 13 fl oz	31.0 oz 78 fl oz	0 0	4 hr 4 hr	Alternate with a non-FRAC code 19 fungicide.
Buckeye rot	M1 + 4	Ridomil Gold Copper (copper hydroxide + mefenoxam)	2 lb	6 lb	14	2	Limited to 3 apps per season. Tankmix with mancozeb.
	11	Heritage Quadris FL (azoxystrobin)	3.2 oz 6.2 fl oz	1.6 lb 37 fl oz	0	4 hr	Must alternate or tank mix with a fungicide from a different FRAC group; use of an adjuvant or tank mixing with EC products may cause phytotoxicity.
	11	Cabrio 2.09 F (pyraclostrobin)	16 fl oz	96 fl oz	0	0.5	Only 2 sequential appl. Allowed. Limit is 6 appl/crop. Must alternate or tank mix with a fungicide from a different FRAC group, see label.
	11 & M5	Quadris Opti (azoxystrobin + chlorothalonil)	1.6 pt	8 pt	0	0.5	Must alternate with a non-FRAC code 11 fungicide; use of an adjuvant may cause phytotoxicity.
(suppression)	11 & 27	Tanos (famoxadone + cymoxanil)	8 oz	72 oz	3	0.5	Do not alternate or tank mix with other FRAC group 11 fungicides.
	22 & M3	Gavel 75DF (zoaximide + mancozeb)	2.0 lb	16 lb	5	2	See label
Early blight	M1	(copper compounds) **Many brands available:** Badge SC, Badge X2, Basic Copper 50W HB, Basic Copper 53, C-O-C-S WDG, Champ DP, Champ F2 FL, Champ WG, Champion WP, C-O-C DF, C-O-C WP, Copper Count N, Cuprofix Ultra 40D, Cueva, Kentan DF, Kocide 3000, Kocide 2000, Kocide DF, Nordox, Nordox 75WG, Nu Cop 50WP, Nu Cop 3L, Nu Cop 50DF, Nu Cop HB	**SEE INDIVIDUAL LABELS**		1	Varies by product from 4 hr to 2 days.	Mancozeb or maneb enhances bactericidal effect of fix copper compounds. **See label for details.**
	M3	(mancozeb) **Many brands available:** Dithane DF, Dithane F45, Dithane M45, Koverall, Manzate FL, Manzate Pro-Stik, Penncozeb 4FL, Penncozeb 75DF, Penncozeb 80WP	**SEE INDIVIDUAL LABELS**		5	1	
	M3	Ziram 76DF (ziram)	4 lbs	23.7 lb	7	2	Do not use on cherry tomatoes.
	M3 & M1	ManKocide (mancozeb + copper hydroxide)	5 lb	112 lb	5	2	
	M5	**(chlorothalonil)** **Many brands available:** Bravo Ultrex, Bravo Weather Stik, Bravo Zn, Chloronil 720, Echo 720, Echo 90 DF, Echo Zn, Equus 500 Zn, Equus 720 SST, Equus DF, Initiate 720	**SEE INDIVIDUAL LABELS**		0	0.5	Use higher rates at fruit set and lower rates before fruit set.
	4 & M5	Ridomil Gold Bravo 76.4 W (chlorothalonil + mefenoxam)	3 lb	12 lb	14	2	Limit is 4 appl./crop.
	7	Endura (boscalid)	12.5 oz	25 oz	0	0.5	Alternate with non-FRAC code 7 fungicides.
	7	Fontelis (penthiopyrad)	24 fl oz	72 fl oz	0	0.5	No more than 2 sequential applications before switching to another effective fungicide with a different mode of action. See label for additional instructions pertaining to greenhouse useage.
	9	Scala SC (pyrimethanil)	7 fl oz	35 fl oz	1	0.5	Use only in a tank mix with another effective non-FRAC code 9 fungicide ; Has a 30 day plant back with off label crops.

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	9 & 3	Inspire Super (cyprodinil + difenoconazole)	20 fl oz	47 fl oz	0	0.5	Limit is 5 apps per season with no more than 2 sequential apps. Must tank mix or alternate with another effective fungicide from another FRAC group. Has up to a 8 month plant back restriction with off label crops.
	9 & 12	Switch 62.5WG (cyprodinil + fludioxonil)	14 oz	56 oz per year	0	0.5	After 2 apps. alternate with non-FRAC code 9 or 12 fungicides for next 2 applications. Has a 30 day plant back with off label crops.
	11	Heritage Quadris FL (azoxystrobin)	3.2 oz 6.2 fl oz	1.6 lb 37 fl oz	0	4 hr	Must alternate or tank mix with a fungicide from a different FRAC group; use of an adjuvant or tank mixing with EC products may cause phytotoxicity.
	11	Cabrio 2.09 F (pyraclostrobin)	16 fl oz	96 fl oz	0	0.5	Only 2 sequential apps. allowed. Limit is 6 apps/crop. Must alternate or tank mix with a fungicide from a different FRAC group.
	11	Flint (trifloxystrobin)	4 oz	16 oz	3	0.5	Limit is 5 apps/crop. Must alternate or tank mix with a fungicide from a different FRAC group.
	11	Evito Aftershock (fluoxastrobin)	5.7 fl oz	22.8 fl oz	3	0.5	Limit is 4 apps/crop. Must alternate or tank mix with a fungicide from a different FRAC group.
	11	Reason 500 SC (fenamidone)	8.2 oz	24.6 lb	14	0.5	Must alternate with a fungicide from a different FRAC group. See supplemental label for restrictions and details.
	11 & M5	Quadris Opti (azoxystrobin + chlorothalonil)	1.6 pt	8 pt	0	0.5	Must alternate with a non-FRAC code 11 fungicide; use of an adjuvant may cause phytotoxicity.
	11 & 3	Quadris Top (azoxystrobin + difenoconazole)	8 fl oz	47 fl oz	0	0.5	Limit is 4 apps per season with no more than 2 sequential apps. Must tank mix or alternate with another effective fungicide from another FRAC group. Has up to a 1 year plant back restriction for certain off label crops.
	11 & 7	Priaxor (pyraclostrobin + fluxapyroxad)	8 fl oz	24 fl oz	0	0.5	Limit is 3 apps per season; no more than 2 sequential apps. See label about compatibility with other formulated products and adjuvants.
	11 & 27	Tanos (famoxadone + cymoxanil)	8 oz	72 oz	3	0.5	Do not alternate or tank mix with other FRAC group 11 fungicides.
	19	Ph-D WDG Oso 5% SC (polyoxin D zinc salt)	6.2 oz 13 fl oz	31.0 oz 78 fl oz	0 0	4 hr 4 hr	Alternate with a non-FRAC code 19 fungicide.
	22 & M3	Gavel 75DF (zoaximide + mancozeb)	2.0 lb	16 lb	5	2	
	28	Previcur Flex (propamocarb hydrochloride)	1.5 pt	7.5 pt	5	0.5	Must tank mix with chlorothalonil or mancozeb.
	28	Promess (propamocarb hydrochloride)	1.5 pt	7.5 pt	5	0.5	Must tank mix with chlorothalonil or mancozeb.
	40 & 3	Revus Top (mandipropamid + difenoconazole)	7 fl oz	28 fl oz	1	0.5	Limit is 4 apps per season; no more than 2 sequential apps. Not labeled for transplants.
Late blight	M1	**(copper compounds)** **Many brands available:** Badge SC, Badge X2, Basic Copper 50W HB, Basic Copper 53, C-O-C-S WDG, Champ DP, Champ F2 FL, Champ WG, Champion WP, C-O-C DF, C-O-C WP, Copper Count N, Cuprofix Ultra 40D, Cueva, Kentan DF, Kocide 3000, Kocide 2000, Kocide DF, Nordox, Nordox 75WG, Nu Cop 50WP, Nu Cop 3L, Nu Cop 50DF, Nu Cop HB	**SEE INDIVIDUAL LABELS**		1	Varies by product from 4 hr to 2 days.	
	M3	**(mancozeb)** **Many brands available:**	**SEE INDIVIDUAL LABELS**		5	1	

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		Dithane DF, Dithane F45, Dithane M45, Koverall, Manzate, Manzate Pro-Stik, Penncozeb 4FL, Penncozeb 75DF, Penncozeb 80WP					
	M3 & M1	ManKocide (mancozeb + copper hydroxide)	5 lb	112 lb	5	2	
	M5	(chlorothalonil) **Many brands available:** Bravo Ultrex, Bravo Weather Stik, Bravo Zn, Chloronil 720, Echo 720, Echo 90 DF, Echo Zn, Equus 500 Zn, Equus 720 SST, Equus DF, Initiate 720	**SEE INDIVIDUAL LABELS**		0	0.5	Use higher rates at fruit set and lower rates before fruit set.
	4 & M3	Ridomil MZ 68 WP (mefenoxam + mancozeb)	2.5 lb	7.5 lb	5	2	Limit is 3 apps./crop.
	4 & M1	Ridomil Gold Copper 64.8 W (mefenoxam + copper hydroxide)	2 lb	6 lb	14	2	Limit is 3 apps./crop. Tank mix with mancozeb fungicide.
	4 & M5	Ridomil Gold Bravo 76.4 W (chlorothalonil + mefenoxam)	3 lb	12 lb	14	2	Limit is 4 apps./crop.
	11	Heritage Quadris FL (azoxystrobin)	3.2 oz 6.2 fl oz	1.6 lb 37 fl oz	0	4 hr	Must alternate or tank mix with a fungicide from a different FRAC group; use of an adjuvant or tank mixing with EC products may cause phytotoxicity.
	11	Cabrio 2.09 F (pyraclostrobin)	16 fl oz	96 fl oz	0	0.5	Only 2 sequential appl. Allowed. Limit is 6 appl/crop. Must alternate or tank mix with a fungicide from a different FRAC group.
	11	Flint (trifloxystrobin)	4 oz	16 oz	3	0.5	Limit is 5 appl/crop. Must alternate or tank mix with a fungicide from a different FRAC group.
	11	Evito Aftershock (fluoxastrobin)	5.7 fl oz	22.8 fl oz	3	0.5	Limit is 4 appl/crop. Must alternate or tank mix with a fungicide from a different FRAC group.
	11	Reason 500 SC (fenamidone)	8.2 oz	24.6 lb	14	0.5	Must alternate with a fungicide from a different FRAC group.
	11 & M5	Quadris Opti (azoxystrobin + chlorothalonil)	1.6 pt	8 pt	0	0.5	Must alternate with a non-FRAC code 11 fungicide; use of an adjuvant may cause phytotoxicity.
(suppression)	11 & 7	Priaxor (pyraclostrobin + fluxapyroxad)	8 fl oz	24 fl oz	7	0.5	Limit is 3 apps per season; no more than 2 sequential apps. See label about compatibility with other formulated products and adjuvants.
	11 & 27	Tanos (famoxadone + cymoxanil)	8 oz	72 oz	3	0.5	Do not alternate or tank mix with other FRAC group 11 fungicides.
	19	Oso 5% SC (polyoxin D zinc salt)	13 fl oz	78 fl oz	0	4 hr	Alternate with a non-FRAC code 19 fungicide.
	21	Ranman (cyazofamid)	2.75 oz	16oz	0	0.5	Limit is 6 apps./crop.
	22 & M3	Gavel 75DF (zoaximide + mancozeb)	2.0 lb	16 lb	5	2	
	27	Curzate 60DF (cymoxanil)	5 oz	30 oz per year	3	0.5	Must tank mix with another effective product.
	28	Previcur Flex (propamocarb hydrochloride)	1.5 pt	7.5 pt	5	0.5	Must tank mix with Chlorothalonil or mancozeb.
	28	Promess (propamocarb hydrochloride)	1.5 pt	7.5 pt	5	0.5	Must tank mix with Chlorothalonil or mancozeb.
	33	Aliette 80 WDG (fosetyl-al)	5 lb	20lb	14	0.5	See label for warnings concerning the use of copper compounds.
	33	Alude (mono- and di-potassium salts of phosphorous acid)	1.5 qt/ acre/ 25 gal	-	-	4 hr	For transplants only.
	40	Forum (dimethomorph)	6 oz	30 oz	4	0.5	Only 2 sequential appl. See label for details

