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Target Spot Resistance Screening; and UF/IFAS Hybrid Outlook

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TARGET SPOT

INTRODUCTION

Target spot, caused by the fungus *Corynespora cassiicola*, is a common disease of tomato in Florida that affects all aerial portions of the plant (leaves, stems and fruit). In favorable conditions for disease development, it has the potential to cause serious problems with defoliation and fruit rots, leading to dramatic yield reductions. Because there are no commercially available resistant varieties, growers are reliant on the timely application of fungicides for disease management. In recent years, growers have observed a rise in the severity and frequency of target spot outbreaks, with only limited levels of success managing the disease. Moreover, there is growing evidence that fungicide resistance is jeopardizing the effectiveness of several classes of fungicides.

Grower demand for additional research to limit production losses to target spot resulted in a 2016-17 Florida Department of Agriculture and Consumer Services (FDACS) Specialty Crop Block Grant. One aspect of this research project focuses on developing integrated disease management approaches, while another involves the screening of tomato germplasm to identify novel sources of resistance. The long-term goal of the latter is the development of commercial hybrids with resistance to target spot.

Previous screening efforts have had limited success toward the identification of target spot-resistant germplasm. Bliss et al. (1973) reported only two highly resistant accessions from more than 200 that were screened (PI 120265 and PI 112215). But although Scott and Gardner (2007) described PI 120265 as providing effective resistance in Florida, Smith et al. (2006) reported a susceptible response in this PI. More recently, G. Vallad screened 155 accessions using greenhouse assays. In these tests, PI 120265 showed only slight resistance, but several accessions were identified which were more resistant than this PI (unpublished data).

Our goal is to identify novel sources of resistance to *C. cassiicola* among *Solanum* spp. that are more closely-related to cultivated tomato. Here, we report on the results of our initial screening efforts.

MATERIALS AND METHODS

Seed of Solanum accessions were obtained from the Tomato Genetics Resource Center in Davis, CA. 'Sanibel' and 'Florida 47' were included as controls. Seed were sown directly into 128-well transplant trays. Transplants were grown in a greenhouse for six to seven weeks before being subjected to disease screens. Screens were conducted in a growth room set at 26/22°C day/night temperature and a 12:12 photoperiod. Transplants were arranged in individual Speedling trays (each tray containing each commercial control) and misted to run-off with inoculum. Inoculum was prepared from one week old fungal colonies grown on half-strength potato dextrose agar incubated at room temperature under continuous light, then adjusted to a 1 x 104 conidia per ml plus Tween 20 (0.01%, v/v). Immediately after inoculation, trays were covered with inverted Tupperware® bins to maintain high humidity. Inoculated plants were maintained in the growth room for 72 hours, and then evaluated for disease response relative to controls.

RESULTS AND DISCUSSION

We screened 83 accessions representing nine different *Solanum* spp. Our results identified seven of these accessions as resistant and 22 as moderately-resistant. The rest were susceptible or moderately-susceptible. Resistant accessions were identified among *S. lycopersicum, S. habrochaites, S. cheesmaniae,* and *S. pimpinellifolium* spp. This is advantageous for breeding, since all of these are compatible with cultivated tomato. Ongoing work will involve re-screening of better accessions to validate resistance, and evaluation of resistant accessions in replicated field trials. Ultimately, the identification and introgression of durable resistance to target spot could greatly reduce the need for fungicide applications to manage this disease.

HYBRID OUTLOOK

STAKED TOMATOES

Fla. 8970 is a recent UF/IFAS hybrid release. The hybrid has large fruit, high yield potential, and consistently high marketability. Resistances are to TYLCV and FCR.

Fla. 8982 is a large-fruited, heat tolerant hybrid with resistances to TSWV and to Fusarium wilt races 1-3. It has performed consistently well across multiple field trials, demonstrating high yield potential. Fruit are crimson and resistant to graywall.

Fla. 8983 is a new hybrid with resistances to TSWV and to Fusarium wilt races 1-3. Fruit are medium to large (approx. 160 g), crimson, resistant to graywall, and have very good eating quality. Further evaluations are underway to determine suitability as a premium quality variety.