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			Applic.	Season	Harvest	Reentry	
	40	Revus (mandipropamid)	8 fl oz	32 fl oz	1	4 hr	Supplemental label; No more than 2 sequential appl.; See label
	40 & 3	Revus Top (mandipropamid + difenoconazole)	7 fl oz	28 fl oz	1	0.5	4 apps per season; no more than 2 sequential apps. Not labeled for transplants. See label
	43	Presidio (Fluopicolide)	4 fl oz	12 fl oz/per season	2	0.5	4 apps per season; no more than 2 sequential apps. 10 day spray interval; Tank mix with another labeled non-FRAC code 43 fungicide; 18 month rotation with off label crops; see label.
	45 & 40	Zampro (ametoctradin + dimethomorph)	14 fl oz	42 fl oz	4	0.5	Addition of a spreading or penetrating adjuvant is recommended to improve performance. Limit of 3 applications per season.
Leaf mold	M3	**(mancozeb)** **Many brands available:** Dithane DF, Dithane F45, Dithane M45, Koverall, Manzate, Manzate Pro-Stik, Penncozeb 4FL, Penncozeb 75DF, Penncozeb 80WP	**SEE INDIVIDUAL LABELS**		5		
	M5	**(chlorothalonil)** **Many brands available:** Bravo Ultrex, Bravo Weather Stik, Bravo Zn, Chloronil 720, Echo 720, Echo 90 DF, Echo Zn, Equus 500 Zn, Equus 720 SST, Equus DF, Initiate 720	**SEE INDIVIDUAL LABELS**		0	0.5	Use higher rates at fruit set and lower rates before fruit set.
	9 & 3	Inspire Super (cyprodinil + difenoconazole)	20 fl oz	47 fl oz	0	0.5	Limit is 5 apps per season with no more than 2 sequential apps. Must tank mix or alternate with another effective fungicide from another FRAC group. Has up to a 8 month plant back restriction with off label crops.
	11 & 3	Quadris Top (azoxystrobin + difenoconazole)	8 fl oz	47 fl oz	0	0.5	Limit is 4 apps per season with no more than 2 sequential apps. Must tank mix or alternate with another effective fungicide from another FRAC group.
	11 & 27	Tanos (famoxadone + cymoxanil)	8 oz	72 oz	3	0.5	Do not alternate or tank mix with other FRAC group 11 fungicides.
	19	Oso 5% SC (polyoxin D zinc salt)	13 fl oz	78 fl oz	0	4 hr	Alternate with a non-FRAC code 19 fungicide.
	22 & M3	Gavel 75DF (zoaximide + mancozeb)	2.0 lb	16 lb	5	2	
	40 & 3	Revus Top (mandipropamid + difenoconazole)	7 fl oz	28 fl oz	1	0.5	4 apps per season; no more than 2 sequential apps. Not labeled for transplants.
Grey leaf spot	M1	**(copper compounds)** **Many brands available:** Badge SC, Badge X2, Basic Copper 50W HB, Basic Copper 53, C-O-C-S WDG, Champ DP, Champ F2 FL, Champ WG, Champion WP, C-O-C DF, C-O-C WP, Copper Count N, Cuprofix Ultra 40D, Cueva, Kentan DF, Kocide 3000, Kocide 2000, Kocide DF, Nordox, Nordox 75WG, Nu Cop 50WP, Nu Cop 3L, Nu Cop 50DF, Nu Cop HB	**SEE INDIVIDUAL LABELS**		1	Varies by product from 4 hr to 2 days.	Mancozeb or maneb enhances bactericidal effect of fix copper compounds.
	M3	**(mancozeb)** **Many brands available:** Dithane DF, Dithane F45, Dithane M45, Koverall, Manzate, Manzate Pro-Stik, Penncozeb 4FL, Penncozeb 75DF, Penncozeb 80WP	**SEE INDIVIDUAL LABELS**		5	1	
	M3 & M1	ManKocide (mancozeb + copper hydroxide)	5 lb	112 lb	5	2	
	M5	(chlorothalonil) **Many brands available:** Bravo Ultrex, Bravo Weather Stik, Bravo Zn, Chloronil 720, Echo 720, Echo 90 DF, Echo Zn, Equus 500 Zn, Equus 720 SST, Equus DF, Initiate 720	**SEE INDIVIDUAL LABELS**		0	0.5	Use higher rates at fruit set and lower rates before fruit set.

Products Sorted byDisease and then in Order by FRAC Group Corresponding to the Mode of Action.
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Pertinent Diseases or Pathogens	Fungicide Group [1]	Chemical (active ingredients)	Max. Rate/Acre		Min. Days to		Remarks [2]
			Applic.	Season	Harvest	Reentry	
	4 & M5	Ridomil Gold Bravo 76.4 W (chlorothalonil + mefenoxam)	3 lb	12 lb	14	2	Limit is 4 apps./crop.
	9 & 3	Inspire Super (cyprodinil + difenoconazole)	20 fl oz	47 fl oz	0	0.5	Limit is 5 apps per season with no more than 2 sequential apps. Must tank mix or alternate with another effective fungicide from another FRAC group. Has up to a 8 month plant back restriction with off label crops.
	11	Flint (trifloxystrobin)	4 oz	16 oz	3	0.5	Limit is 5 apps/crop. Must alternate or tank mix with a fungicide from a different FRAC group.
	11 & 3	Quadris Top (azoxystrobin + difenoconazole)	8 fl oz	47 fl oz	0	0.5	Limit is 4 apps per season with no more than 2 sequential apps. Must tank mix or alternate with another effective fungicide from another FRAC group. Has up to a 1 year plant back restriction for certain off label crops.
	22 & M3	Gavel 75DF (zoaximide + mancozeb)	2.0 lb	16 lb	5	2	
	40 & 3	Revus Top (mandipropamid + difenoconazole)	7 fl oz	28 fl oz	1	0.5	4 apps per season; no more than 2 sequential apps. Not labeled for transplants.
Phytophthora crown rot, Phytophthora root rot (*Phytophthora* spp.)	4	Ridomil Gold SL Ultra Flourish (mefenoxam)	1 pt 2 pt	3 pt 6 pt	28 7	2* 2*	Do not apply more than 6 lb mefenoxam/A per crop to the soil. *There is a reentry interval exemption if material is soil-injected or soil-incorporated.
	4	Metastar 2E (metalaxyl)	2 qt	6 qt	2	28	Soil applied by drip injection.
	11	Reason 500 SC (fenamidone)	8.2 oz	24.6 lb	14	0.5	Must alternate with a fungicide from a different FRAC group. *(Phytophthora capsici*-suppression only)
	14	Terramaster 4EC (etridiazole)	7 fl oz	27.4 fl oz	3	0.5	Greenhouse use only.
	21	Ranman (cyazofamid)	2.75 fl oz	16.5 fl oz	0		Apply to the base of plant at the time of transplanting. Make additional applications on a 7 to 10 day schedule if conditions are favorable for disease.
	28	Previcur Flex (propamocarb hydrochloride)	**SEE LABEL**		5	0.5	GREENHOUSE APPLICATION: 6 apps/crop cycle. Do not mix with other products. Can cause phytotoxicity if applied in intense sunlight.
	33	Aliette 80 WDG Linebacker WDG (fosetyl-aluminum)	5 lb	2 lb	14	0.5	See label for warnings concerning the use of copper compounds.
	33	Alude (mono- and di-potassium salts of phosphorous acid)	1.5 qt/ acre/ 25 gal	-	-	4 hr	For transplants only.
	43	Presidio (fluopicolide)	4 fl oz	12 fl oz	2	0.5	4 apps per season; no more than 2 sequential apps. 10 day spray interval; Tank mix with another labeled non-FRAC code 43 fungicide; 18 month rotation with off label crops.
	45 & 40	Zampro (ametoctradin + dimethomorph)	14 fl oz	42 fl oz	4	0.5	Addition of a spreading or penetrating adjuvant is recommended to improve performance. Limit of 3 applications per season.

TOMATO FUNGICIDES (continued)

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Pertinent Diseases or Pathogens	Fungicide Group [1]	Chemical (active ingredients)	Max. Rate/Acre		Min. Days to		Remarks [2]
			Applic.	Season	Harvest	Reentry	
Powdery mildew	M2	**(sulfur)** **Many brands available:** Cosavet DF, Kumulus DF, Micro Sulf, Microfine Sulfur, Microthiol Disperss, Sulfur 6L, Sulfur 90W, Super Six, That Flowable Sulfur, Tiolux Jet, Thiosperse 80%, Wettable Sulfur, Wettable Sulfur 92, Yellow Jacket Dusting Sulfur, Yellow Jacket Wettable Sulfur	**SEE INDIVIDUAL LABELS**		1	1	Follow label closely, may cause leaf burn if applied during high temperatures.
	3	Rally 40WSP Nova 40 W Sonoma 40WSP (myclobutanil)	4 oz	1.25 lb	0	1	Note that a 30 day plant back restriction exists.
	7	Fontelis (penthiopyrad)	24 fl oz	72 fl oz	0	0.5	No more than 2 sequential applications before switching to another effective fungicide with a different mode of action. See label for additional instructions pertaining to greenhouse useage.
	9 & 3	Inspire Super (cyprodinil + difenoconazole)	20 fl oz	47 fl oz	0	0.5	Limit is 5 apps per season with no more than 2 sequential apps. Must tank mix or alternate with another effective fungicide from another FRAC group. Has up to a 8 month plant back restriction with off label crops.
	9 & 12	Switch 62.5WG (cyprodinil + fludioxonil)	14 oz	56 oz per year	0	0.5	After 2 apps alternate with non-FRAC code 9 or 12 fungicides for next 2 applications. Has a 30 day plant back with off label crops.
	11	Heritage Quadris FL (azoxystrobin)	3.2 oz 6.2 fl oz	1.6 lb 37 fl oz	0	4 hr	Must alternate or tank mix with a fungicide from a different FRAC group; use of an adjuvant or tank mixing with EC products may cause phytotoxicity.
	11	Cabrio 2.09 F (pyraclostrobin)	16 fl oz	96 fl oz	0	0.5	Only 2 sequential apps. allowed. Limit is 6 appl/crop. Must alternate or tank mix with a fungicide from a different FRAC group.
	11	Flint (trifloxystrobin)	4 oz	16 oz	3	0.5	Limit is 5 apps/crop; must alternate or tank mix with a fungicide from a different FRAC group.
	11 & M5	Quadris Opti (azoxystrobin + chlorothalonil)	1.6 pt	8 pt	0	0.5	Must alternate with a non-FRAC code 11 fungicide; use of an adjuvant may cause phytotoxicity.
	11 & 3	Quadris Top (azoxystrobin + difenoconazole)	8 fl oz	47 fl oz	0	0.5	Limit is 4 apps per season with no more than 2 sequential apps. Must tank mix or alternate with another effective fungicide from another FRAC group. Has up to a 1 year plant back restriction for certain off label crops.
	11 & 7	Priaxor (pyraclostrobin + fluxapyroxad)	8 fl oz	24 fl oz	0	0.5	Limit is 3 apps per season; no more than 2 sequential apps. See label about compatibility with other formulated products and adjuvants.
	19	Ph-D WDG Oso 5% SC (polyoxin D zinc salt)	6.2 oz 13 fl oz	31.0 oz 78 fl oz	0 0	4 hr 4 hr	Alternate with a non-FRAC code 19 fungicide.
	40 & 3	Revus Top (mandipropamid + difenoconazole)	7 fl oz	28 fl oz	1	0.5	4 apps per season; no more than 2 sequential apps. Not labeled for transplants.
Pythium diseases **(*Pythium spp.*)**	4	Ridomil Gold GR Ridomil Gold SL Ultra Flourish (mefenoxam)	20 lb 2 pt 2 pt	40 lb 3 pt 6 pt	28 7 7	2* 2* 2	*There is a reentry interval exemption if material is soil-injected or soil-incorporated.
	4	Metastar 2E (metalaxyl)	2 qt	6 qt	28	2	Soil applied by drip injection.
	14	Terramaster 4EC (etridiazole)	7 fl oz	27.4 fl oz	3	0.5	Greenhouse use only.

TOMATO FUNGICIDES (continued)

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Pertinent Diseases or Pathogens	Fungicide Group [1]	Chemical (active ingredients)	Max. Rate/Acre Applic.	Max. Rate/Acre Season	Min. Days to Harvest	Min. Days to Reentry	Remarks [2]
	21	Ranman (cyazofamid)	3 fl oz/ 100 gal	-	0	-	For greenhouse transplant production; make a single application to the seedling tray 1 week prior up to the time of transplanting. Do not use any surfactant.
	28	Previcur Flex (propamocarb hydrochloride)	**SEE INDIVIDUAL LABELS**		5	0.5	GREENHOUSE APPLICATION: 6 apps/crop cycle. Do not mix with other products. Can cause phytotoxicity if applied in intense sunlight.
	28	Previcur Flex (propamocarb hydrochloride)	1.5 pts/ treated acre	7.5 pt/ treated acre	5	0.5	(Root rots and seedling diseases) Applied to lower portion of plant and soil, or as a soil drench or drip irrigation.
	28	Promess (propamocarb hydrochloride)	1.5 pt	7.5 pt	5	0.5	Must tank mix with chlorothalonil or mancozeb.
	33	Alude (mono- and di-potassium salts of phosphorous acid)	1.5 qt/ acre/ 25 gal	-	-	4 hr	For transplants only.
Rhizoctonia root rot, Rhizoctonia fruit rot (*Rhizoctonia solani*)	M5	**(chlorothalonil)** **Many brands available:** Bravo Ultrex, Bravo Weather Stik, Bravo Zn, Chloronil 720, Echo 720, Echo 90 DF, Echo Zn, Equus 500 Zn, Equus 720 SST, Equus DF, Initiate 720	**SEE INDIVIDUAL LABELS**		0	0.5	Use higher rates at fruit set and lower rates before fruit set.
	7	Fontelis (penthiopyrad)	1.0 - 1.6 fl oz/ 1000 row-ft	24 fl oz	0	0.5	Apply at-plant, pre-plant incorporated, in-furrow, as a transplant drench, or by drip irrigation.
(*suppression*)	11	Cabrio (pyraclostrobin)	16 oz	96 oz	0	0.5	Limit is 2 sequential applications before alternating to another effective fungicide from a different FRAC group.
(suppression)	11 & 7	Priaxor (pyraclostrobin + fluxapyroxad)	8 fl oz	24 fl oz	7	0.5	Limit is 3 apps per season; no more than 2 sequential apps. See label about compatibility with other formulated products and adjuvants.
	14	Blocker 4F Terraclor 75 WP (PCNB)	**SEE INDIVIDUAL LABELS**		Soil treatment at planting	0.5	See label for application type and restrictions
	14	Par-Flo 4F (PCNB)	12 fl oz per 100 gal.	2 app.	Soil drench	0.5	Limited to only container-grown plants in nurseries or greenhouse.
Septoria leaf spot	M1	**(copper compounds)** **Many brands available:** Badge SC, Badge X2, Basic Copper 50W HB, Basic Copper 53, C-O-C-S WDG, Champ DP, Champ F2 FL, Champ WG, Champion WP, C-O-C DF, C-O-C WP, Copper Count N, Cuprofix Ultra 40D, Cueva, Kentan DF, Kocide 3000, Kocide 2000, Kocide DF, Nordox, Nordox 75WG, Nu Cop 50WP, Nu Cop 3L, Nu Cop 50DF, Nu Cop HB	**SEE INDIVIDUAL LABELS**		1	Varies by product from 4 hr to 2 days.	
	M3	**(mancozeb)** **Many brands available:** Dithane DF, Dithane F45, Dithane M45, Koverall, Manzate, Manzate Pro-Stik, Penncozeb 4FL, Penncozeb 75DF, Penncozeb 80WP	**SEE INDIVIDUAL LABELS**		5		
	M3	Ziram 76DF (ziram)	4 lbs	23.7 lb	7	2	Do not use on cherry tomatoes.
	M3 & M1	ManKocide (mancozeb + copper hydroxide)	5 lbs	112 lb	5	2	
	M5	(chlorothalonil) **Many brands available:** Bravo Ultrex, Bravo Weather Stik, Bravo Zn, Chloronil 720, Echo 720, Echo 90 DF, Echo Zn, Equus 500 Zn, Equus 720 SST, Equus DF, Initiate 720	**SEE INDIVIDUAL LABELS**		0	0.5	Use higher rates at fruit set and lower rates before fruit set.
	4 & M5	Ridomil Gold Bravo 76.4 W (chlorothalonil + mefenoxam)	3 lb	12 lb	14	2	Limit is 4 apps./crop.

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Pertinent Diseases or Pathogens	Fungicide Group [1]	Chemical (active ingredients)	Max. Rate/Acre		Min. Days to		Remarks [2]
			Applic.	Season	Harvest	Reentry	
	7	Fontelis (penthiopyrad)	24 fl oz	72 fl oz	0	0.5	No more than 2 sequential apps. before switching to another effective fungicide with a different mode of action. See label for additional instructions pertaining to greenhouse useage.
	9 & 3	Inspire Super (cyprodinil + difenoconazole)	20 fl oz	47 fl oz	0	0.5	Limit is 5 apps per season with no more than 2 sequential apps. Must tank mix or alternate with another effective fungicide from another FRAC group. Has up to a 8 month plant back restriction with off label crops.
	11	Heritage Quadris FL (azoxystrobin)	3.2 oz 6.2 fl oz	1.6 lb 37 fl oz	0	4 hr	Must alternate or tank mix with a fungicide from a different FRAC group; use of an adjuvant or tank mixing with EC products may cause phytotoxicity.
	11	Cabrio 2.09 F (pyraclostrobin)	16 fl oz	96 fl oz	0	0.5	Only 2 sequential appl. Allowed. Limit is 6 apps/crop. Must alternate or tank mix with a fungicide from a different FRAC group.
	11	Flint (trifloxystrobin)	4 oz	16 oz	3	0.5	Limit is 5 apps/crop. Must alternate or tank mix with a fungicide from a different FRAC group.
	11	Reason 500 SC (fenamidone)	8.2 oz	24.6 lb	14	0.5	Must alternate with a fungicide from a different FRAC group.
	11 & M5	Quadris Opti (azoxystrobin + chlorothalonil)	1.6 pt	8 pt	0	0.5	Must alternate with a non-FRAC code 11 fungicide; use of an adjuvant may cause phytotoxicity.
	11 & 3	Quadris Top (azoxystrobin + difenoconazole)	8 fl oz	47 fl oz	0	0.5	Limit is 4 apps per season with no more than 2 sequential apps. Must tank mix or alternate with another effective fungicide from another FRAC group. Up to a 1 year plant back restriction for certain off label crops.
	11 & 7	Priaxor (pyraclostrobin + fluxapyroxad)	8 fl oz	24 fl oz	0	0.5	Limit is 3 apps per season; no more than 2 sequential apps. See label about compatibility with other formulated products and adjuvants.
	11 & 27	Tanos (famoxadone + cymoxanil)	8 oz	72 oz	3	0.5	Do not alternate or tank mix with other FRAC group 11 fungicides.
	40 & 3	Revus Top (mandipropamid + difenoconazole)	7 fl oz	28 fl oz	1	0.5	4 apps per season; no more than 2 sequential apps. Not labeled for transplants.
Sour Rot (*Geotrichum candidum*)	3	Mentor (propiconazole)	8 oz /100 gal or /50,000 lb of fruit	-	-	-	Apply as a post-harvest dip, drench, or high-volume spray for the post-harvest control of certain rots. See label for details.
Southern blight	7	Fontelis (penthiopyrad)	1.0 - 1.6 fl oz/ 1000 row-ft	24 fl oz	0	0.5	Apply at-plant, pre-plant incorporated, in-furrow, as a transplant drench, or by drip irrigation.
	11	Evito Aftershock (fluoxastrobin)	5.7 fl oz	22.8 fl oz	3	0.5	Limit is 4 appl/crop. Must alternate or tank mix with a fungicide from a different FRAC group.
(*suppression*)	11	Cabrio (pyraclostrobin)	16 oz	96 oz	0	0.5	Limit is 2 sequential applications before alternating to another effective fungicide from a different FRAC group.
(suppression)	11 & 7	Priaxor (pyraclostrobin + fluxapyroxad)	8 fl oz	24 fl oz	0	0.5	Limit is 3 apps per season; no more than 2 sequential apps. See label about compatibility with other formulated products and adjuvants.
	14	Blocker 4F Terraclor 75 WP (PCNB)	**SEE INDIVIDUAL LABELS**		Soil treatment at planting	0.5	See label for application type and restrictions.
(suppression)	19	Oso 5% SC (polyoxin D zinc salt)	13 fl oz	78 fl oz	0	4 hr	Alternate with a non-FRAC code 19 fungicide.

TOMATO FUNGICIDES (continued)

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Pertinent Diseases or Pathogens	Fungicide Group [1]	Chemical (active ingredients)	Max. Rate/Acre		Min. Days to		Remarks [2]
			Applic.	Season	Harvest	Reentry	
Target spot	M5	(chlorothalonil) **Many brands available:** Bravo Ultrex, Bravo Weather Stik, Bravo Zn, Chloronil 720, Echo 720, Echo 90 DF, Echo Zn, Equus 500 Zn, Equus 720 SST, Equus DF, Initiate 720	**SEE INDIVIDUAL LABELS**		0	0.5	Use higher rates at fruit set and lower rates before fruit set.
	4 & M5	Ridomil Gold Bravo 76.4 W (chlorothalonil + mefenoxam)	3 lb	12 lb	14	2	Limit is 4 appl./crop.
	7	Endura (boscalid)	12.5 oz	25 oz	0	0.5	Alternate with non-FRAC code 7 fungicides.
	7	Fontelis (penthiopyrad)	24 fl oz	72 fl oz	0	0.5	No more than 2 sequential apps. before switching to another effective fungicide with a different mode of action. See label for additional instructions pertaining to greenhouse useage.
	9	Scala SC (pyrimethanil)	7 fl oz	35 fl oz	1	0.5	Use only in a tank mix with another effective non-FRAC code 9 fungicide; has a 30 day plant back with off label crops.
	9 & 3	Inspire Super (cyprodinil + difenoconazole)	20 fl oz	47 fl oz	0	0.5	Limit is 5 apps./season with no more than 2 sequential apps. Must tank mix or alternate with another effective fungicide from another FRAC group. Has up to a 8 month plant back restriction with off label crops.
	11	Heritage Quadris FL (azoxystrobin)	3.2 oz 6.2 fl oz	1.6 lb 37 fl oz	0	4 hr	Must alternate or tank mix with a fungicide from a different FRAC group; use of an adjuvant or tank mixing with EC products may cause phytotoxicity.
	11	Cabrio 2.09 F (pyraclostrobin)	16 fl oz	96 fl oz	0	0.5	Only 2 sequential appl. Allowed. Limit is 6 appl/crop. Must alternate or tank mix with a fungicide from a different FRAC group.
	11	Evito Aftershock (fluoxastrobin)	5.7 fl oz	22.8 fl oz	3	0.5	Limit is 4 appl/crop. Must alternate or tank mix with a fungicide from a different FRAC group.
	11 & M5	Quadris Opti (azoxystrobin + chlorothalonil)	1.6 pt	8 pt	0	0.5	Must alternate with a non-FRAC code 11 fungicide; use of an adjuvant may cause phytotoxicity.
	11 & 3	Quadris Top (azoxystrobin + difenoconazole)	8 fl oz	47 fl oz	0	0.5	Limit is 4 apps per season with no more than 2 sequential apps. Must tank mix or alternate with another effective fungicide from another FRAC group. Has up to a 1 year plant back restriction for certain off label crops.
	11 & 7	Priaxor (pyraclostrobin + fluxapyroxad)	8 fl oz	24 fl oz	0	0.5	Limit is 3 apps per season; no more than 2 sequential apps. See label about compatibility with other formulated products and adjuvants.
	11 & 27	Tanos (famoxadone + cymoxanil)	8 oz	72 oz	3	0.5	Do not alternate or tank mix with other FRAC group 11 fungicides.
	40 & 3	Revus Top (mandipropamid + difenoconazole)	7 fl oz	28 fl oz	1	0.5	4 apps per season; no more than 2 sequential apps. Not labeled for transplants.
Timber Rot, Sclerotinia stem rot, or White mold (*Sclerotinia sclerotiorum*)	11	Heritage Quadris FL (azoxystrobin)	3.2 oz 6.2 fl oz	1.6 lb 37 fl oz	0	4 hr	Must alternate or tank mix with a fungicide from a different FRAC group; use of an adjuvant or tank mixing with EC products may cause phytotoxicity.
(*suppression*)	11	Cabrio 2.09 F (pyraclostrobin)	16 fl oz	96 fl oz	0	0.5	Only 2 sequential apps. allowed. Limit is 6 apps/crop. Must alternate or tank mix with a fungicide from a different FRAC group.
(suppression)	11 & 7	Priaxor (pyraclostrobin + fluxapyroxad)	8 fl oz	24 fl oz	0	0.5	Limit is 3 apps per season; no more than 2 sequential apps. See label about compatibility with other formulated products and adjuvants.

[1] FRAC code (fungicide group): Number (1 through 46) and letters (U and P) are used to distinguish the fungicide mode of action groups. All fungicides within the same group (with same number or letter) indicate same active ingredient or similar mode of action. This information must be considered for the fungicide resistance management decisions. U = unknown, or a mode of action that has not been classified yet and is typically associated with another number; P = host plant defense inducers. Source: FRAC Code List 2013; http://www.frac.info/ (FRAC = Fungicide Resistance Action Committee).

[2] Information provided in this table applies only to Florida. Be sure to read a current product label before applying any chemical. The use of brand names and any mention or listing of commercial products or services in the publication does not imply endorsement by the University of Florida Cooperative Extension Service nor discrimination against similar products or services not mentioned.

Tomato Biopesticides And Other Disease Control Products

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TOMATO BIOPESTICIDES AND OTHER DISEASE CONTROL PRODUCTS

Ordered alphabetically by commercial name. (Updated June 2014)

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Product (active ingredient), Fungicide Group[1]	Pertinent Diseases or Pathogens	Minimum Days to: Harvest	Minimum Days to: Reentry	OMRI Listed	Remarks[2]
Actinovate, ActinoGrow (*Streptomyces lydicus* WYEC 108), NC	*Alternaria* spp., Anthracnose, *Aphanomyces*, Botrytis, Charcoal Rot (*Macrophomina phaseolina*), Club root (*Plasmodiophora brassicae*), Downy Mildew, *Erwinia* spp., *Fusarium* spp., *Gaeumannomyces*, Powdery Mildew, Pseudomonas spp., *Phytophthora* spp., *Pythium* spp., *Rhizoctonia* spp., *Sclerotinia* spp., Southern Blight, Verticillium spp., *Xanthomonas* spp.	0	1 hr	Yes	See label for specific rates and application recommendations.
AgriPhage (bacteriophage), NC	Bacterial spot, Bacterial speck	0	0	No	Bacterial strains must be characterized preiodically by manufacturer to correctly formulate the bacteriophage mixture.
Armicarb 100 **Eco-mate Armicarb "O"** (potassium bicarbonate), NC	Anthracnose, Botrytis, Downy mildew, Phoma, Powdery mildew, Septoria leaf spot	0	4 hr	No	See label for specific rates and application recommendations.
Ballad Plus, (*Bacillus pumilus* strain QST 2808) NC	Bacterial blight, Brown spot, Cercospora leaf spot, Common Rust, Downy mildew, Northern and Southern leaf blight, Pseudomonas spp. Xanthomonas spp.	0	4 hr	No	See label for specific rates and application recommendations.
BioCover (Oil, petroleum)	Powdery mildew, Rust	0	4 hr	No	See label for specific rates, application recommendations, and precautions regarding use with other pesticides.
BIO-TAM (*Trichoderma asperellum* strain ICC 012 + *Trichoderma gamsii* strain ICC 080) NC	*Fusarium* spp., *Phytophthora* spp., *Pythium* spp., *Rhizoctonia* spp., *Sclerotinia* spp., *Sclerotium rolfsii*, *Thielaviopsis basicola*, and *Verticillium* spp.	-	1 hr	Yes	See label for additional rates and recommendations for transplant production and details for specific diseases. Check label for product incompatibility with certain chemical fungicides.
Cease (*Bacillus subtilis* strain QST 713), 44	Bacterial spot, Bacterial speck, Botrytis, Early Blight, Late Blight, Powdery mildew, Target spot, Rhizoctonia spp., Pythium spp., Fusarium spp., Verticillium spp., Phytophthora spp.	0	4 hr	Yes	For foliar applications mix with copper compounds or other effective fungicides. Compatible with soil drench and in-furrow applications. See label for specific rates and application recommendations.
Contans WG (*Coniothyrium minitans* strain CON/M/91-08)	*Sclerotinia sclerotiorum* and *Sclerotinia minor*	0	4 hr	Yes	See label for specific rates and application recommendations.
Double Nickel 55 **Double Nickel LC** (*Bacillus amyloliquefaciencs* strain D747), 44	*Alternaria* spp., Anthracnose, Bacterial diseases, Botrytis, Early blight, Late blight, *Phytophthora* spp., Powdery mildew, *Pythium* spp., Rhizoctonia, Fusarium spp., Rhizoctonia, Phytophthora spp., Pythium spp.	0	4 hr	Yes	See label for additional rates and recommendations for foliar and soil application rates and details for specific diseases. Use as a soil drench at transplant and periodically throughout the season. Can also be used as a seed treatment. See label for details.
Glacial Spray Fluid (Oil, petroleum), NC	Powdery mildew, Rust	0	4 hr	Yes	See label for specific rates, application recommendations, and precautions regarding use with other pesticides.
JMS Stylet-Oil **Organic JMS Stylet-Oil** (paraffinic oil), NC	Potato Virus Y, Tobacco Etch Virus, Cucumber Mosaic Virus	0	4 hr	Yes, but only for one label.	See label for specific rates, application recommendations, and precautions regarding use with other pesticides.
Kaligreen (potassium bicarbonate), NC	Powdery mildew	0	4 hr	Yes	See label for specific rates and application recommendations.
Milstop (potassium bicarbonate), NC	Anthracnose, *Alternaria* spp., Botrytis, Downy mildew, Powdery mildew	0	1 hr	Yes	See label for specific rates and application recommendations.
Oxidate 2.0 (mono- and di-potassium salts of phosphorous acid + hydrogen peroxide), 33 + NC	*Alternaria* spp., Anthracnose, Bacterial diseases, Botrytis, Early blight, Late blight, *Phytophthora* spp., Powdery mildew, *Pythium* spp., Rhizoctonia, Fusarium spp., Rhizoctonia, Phytophthora spp., Pythium spp.	0	1 hr for enclosed areas; until spray dries in open field areas.	No	See label for additional rates and recommendations for transplant production and details for specific diseases. Use as a soil drench at transplant and periodically throughout the season. Can also be used as a seed treatment.

Ordered alphabetically by commercial name. (Updated June 2014)

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BE SURE TO READ A CURRENT LABEL BEFORE APPLYING ANY PRODUCT.

Product (active ingredient), Fungicide Group[1]	Pertinent Diseases or Pathogens	Minimum Days to: Harvest	Minimum Days to: Reentry	OMRI Listed	Remarks[2]
OxiPhos (hydrogen peroxide), NC	Bacterial diseases, Gummy stem blight, Late blight, *Phytophthora* spp., *Pythium* spp., Phytophthora spp., Pythium spp.	0	4 hr	No	See label for recommedations for rates, application methods, and details for specific diseases.
(potassium phosphite; mono- and di-potassium salts of phosphorous acid), 33 **Many brands available:** Alude, Appear, Confine Extra T&O, Fosphite, Fungi-Phite, Helena Prophyt, K-Phite 7LP AG, Phorcephite, Phostrol, Rampart, Reveille	*Alternaria spp., Anthracnose, Bacterial diseases,* Downy mildew, *Fusarium* spp., Late blight, Leaf blights caused by *Cercospora* and *Septoria* spp., *Phytophthora* spp., Powdery mildew, *Pythium* spp., *Rhizoctonia* spp., Root rots	0	4 hr	No	See label for details, specific recommendations, and precautions for tank mixing with copper-based fungicides.
PlantShield HC (*Trichoderma harzianum* Rifai strain KRL-AG2), NC	*Fusarium* spp., Rhizoctonia, *Pythium* spp.	0	4 hr	Yes	Can be applied to plant as a direct drench, furrow spray, chemigation, or in transplant starter solution. See label for details.
Purespray Green (Oil, petroleum)	Powdery mildew, Rust	0	4 hr	Yes	See label for specific rates, application recommendations, and precautions regarding use with other pesticides.
Regalia SC (extract of *Reynoutria sachalinensis*), P	Bacterial canker , Bacterial speck, Bacterial spot, Botrytis, Early blight, Phytophthora spp., Powdery mildew, Target spot, Late blight	0	4 hr	Yes	Tank mix with other effective fungicides for improved disease control under heavy pressure. See label for details.
RootShield Granular (Trichoderma harzianum Rifai strain KRL-AG2), NC	*Fusarium* spp., Rhizoctonia, *Pythium* spp.	0	0	Yes	Granular formulation can be applied in furrow in the field, or to greenhouse planting mix. See label for details.
RootShield WP (*Trichoderma harzianum* Rifai strain KRL-AG2), NC	*Fusarium* spp., Rhizoctonia, *Pythium* spp.	0	Until spray has dried.	Yes	Can be applied as a greenhouse soil drench, or by chemigation in field and greenhouse operations. In furrow or transplant starter solution.
Serenade ASO **Serenade Max** (*Bacillus subtilis* strain QST 713), 44	Bacterial speck, Bacterial spot, Botrytis, Early Blight, Late Blight, Powdery mildew, Target spot	0	4 hr	Yes	For foliar applications mix with copper compounds or other effective fungicides for improved disease control. See label for details.
Serenade Soil (Bacillus subtilis strain QST 713), 44	*Fusarium* spp., *Phytophthora* spp., *Pythium* spp., *Rhizoctonia* spp., *Verticillium* spp.	0	4 hr	Yes	Formulation compatible with soil drench, in-furrow, and chemigation applications. Mix with other effective fungicides for improved disease control. See label for details.
Sil-Matrix (potassium silicate), NC	Broad spectrum fungicide	0	4 hr	No	Must be used in a rotational program with other fungicides when conditions are conducive for disease development. See label for details.
Soilgard 12G (Gliocladium virens GI-21), NC	Fusarium root and crown rot, *Phytophthora capsici, Pythium* spp., Rhizoctonia, *Sclerotinia* spp., *Sclerotium* spp.	0	0	Yes	For best results apply to transplants or as a drench during transplanting. Subsequent applications can be made as drench, directed spray, or by chemigation. Chemical fungicides should not be mixed with or applied to soil or plant media at the same time as SoilGard 12G. See label for details.
Sonata (*Bacillus pumilus* QST 2808), NC	Early Blight, Downy mildew, Late Blight, Powdery mildew, Rust	0	4 hr	Yes	Mix or alternate with other effective fungicides for improved disease control. See label for details.
Sporatec (oils of clove, rosemary and thyme), NC	Bacterial spot, Botrytis, Early blight, Gray mold, Late blight, Powdery mildew	0	0	Yes	Exercise care when applying. Begin applications once disease is observed. Use of a spreader and/or penetrant adjuvant recommended for improved performance. Do not apply when temps are above 90ºF. See label for details. Ingredients are exempt from FIFRA.
Taegro ECO (*Bacillus amyloliquefaciencs* strain FZB24), NC	Foliar diseases: Downy mildew, Powdery mildew, Pseudomonas spp., Xanthomonas spp.; Soilborne diseases: *Fusarium* spp., *Phytophthora* spp., *Pythium* spp., *Rhizoctonia* spp., *Sclerotinia* spp.	-	1 day	No	See label for specific instructions regarding soil injected, spray, or incorporated applications. Maximum of 12 applications per season. For best efficacy, product should be applied prior to disease or disease establishment. May be applied to greenhouse produced crops.
Tenet (*Trichoderma asperellum* ICC 012; *Trichoderma gamsii* ICC 080), NC	*Fusarium* spp., *Phytophthora* spp., *Pythium* spp., *Rhizoctonia* spp., *Sclerotium rolfsii*, *Sclerotinia* spp., *Thielaviopsis basicola*, and *Verticillium* spp.	0	1 hr	Yes	For best results apply 1 week prior to planting, with 2 or more additional applications throughout the production cycle. May be applied through fertigation systems in combination with most common fertilizers. Can be applied to fumigated soil after fumigant has dissipated. Tenet has no curative activity. See label for details regarding application and fungicide incompatibility.

TOMATO BIOPESTICIDES AND OTHER DISEASE CONTROL PRODUCTS (continued)

Ordered alphabetically by commercial name. (Updated June 2014)

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BE SURE TO READ A CURRENT LABEL BEFORE APPLYING ANY PRODUCT.

Product (active ingredient), Fungicide Group[1]	Pertinent Diseases or Pathogens	Minimum Days to: Harvest	Minimum Days to: Reentry	OMRI Listed	Remarks[2]
Terraclean (hydrogen dioxide), NC	Soilborne plant pathogens caused by species of *Fusarium, Phytophthora, Pythium,* and *Rhizoctonia*	0	0	No	Can be applied by flood irrigation, drip irrigation, or as a soil drench. See label for application details and instructions regarding applications with liquid fertilizer mixtures.
Trilogy (clarified hydrophobic extract of neem oil), NC	*Alternaria* spp., Anthracnose, Botrytis, Early blight, Powdery mildew	0	4 hr	Yes	See label for specific rates, application recommendations, and precautions regarding use with other pesticides.
Vacciplant (laminarin), P	Anthracnose, Bacterial speck, Bacterial spot, Early blight, Phytophthora blight, Powdery mildew	0	4 hr	No	Start applications preventively, when weather conditions are favorable for disease development. Repeat applications until disease conditions end. Add a labeled copper product to VacciPlant if the disease symptoms appear.

[1] FRAC code (fungicide group): Number (33 and 44) and letters (NC and P) are used to distinguish the fungicide mode of action groups. All fungicides within the same group (with same number or letter) indicate same active ingredient or similar mode of action. This information must be considered for the fungicide resistance management decisions. However, products with NC or P are considered low risk and don't require any rotation unless specifically directed on the label. NC = not classified, includes mineral oils, organic oils, potassium bicarbonate, and other materials of biological origin; P = host plant defense inducers. Source: FRAC Code List 2013; http://www.frac.info/ (FRAC = Fungicide Resistance Action Committee).

[2] Information provided in this table applies only to Florida. Be sure to read a current product label before applying any product. The use of brand names and any mention or listing of commercial products or services in the publication does not imply endorsement by the University of Florida Cooperative Extension Service nor discrimination against similar products or services not mentioned.

Selected Insecticides Approved for Use on Insects Attacking Tomatoes

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SELECTED INSECTICIDES APPROVED FOR USE ON INSECTS ATTACKING TOMATOES

Labels change frequently. Be sure to read a current product label before applying any chemical.

Trade Name (Active Ingredient, Mode of Action Number)	Rate (Product/ acre)	Maximum Rate	REI (hours)	PHI (days)	Insect or mite pest	Notes[2]
Acramite-50WS (bifenazate, un)	0.75-1.0 lb	One application allowed per season.	12	3	twospotted spider mite	One application per season. Field grown only. Acramite-50WS is not systemic in action; therefore complete coverage of both upper and lower leaf surfaces and of fruit is necessary for effective control.
Admire Pro (imidacloprid, 4A)	7-10.5 fl oz	Maximum allowed on tomato is 10.5 fl. oz/A.	12	21	aphids, Colorado potato beetle, flea beetles, leafhoppers, thrips (foliar feeding thrips only), whitefly	Application restrictions exist for this product because of risk to bees and other insect pollinators. Follow application restrictions found in directions for use to protect pollinators.
Admire Pro (imidacloprid, 4A)	0.6 fl oz per 1000 plants		12	0 (soil)	aphids, whitefly	Greenhouse use: 1 application to mature plants, see label for cautions.
Admire Pro (imidacloprid, 4A)	0.44 fl oz per 10,000 plants		12	21	aphids, whitefly	Planthouse: 1 application. See label.
Agree WG (*Bacillus thuringiensis* subspecies *aizawai*, 11)	0.5-2.0 lb		4	0	armyworms, hornworms, loopers, tomato fruitworm	Apply when larvae are small for best control. Can be used in greenhouse. OMRI-listed.

SELECTED INSECTICIDES APPROVED FOR USE ON INSECTS ATTACKING TOMATOES (continued)

Labels change frequently. Be sure to read a current product label before applying any chemical.

Trade Name (Active Ingredient, Mode of Action Number)	Rate (Product/ acre)	Maximum Rate	REI (hours)	PHI (days)	Insect or mite pest	Notes[2]
***AgriMek SC** (abamectin, 6)	1.75-3.5 fl oz	Do not apply more than 10.25 fl. oz./A in a growing season.	12	7	broad mite, Colorado potato beetle, *Liriomyza* leafminers, spider mite, *Thrips palmi*, tomato pinworm, tomato russet mite	Do not make more than 2 sequential applications of Agri-Mek SC or any other foliar applied abamectin-containing product in a growing season.
***Agri-Mek 0.15 EC** (abamectin, 6)	8.0-16.0 fl. oz	Do not apply more than 48 fl oz per acre per season.	12	7	broad mite, Colorado potato beetle, *Liriomyza* leafminers, spider mite, *Thrips palmi*, tomato pinworm, tomato russet mite	Do not make more than 2 sequential applications per season.
***Ambush 25W** (permethrin, 3A)	3.2-12.8 oz	Do not apply more than 76.8 oz/A per season.	12	up to day of harvest	beet armyworm, cabbage looper, Colorado potato beetle, granulate cutworm, hornworms, southern armyworm, tomato fruitworm, tomato pinworm	**Do not use on cherry tomatoes.** Not recommended for control of vegetable leafminer in Florida.
***Asana XL (0.66EC)** (esfenvalerate, 3A)	2.9-9.6 fl oz	Do not apply more than 0.5 lb ai per acre per season, or 10 applications at highest rate.	12	1	beet armyworm (aids in control), cabbage looper, Colorado potato beetle, cutworms, flea beetles, grasshoppers, hornworms, potato aphid, southern armyworm, tomato fruitworm, tomato pinworm, whitefly, yellowstriped armyworm	Not recommended for control of vegetable leafminer in Florida.
Assail 70WP (acetamiprid, 4A)	0.6-1.7 oz	Do not exceed a total of 6.8 oz. Assail 70 WP per acre per growing season including any pretransplant applications of acetamiprid.	12	7	aphids, Colorado potato beetle, thrips, whitefly	Do not apply to crop that has been already treated with imidacloprid or thiamethoxam at planting. Begin applications for whitefly when first adults are noticed. Do not make more than 4 applications per season. Do not apply more than once every 7 days.
Athena* (bifenthrin & abamectin, 3A & 6)	7-17 fl. oz/A	Do not apply more than 33.5 fl. oz./A in a growing season after transplanting.	12	7	tomato pinworm, broad mite, carmine spider mite, tomato russet mite, two spotted spider mite, leafminer spp. (adult), psyllids, thrips (adult), whitefly (adult); aphids, armyworms, cabbageworm, corn earworm, Colorado potato beetle, cucumber beetle (adult), cutworms, tobacco budworm	Do not make applications less than 10 days apart. Do not make more than 2 consecutive applications.
Avaunt (indoxacarb, 22)	2.5-3.5 oz	Do not apply more than 14 ounces of product per acre per crop. Minimum spray interval is 5 days.	12	3	beet armyworm, hornworms, loopers, southern armyworm, tomato fruitworm, tomato pinworm, suppression of leafminers	
Aza-Direct (azadirachtin, un)	1-2 pts, up to 3.5 pts, if needed		4	0	aphids, beetles, caterpillars, leafhoppers, leafminers, mites, stink bugs, thrips, weevils, whitefly	Antifeedant, repellant, insect growth regulator. OMRI-listed.
Azatin XL (azadirachtin, un)	5-21 fl oz		4	0	aphids, beetles, caterpillars, leafhoppers, leafminers, thrips, weevils, whitefly	Antifeedant, repellant, insect growth regulator.
***Baythroid XL** (beta-cyfluthrin, 3A)	1.6-2.8 fl oz	Do not apply more than 16.8 fl oz per acre per season.	12	0	beet armyworm, cabbage looper, Colorado potato beetle, dipterous leafminers, flea beetles, hornworms, potato aphid, southern armyworm, stink bugs, tomato fruitworm, tomato pinworm, variegated cutworm, thrips (except *Thrips palmi*), whitefly adults	
Belay 50 WDG (clothianidin, 4A)	1.6-2.1 oz (foliar application)	Do not apply more than 6.4 oz per acre per season.	12	7	aphids, Colorado potato beetle, flea beetles, leafhoppers, leafminers (suppression), Lygus, stink bugs, whiteflies (suppression)	Do not use an adjuvant. Toxic to bees. Do not release irrigation water from the treated area.
Belay 50 WDG (clothianidin, 4A)	4.8-6.4 oz (soil application)	Do not apply more than 6.4 oz per acre per season.	12	Apply at planting	aphids, Colorado potato beetle, flea beetles, leafhoppers, leafminers (suppression), Lygus, foliar feeding thrips, whiteflies (suppression)	See label for application instructions. Do not release irrigation water from the treated area.
Beleaf 50 SG (flonicamid, 9C)	2.0-2.8 oz	Do not apply more than 8.4 oz per acre per season.	12	0	aphids, plant bugs	Begin applications before pests reach damaging levels. Do not apply more than 2 applications per season. Allow a minimum of 7 days between applications.
Belt SC (flubendiamide, 28)	1.5 fl oz	Do not apply more than 4.5 oz per acre per crop season.	12	1	Beet armyworm, cabbage looper, cutworm species, fall armyworm, southern armyworm, tomato fruitworm, tomato hornworm, tomato pinworm, yellow striped armyworm	Do not apply more than 1.5 oz per acre per 3 day interval.
Biobit HP (*Bacillus thuringiensis* subspecies *kurstaki*, 11)	0.5-2.0 lb		4	0	caterpillars (will not control large armyworms)	Treat when larvae are young. Good coverage is essential. Can be used in the greenhouse. OMRI-listed.

SELECTED INSECTICIDES APPROVED FOR USE ON INSECTS ATTACKING TOMATOES (continued)

Labels change frequently. Be sure to read a current product label before applying any chemical.

Trade Name (Active Ingredient, Mode of Action Number)	Rate (Product/ acre)	Maximum Rate	REI (hours)	PHI (days)	Insect or mite pest	Notes[2]
***Brigade 2EC** (bifenthrin, 3A)	2.1-5.2 fl oz	Make no more than 4 applications per season.	12	1	aphids, armyworms, corn earworm, cutworms, flea beetles, grasshoppers, mites, stink bug spp., tarnished plant bug, thrips, whitefly	Do not make applications less than 10 days apart.
CheckMate TPW-F (pheromone, un)	1.2-6.0 fl oz		0	0	tomato pinworm	For mating disruption - See label for details.
Closer SC (sulfoxaflor, 4C)	1.5-4.5 fl. oz/A	Do not apply more than a total of 17 fl. oz./A per year.	12	1	aphids, plant bugs, whitefly, thrips (suppression only)	Do not make applications less than 7 days apart. Do not make more than four applications per crop. Do not make more than 2 consecutive applications per crop.
Confirm 2F (tebufenozide, 18)	6-16 fl oz	Do not apply more than 64 fl. oz./A per season.	4	7	armyworms, black cutworm, hornworms, loopers	Product is a slowacting IGR that will not kill larvae immediately.
Coragen (chlorantraniliprole/ rynaxypyr, 28)	3.5-7.5 fl oz	Do not apply more than 15.4 fl oz per acre per crop.	4	1	beet armyworm, Colorado potato beetle, fall armyworm, hornworms, leafminer larvae, loopers, southern armyworm, tomato fruitworm, tomato pinworm	Can be applied by drip chemigation or as a soil application at planting. See label for details.
Courier 40SC (buprofezin, 16)	9.0-13.6 fl oz	Do not apply more than 27.2 fl. oz./A per crop cycle.	12	1	leafhoppers, mealybugs, planthoppers, whitefly nymphs	Apply when a threshold is reached of 5 whitefly nymphs per 10 leaflets from the middle of the plant. Product is a slow-acting IGR that will not kill nymphs immediately. No more than 2 applications per season. Allow at least 5 days between applications.
Crymax WDG (*Bacillus thuringiensis* subspecies *kurstaki*, 11)	0.5-2.0 lb		4	0	armyworms, loopers, tomato fruitworm, tomato hornworm, tomato pinworm	Use high rate for armyworms. Treat when larvae are young.
***Danitol 2.4 EC** (fenpropathrin, 3A)	7-10.67 fl oz	Do not exceed 42.67 fl. oz. total application /A per season.	24	3	beet armyworm, cabbage looper, fruitworms, potato aphid, silverleaf whitefly, stink bugs, thrips, tobacco hornworm, tomato pinworm, twospotted spider mite, yellowstriped armyworm	
Deliver (*Bacillus thuringiensis* subspecies *kurstaki*, 11)	0.25-1.5 lb		4	0	armyworms, cutworms, loopers, tomato fruitworm, tomato pinworm	Use higher rates for armyworms. OMRI-listed.
***Diazinon AG500; *50 W** (diazinon, 1B)	**AG500:** 1-4 qt **50W:** 2-8 lb	Do not make more than one soil application per year regardless of target pest.	48	pre-plant	cutworms, mole crickets, wireworms	Incorporate into soil - see label.
Dimethoate 4 EC (dimethoate, 1B)	0.5-1.0 pt	Maximum total rate per year is 1 lb ai/A.	48	7	aphids, leafhoppers, leafminers	Minimum 6 day reapplication interval.
DiPel DF (*Bacillus thuringiensis* subspecies *kurstaki*, 11)	0.25-2.0 lb		4	0	caterpillars	Treat when larvae are young. Good coverage is essential. Can be used for organic production.
Durivo (thiamethoxam & chlorantraniliprole, 4A & 28)	10-13 fl oz	Do not exceed a total of 13.0 fl. oz./A per growing season.	12	30	aphids, beet armyworm, Colorado potato beetle, fall armyworm, flea beetles, hornworms, leafhoppers, loopers, southern armyworm, thrips, tomato fruitworm, tomato pinworm, whitefly, yellowstriped armyworm	Several methods of soil application – see label.
***Endigo ZC** (lambda-cyhalothrin & thiamethoxam, 3A & 4A)	4.0-4.5 fl oz	Do not exceed a total of 19.0 fl oz per acre per season.	24	5	aphids, blister beetles, cabbage looper, Colorado potato beetle, cucumber beetle adults, cutworms, fall, southern, and yellowstriped armyworm (1st and 2nd instars), flea beetles, grasshoppers, hornworms, leafhoppers, plant bugs, stink bugs, tomato fruitworm, vegetable weevil adult	See label for limits on each active ingredient.
Entrust (spinosad, 5)	0.5-2.5 oz	Do not apply more than 9 oz per acre per crop.	4	1	armyworms, Colorado potato beetle, flower thrips, hornworms, Liriomyza leafminers, loopers, tomato fruitworm, tomato pinworm	OMRI-listed2. For thrips, rotate to other class of effective insecticide after 2 applications of a Group 5 insecticide for at least 2 applications.
Esteem Ant Bait (pyriproxyfen, 7C)	1.5-2.0 lb		12	1	red imported fire ant	Apply when ants are actively foraging.
Extinguish ((S) methoprene, 7A)	1.0-1.5 lb		4	0	fire ants	Slowacting IGR (insect growth regulator). Best applied early spring and fall where crop will be grown. Colonies will be reduced after three weeks and eliminated after 8 to 10 weeks. May be applied by ground equipment or aerially.

SELECTED INSECTICIDES APPROVED FOR USE ON INSECTS ATTACKING TOMATOES (continued)

Labels change frequently. Be sure to read a current product label before applying any chemical.

Trade Name (Active Ingredient, Mode of Action Number)	Rate (Product/ acre)	Maximum Rate	REI (hours)	PHI (days)	Insect or mite pest	Notes[2]
Exirel (cyantraniliprole, 28)	7-20.5 fl. oz.	Do not apply a total of more than 0.4 lb ai/A per crop.	12	1	Beet armyworm, Colorado potato beetle, European corn borer, fall armyworm, southern armyworm, tomato fruitworm, tomato pinworm, tomato hornworm, loopers, green peach aphid, *Liriomyza* leafminers, pepper weevil (suppression), potato aphid, foliage feeding thrips (suppression), whitefly.	Application restrictions exist for this product because of risk to bees and other pollinators. Follow application restrictions found in the directions for use to protect pollinators. Minimum application interval between treatmenst is 5 days.
Fulfill (pymetrozine, 9B)	2.75 oz	Do not apply more than 5.5 oz/acre per crop.	12	0	green peach aphid, potato aphid, suppression of whitefly	(FL-040006) 24(c) label for growing transplants also (FL-03004).
Gladiator* (zeta-cypermethrin & avermectin B1, 3A & 6)	10-19 fl. oz.	Do not apply more than 57 fl. oz./A per 12-month cropping year.	12	7	Armyworms, corn earworm, cutworms, hornworms, tobacco budworm, tomato fruitworm, tomato pinworm, cucumber beetle, flea beetle, Colorado potato beetle, leafhoppers, aphids, brown stink bug, *Liriomyza* leafminers, broad mite, spider mites, tomato russet mite, *Thrips palmi*.	
Grandevo (*Chromobacterium subtsugae*, un)	1.0-3.0 lb		4	0	Armyworms, hornworms, loopers, tomato fruitworm, tomato pinworm, variegated cutworm, aphids, mites, thrips, whiteflies	Thorough coverage is necessary for effective control.
***Hero** (bifenthrin & zeta-cypermethrin, 3A)	4.0-10.3 oz	Do not apply more than 43.26 fl. oz./A per season.	12	1	Armyworms, cabbage looper, Colorado potato beetle, cucumber beetle, cutworms, flea beetles, grasshoppers, hornworms, leafhoppers, stink bugs, tobacco budworm, tomato fruitworm, tomato pinworm, vegetable leafminer, thrips, twospotted spider mite, whiteflies	Do not make more than 4 applications per season. Do not make applications less than 10 days apart.
Intrepid 2F (methoxyfenozide, 18)	4-16 fl oz	Do not apply more than 64 fl oz per acre per season.	4	1	beet armyworm, cabbage looper, fall armyworm, hornworms, southern armyworm, true armyworm, yellowstriped armyworm, suppression of tomato fruitworm and tomato pinworm	Product is a slow-acting IGR that will not kill larvae immediately.
Javelin WG (*Bacillus thuringiensis* subspecies *kurstaki*, 11)	0.12-1.5 lb		4	0	most caterpillars, but not *Spodoptera* species (armyworms)	Treat when larvae are young. Thorough coverage is essential. OMRI-listed[2].
Kanemite 15 SC (acequinocyl, 20B)	31 fl oz	Do not apply more than 62 fl. oz/A per season.	12	1	twospotted spider mite	Do not use less than 100 gal per acre. Make no more than 2 applications at least 21 days apart.
Karate with Zeon* (lambdacyhalothrin, 3A)	0.96-1.92 fl. oz.	Do not apply more than 23.04 fl. oz. /A per season.	24	5	beet armyworm, fall armyworm, yellow striped armyworm, cabbage looper, cutworms, hornworms, tobacco budworm, tomato fruitworm, tomato pinworm, aphids, Colorado potato beetle, Cucumber beetle, flea beetles, grasshoppers, leafhoppers, leafminers, spider mites, stink bugs, thrips (except western flower thrips), whiteflies.	
Knack IGR (pyriproxyfen, 7C)	8-10 fl oz	Do not exceed 20 fl. oz./A per season.	12	14	immature whitefly	Apply when a threshold is reached of 5 nymphs per 10 leaflets from the middle of the plant. Product is a slow-acting IGR that will not kill nymphs immediately. Make no more than two applications per season. Treat whole fields.
***Lannate LV** (methomyl, 1A) **Lannate SP**	**LV:** 1.5-3.0 pt **SP:** 0.5-1.0 lb	Do not apply more than 21 pt LV/acre/crop (15 for tomatillos) or 7 lb SP /acre/crop (5 lb for tomatillos).	48	1	aphids, armyworm, beet armyworm, fall armyworm, hornworms, loopers, southern armyworm, tomato fruitworm, tomato pinworm, variegated cutworm	
Leverage* 360 (beta-cyfluthrin & imidacloprid, 3A & 4A)	3.8-4.1		12	0	Aphids, early instar beet armyworm, southern armyworm, and yellowstriped armyworm, cabbage looper, Colorado potato beetle, leafhoppers, thrips (except Thrips palmi), stink bugs, tarnished plant bug, tomato fruitworm, tomato hornworm, tomato pinworm, variegated cutworm.	
Malathion 5 (malathion, 1B)	1.0-2.5 pt	10 pints	12	1	aphids, *Drosophila*, spider mites	8F can be used in greenhouse.

SELECTED INSECTICIDES APPROVED FOR USE ON INSECTS ATTACKING TOMATOES (continued)

Labels change frequently. Be sure to read a current product label before applying any chemical.

Trade Name (Active Ingredient, Mode of Action Number)	Rate (Product/acre)	Maximum Rate	REI (hours)	PHI (days)	Insect or mite pest	Notes[2]
Malathion 8 F	1.5 pt					
MBI-203 EP (*Chromobacterium subtsugae,* un)	4.0-12.0 quarts		4	0	Loopers, hornworms, tomato fruitworm, variegated cutworm, saltmarsh caterpillar, armyworms, tomato pinworm	OMRI listed. Can be used in the greenhouse.
MET52 EC (*Metarhizium anispoliae* strain F52, un)	drench: 40-80 fl. oz.; foliar: 0.5 pint - 2qt	0	0	Thrips, white-flies, mites	unk.	**MET52 EC** (*Metarhizium anispoliae* strain F52)
Movento (spirotetramat, 23)	4.0-5.0 fl oz	Maximum of 10 fl oz/acre per season.	24	1	aphids, psyllids, whitefly, broad mites, tomato russet mite. Pests suppressed: leafminers, two spotted spider mite, western flower thrips larvae	
M-Pede 49% EC (Soap, insecticidal, un)	1-2% V/V		12	0	aphids, leafhoppers, mites, plant bugs, thrips, whitefly	OMRI-listed
Mycotrol O (*Beauveria bassiana* strain GHA, un)	0.5 quart -1 quart/100 gallons		4	0	whitefly, aphids, thrips	OMRI Listed
***Mustang** (zeta-cypermethrin, 3)	2.4-4.3 oz	Do not apply more than 25.8 fl. oz./A per season.	12	1	beet armyworm, cabbage looper, Colorado potato beetle, cutworms, fall armyworm, flea beetles, grasshoppers, green and brown stink bugs, hornworms, leafminers, leafhoppers, *Lygus* bugs, plant bugs, southern armyworm, tobacco budworm, tomato fruitworm, tomato pinworm, true armyworm, yellowstriped armyworm. Aids in control of aphids, thrips and whitefly.	Not recommended for vegetable leafminer in Florida. Do not make applications less than 7 days apart.
Neemix 4.5 (azadirachtin, un)	4.0-16.0 fl oz		12	0	aphids, armyworms, hornworms, psyllids, Colorado potato beetle, cutworms, leafminers, loopers, tomato fruitworm (corn earworm), tomato pinworm, whitefly	IGR, feeding repellant. OMRI-listed.
Oberon 2SC (spiromesifen, 23)	7.0-8.5 fl oz	Maximum amount per crop: 25.5 fl oz/A.	12	1	broad mite, twospotted spider mite, whiteflies (eggs and nymphs)	No more than 3 applications.
PFR-97 (*Isaria fumosorosea* Apopka strain 97, un)	1.0-2.0 lbs		4	0	Aphids, broad mites, rust mites, spider mites, leafminers, thrips, whiteflies	Repeat applications at 3-10 days are needed to maintain control. Can be used in greenhouse for food crop transplants raised to be planted into the field. OMRI listed.
Platinum (thiamethoxam, 4A)	5-11 fl oz	Do not exceed a total of 11 fl. oz. Platinum/A per growing season.	12	30	aphids, Colorado potato beetles, flea beetles, leafhoppers (suppression), thrips, tomato pinworm, whitefly	Soil application. Not for use in nurseries, plant propagation houses, greenhouses, or on plants grown for use as transplants. See label for rotational restrictions. Do not use with other neonicotinoid insecticides
Platinum 75 SG	1.66-3.67 oz	Do not exceed a total of 3.67 Platinum 75 SG/A per growing season.				
Portal XLO (fenpyroximate, 21A)	2.0 pt	Do not apply more than 4.0 pints/A per crop cycle.	12	1	mites, including broad mites; whitefly	Do not make more than two applications per growing season. Allow 14 days between applications.
***Pounce 25 WP** (permethrin, 3A)	3.2-12.8 oz		12	0	beet armyworm, cabbage looper, Colorado potato beetle, dipterous leafminers, granulate cutworm, hornworms, southern armyworm, tomato fruitworm, tomato pinworm	Do not apply to cherry or grape tomatoes (fruit less than 1 inch in diameter). Do not apply more than 0.6 lb ai per acre per season.
***Proaxis Insecticide** (gamma-cyhalothrin, 3A)	1.92-3.84 fl oz	Do not apply more than 2.88 pints per acre per season.	24	5	blister beetles, cabbage looper, Colorado potato beetle, cucumber beetles (adults), cutworms, hornworms, flea beetles, grasshoppers, leafhoppers, plant bugs, stink bugs, tobacco budworm, tomato fruitworm, tomato pinworm, vegetable weevil (adult); first and second instar only of the following Lepidoptera: beet armyworm, fall armyworm, southern armyworm, yellowstriped armyworm; suppression of: aphids, spider mites, thrips, whitefly	

SELECTED INSECTICIDES APPROVED FOR USE ON INSECTS ATTACKING TOMATOES (continued)

Labels change frequently. Be sure to read a current product label before applying any chemical.

Trade Name (Active Ingredient, Mode of Action Number)	Rate (Product/ acre)	Maximum Rate	REI (hours)	PHI (days)	Insect or mite pest	Notes[2]
***Proclaim** (emamectin benzoate, 6)	2.4-4.8 oz	No more than 28.8 oz/A per season.	12	7	beet armyworm, cabbage looper, fall armyworm, hornworms, southern armyworm, tobacco budworm, tomato fruitworm, tomato pinworm, yellowstriped armyworm	Do not use in greenhouses, nurseries, plant propagation houses, or on any plants grown for use as transplants.
Provado 1.6F (imidacloprid, 4A)	3.8-6.2 fl oz	Maximum per crop per season 19.2 fl oz/A.	12	0	aphids, Colorado potato beetle, leafhoppers, whitefly	Do not apply to crop that has been already treated with imidacloprid or thiamethoxam at planting.
Pyganic Crop Protection EC 5.0 II (pyrethrins, 3)	4.5-18.0 fl oz	11.25 pints.	12	0	aphids, beetles, caterpillars, grasshoppers, leafhoppers, leafminers, mites, plant bugs, thrips, whiteflies	Pyrethrins degrade rapidly in sunlight. Thorough coverage is important. OMRI-listed. Do not apply more than 10 times per season.
Radiant SC (spinetoram, 5)	5-10 fl oz.	Do not apply more than 34 fl. oz./A per calendar year.	4	1	armyworms (except yellow-striped), Colorado potato beetle, flower thrips, hornworms, *Liriomyza* leafminers, loopers, *Thrips palmi*, tomato fruitworm, tomato pinworm	For thrips, if additional treatment is needed after two applications, switch to an alternate mode of action (not group 5) for at least two applications.
Requiem 25EC (extract of *Chenopodium ambrosioides*, un)	2-4 qt	Limited to 10 applications per crop cycle.	4	0	chilli thrips, eastern flower thrips, Florida flower thrips, green peach aphid, *Liriomyza* leafminers, melon thrips, potato aphid, western flower thrips, silverleaf whitefly	Begin applications before pests reach damaging levels.
Rimon 0.83EC (novaluron, 15)	9.0-12.0 fl oz	Do not apply more than 36 fl oz per acre per season.	12	1	armyworms, Colorado potato beetle, foliage feeding caterpillars, loopers, tomato fruitworm, tomato hornworm, tomato pinworm. Suppression of immature plant bugs, stink bugs, thrips, whiteflies.	Minimum of 7 days between applications.
Safari 20 SG (dinotefuran, 4A)	7.0-14.0 oz		12	1	Aphids, leafminers, whiteflies	For transplant production only. Can be applied as foliar spray or soil drench.
Scorpion (dinotefuran, 4A)	Soil: 9-10.5 fl. oz.; foliar: 2-7 fl. oz.	Do not apply more than 21 fl. oz/A per season as a soil application. Do not apply more than 10.5 fl. oz/A per season foliarly.	12	1	Stink bugs, cucumber beetle, flea beetle, leafhoppers, leafminers, aphids, thrips, whiteflies	Application restrictions exist for this product because of risk to bees and other insect pollinators. Follow application restrictions found in the directions for use to protect pollinators. Do not combine soil and foliar applications. Use one method or the other.
Sevin 80S; XLR; 4F (carbaryl, 1A)	**80S:** 0.63-2.5 **XLR; 4F:** 0.5-2.0 A	Do not apply a total of more than 10 lb or 8 qt per acre per crop.	12	3	Colorado potato beetle, cutworms, fall armyworm, flea beetles, lace bugs, leafhoppers, plant bugs, tomato fruitworm, tomato hornworm, tomato pinworm. Suppression of thrips and stinkbugs.	Do not apply more than seven times.
10% Sevin Granules (carbaryl, 1A)	20 lb		12	3	ants, centipedes, crickets, cutworms, earwigs, grasshoppers, millipedes, sowbugs, springtails	Maximum of 4 applications, not more often than once every 7 days.
Sivanto 200 SL (flupyradifurone, 4D)	7.0-14.0 fl. oz.	Do not apply more than 28.0 fl. oz./A per year.	4	1	leafhoppers, aphids, Colorado potato beetle, psyllids, whiteflies. Suppression of *Scirtothrips dorsalis*.	Minimum interval between applications: 7 days.
SuffOil-X (unsulfonated residue of petroleum oil, un)	1-2 gallons per 100 gallons of water.		4		Aphids, beetle larvae, leafhoppers, leafminers, mites, thrips, whiteflies	OMRI listed.
Sulfur (many brands, un)			24		tomato russet mite, two spotted spider mite	May burn fruit and foliage when temperature is high. Do not apply within 2 weeks of an oil spray or EC formulation.
Surround WP (kaolin, un)	12.5-50 lbs		4	0	cucumber beetles, flea beetles, grasshoppers, leafhoppers, thrips	OMRI listed.
Trigard (cyromazine, 17)	2.66 oz	Do not apply more than 15.96 oz./A per season.	12	0	Colorado potato beetle (suppression of), leafminers	No more than 6 applications per crop. Does not control CPB adults. Most effective against 1st & 2nd instar larvae.
Ultra Fine Oil, Saf-T-Side, others (stylet oil, un)	1.0-2.0 gal/100 gal		4	0	aphids, beetle larvae, leafhoppers, leafminers, mites, thrips, whitefly, aphid-transmitted viruses (JMS)	Do not exceed four applications per season.
Venom 20 SG (dinotefuran, 4A)	**foliar:** 0.44-0.895 lb	Do not apply more than 1.34 lb./A per season.	12	1	Colorado potato beetle, flea beetle, green peach aphid, leafhopper, leafminer, potato aphid, thrips, whiteflies	Use only one application method (soil or foliar). Limited to three applications per season. Toxic to honeybees.
Venom 20 SG (dinotefuran, 4A)	**soil:** 1.13-1.34 lb	Do not apply more than 2.68 lb/A per season.	12	21	Colorado potato beetle, flea beetle, green peach aphid, leafhopper, leafminer, potato aphid, thrips, whiteflies	Use only one application method (soil or foliar). Must have supplemental label for rates over 6.0 oz/acre.

SELECTED INSECTICIDES APPROVED FOR USE ON INSECTS ATTACKING TOMATOES (continued)

Labels change frequently. Be sure to read a current product label before applying any chemical.

Trade Name (Active Ingredient, Mode of Action Number)	Rate (Product/ acre)	Maximum Rate	REI (hours)	PHI (days)	Insect or mite pest	Notes[2]
Verimark (cyantraniliprole, 28)	5-13.5 fl. oz.	Do not apply more than 0.4 lb ai/A per crop.	4	1	armyworms, loopers, tomato fruitworm, tomato pinworm, flea beetles, green peach aphid, potato aphid (suppression), *Liriomyza* leafminers, thrips (foliage feeding only), whitefly	
Vetica (flubendiamide & buprofezin, 28 & 16)	12.0-17.0 fl oz	Do not apply more than 38 fl oz/A per season.	12	1	armyworms, cabbage looper, cutworms, garden webworm, saltmarsh caterpillar, tobacco budworm, tomato hornworm, tomato fruitworm, tomato pinworm, suppression of leafhoppers, mealybugs, and whiteflies	Do not apply more than 3 times per season or apply more than 38 fl oz per acre per season. Same classes of active ingredients as Belt, Synapse, Coragen (all group 28), and Courier (group 16).
Voliam Flexi (thiamethoxam & chlorantraniliprole, 4A & 28)	4.0-7.0 oz	Do not exceed 14 oz/A per season.	12	1	aphids, beet armyworm, Colorado potato beetle, fall armyworm, flea beetles, hornworms, leafhoppers, loopers, southern armyworm, stink bugs, tobacco budworm, tomato fruitworm, tomato pinworm, whitefly, yellowstriped armyworm, suppression of leafminer	Do not use in greenhouses or on transplants. Do not use if seed has been treated with thiamethoxam or if other Group 4A insecticides will be used. Highly toxic to bees.
*__Voliam Xpress__ (lambda-cyhalothrin & chlorantraniliprole, 3A & 28)	5.0-9.0 fl oz	Do not apply more than 31.0 fl oz /A per season.	24	5	Aphids, armyworms, Colorado potato beetle, cucumber beetle adults, flea beetles, leafhoppers, leafminers, stink bugs, thrips (suppression - does not include Western flower thrips), tobacco budworm, tomato fruitworm, tomato pinworm, whiteflies (suppression)	
***Vydate L** (oxamyl, 1A)	**foliar:** 2.0-4.0 pt	Do not apply more than 32 pts/A per season.	48	3	aphids, Colorado potato beetle, *Liriomyza* leafminers (suppression), whiteflies (suppression)	
***Warrior II** (lambdacyhalothrin, 3A)	0.96-1.92 fl oz	Do not apply more than 23.04 fl. oz/A per season.	24	5	beet armyworm, cabbage looper, Colorado potato beetle, cutworms, fall armyworm, flea beetles, grasshoppers, hornworms, leafhoppers, plant bugs, southern armyworm, stink bugs, thrips, tomato fruitworm, tomato pinworm, vegetable weevil adults, yellowstriped armyworm; Suppression of aphids, leafminers, whitefly	
Xentari DF (*Bacillus thuringiensis* subspecies *aizawai*, 11)	0.5-2.0 lb		4	0	caterpillars	Treat when larvae are young. Thorough coverage is essential. May be used in the greenhouse. Can be used in organic production. OMRI-listed.

[1] Mode of Action (MOA) codes for plant pest insecticides from the Insecticide Resistance Action Committee (IRAC) Mode of Action Classification v. 7.2 April 2012. Number codes (1 through 28) are used to distinguish the main insecticide mode of action groups, with additional letters for certain sub-groups within each main group. All insecticides within the same group (with same number) indicate same active ingredient or similar mode of action. This information must be considered for the insecticide resistance management decisions. un = unknown, or a mode of action that has not been classified yet.

[2] Information provided in this table applies only to Florida. Be sure to read a current product label before applying any product. The use of brand names and any mention or listing of commercial products or services in the publication does not imply endorsement by the University of Florida Cooperative Extension Service nor discrimination against similar products or services not mentioned. OMRI listed: Listed by the Organic Materials Review Institute for use in organic production.

*** Restricted use insecticide.**

Nematicides Registered for Use on Florida Tomato

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		Row Application (6' row spacing - 36" bed)[4]			
Product	Broadcast (Rate)	Recommended Chisel Spacing	Chisels (per Row)	Rate/Acre	Rate/1000 Ft/Chisel
FUMIGANT NEMATICIDES					
Methyl Bromide[1,3] 50-50	300-480 lb	12"	3	250 lb	6.8-11.0 lb
Chloropicrin EC[1]	300-500 lb	Drip applied	See label for use guidelines and additional considerations		
Chloropicrin[1]	300-500 lb	12"	3	150-200 lb	6.9-11.5 lb
Dimethyl Disulfide[1]	35-51 gal	12"	3	17.5 – 25.5	102-149 fl oz
PIC Clor 60[1]	19.5 – 31.5 gal	12"	3	20-25 gal 250-300 lb	117- 147 fl oz
Telone II[2]	9 -18 gal	12"	3	6 -9.0 gal	35-53 fl oz
Telone EC[2]	9 -18 gal	Drip applied	See label for use guidelines and additional considerations		
Telone C-17[2]	10.8-17.1 gal	12"	3	10.8-17.1 gal	63-100 fl oz
Telone C-35[2]	13-20.5 gal	12"	3	13-20.5 gal	76-120 fl oz
Telone Inline[2]	13-20.5 gal	Drip applied	See label for use guidelines and additional considerations		
Metam sodium	50-75 gal	5"	6	25-37.5 gal	73-110 fl oz
Metam potassium	30-62 gal	5"	6	15-31.0 gal	44-91 fl oz
Dominus (AITC[5])	10-40 gal	Drip applied	See label for use guidelines and additional considerations		
NON-FUMIGANT NEMATICIDES					
Vydate L – is currently not available for purchase within commercial markets. Dupont production of the product will not resume until government agencies and DuPont complete investigations into the fire which destroyed the manufacturing facility and obtains government approval on how to safely restart the production process. For users holding Vydate, treat soil before or at planting with any other appropriate nematicide or a Vydate transplant water drench followed by Vydate foliar sprays at 7-14 day intervals through the season; do not apply within 7 days of harvest; refer to directions in appropriate "state labels", which must be in the hand of the user when applying pesticides under state registrations.					

1. If treated area is tarped with impermeable film, dosage may be reduced by 40-50%. All crop and Florida county uses of Dimethyl Disulfide (DMDS) now mandatorily required totally impermeable mulch film (TIF).

2. The manufacturer of Telone II, Telone EC, Telone C-17, Telone C-35, and Telone Inline has restricted use only on soils that have a relatively shallow hard pan or soil layer restrictive to downward water movement (such as a spodic horizon) within six feet of the ground surface and are capable of supporting seepage irrigation regardless of irrigation method employed. Crop use of Telone products do not apply to the Homestead, Dade county production regions of south Florida. Higher label application rates are possible for fields with cyst-forming nematodes. Consult manufacturers label for personal protective equipment and other use restrictions which might apply.

3. As a grandfather clause, it is still possible to continue to use methyl bromide on any previous labeled crop as long as the methyl bromide used comes from existing supplies produced prior to January 1, 2005. A critical use exemption (CUE) for continuing use of methyl bromide was not awarded for tomato, pepper and eggplant for calendar year during 2014 or for 2015. As of January 1, 2014, **all of the prior approved CUE uses of methyl bromide for these crops finally came to an end in Florida**. Specific, certified uses and labeling requirements for any methyl bromide acquired for field use must now be certified and labeled as coming from existing stock from distributors prior to grower purchase and use in these crops. Methyl bromide products purchased and farm delivered as CUE stock before December 31, 2013 are still available for future use. Product formulations are subject to change and availability.

4. Rate/acre estimated for row treatments to help determine the approximate amounts of chemical needed per acre of field. If rows are closer, more chemical will be needed per acre; if wider, less. Reduced rates are possible with use of gas impermeable mulches.

5. Allyl isothiocyanate (AITC)

Rates are believed to be correct for products listed when applied to mineral soils. Higher rates may be required for muck (organic) soils. Growers have the final responsibility to guarantee that each product is used in a manner consistent with the label. The information was compiled by the author as of June 22, 2015 as a reference for the commercial Florida tomato grower. The mentioning of a chemical or proprietary product in this publication does not constitute a written recommendation or an endorsement for its use by the University of Florida, Institute of Food and Agricultural Sciences, and does not imply its approval to the exclusion of other products that may be suitable. Products mentioned in this publication are subject to changing Environmental Protection Agency (EPA) rules, regulations, and restrictions such as requirements for buffer zones, fumigant management plans (FMP), post application summary reports, mandatory good agricultural practices, and EPA approved certified applicator fumigant product training. Additional products may become available or approved for use.

Notes