COMPACT GROWTH HABIT (CGH) TOMATOES

CGH hybrids were evaluated on a grower field in Homestead in winter 2016-17 and at Gulf Coast Research and Education Center (GCREC) in spring 2017. All trials were subjected to a once-over harvest at maturity (~80% vine ripe in Homestead; ~25% vine ripe at GCREC). Total marketable yields in Homestead exceeded 1,200 boxes/acre (>860 boxes XL) for some hybrids. At GCREC, total and XL yields exceeded 2,400 and 1,200 boxes/acre.

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Table 1. Disease response of 83 *Solanum* accessions and controls to target spot infection (*Corynespora cassiicola*).

Accession	Species	Response[1]
LA2094	*S. lycopersicum*	R
LA2099	*S. habrochaites*	R
LA0522	*S. cheesmaniae*	R
LA0932	*S. cheesmaniae*	R
LA0749	*S. cheesmaniae*	R
LA1447	*S. cheesmaniae*	R
LA2093	*S. pimpinellifolium*	R
LA1617	*S. pimpinellifolium*	MR
LA2173	*S. pimpinellifolium*	MR
LA2102	*S. pimpinellifolium*	MR
LA0422	*S. cheesmaniae*	MR
LA1042	*S. cheesmaniae*	MR
LA1043	*S. cheesmaniae*	MR
LA1427	*S. cheesmaniae*	MR
LA0421	*S. cheesmaniae*	MR
LA0521	*S. cheesmaniae*	MR
LA0524	*S. cheesmaniae*	MR
LA0528B	*S. cheesmaniae*	MR
LA0746	*S. cheesmaniae*	MR
LA1037	*S. cheesmaniae*	MR
LA1040	*S. cheesmaniae*	MR
LA1138	*S. cheesmaniae*	MR
LA1402	*S. cheesmaniae*	MR
LA1404	*S. cheesmaniae*	MR
LA1414	*S. cheesmaniae*	MR
LA0526	*S. galapagense*	MR
LA1721	*S. habrochaites*	MR
LA1322	*S. neorickii*	MR
LA2190	*S. neorickii*	MR
15 accessions	*S. cheesmaniae (6), S. pennellii (3), S. chmielewskii (2), S. peruvianum (1), S. habrochaites (1), S. chilense (2)*	MS
39 accessions	*S. pennellii (29), S. habrochaites (2), S. chilense (2), S. peruvianum (2), S. pimpinellifolium (2), S. cheesmaniae (1), S. lycopersicum (1), S. cheesmaniae (1)*	S
Florida 47	*S. lycopersicum*	S
Sanibel	*S. lycopersicum*	S

[1] Average disease response: R = resistant, MR = moderately-resistant, MS = moderately-susceptible, S = susceptible.

Genetics of the Compact Growth Habit Trait

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Tomato yield in Florida has increased steadily throughout the years due to increase in genetic potential and advances in horticultural practices. Nonetheless, further improvement in horticultural performance is still necessary, especially given rapidly growing labor costs and increased competition from international production (United States Department of Agriculture Economic Research Service; USDA ERS; www.ers.usda.gov). Unlike processing tomatoes, much of the fresh-market tomato production in the U.S. relies heavily on manual labor for staking, tying, pruning and harvesting. The fresh-market tomato industry urgently needs solutions that contribute to reduced production costs and, especially, to a reduced dependence on manual labor. The development of mechanically-harvestable fresh-market tomato varieties is an attractive goal that may address this.

Compact growth habit (CGH) of tomatoes refers to a plan type with determinate growth, shortened internodes, and a spreading characteristic resulting from increased side branching (Burton et al. 1955; Kemble et al. 1994a, 1994b; Frasca et al. 2014). Unlike tomatoes with normal growth habit, CGH tomatoes have a concentrated fruit set and do not require staking, tying or pruning. Therefore, CGH is one of the most important traits to be incorporated into fresh-market tomatoes to make them suitable for machine harvest.

The tomato *br* (*br*achytic) qualitative locus has been utilized to achieve CGH plant type in the UF/IFAS tomato breeding program. The *br* has been described previously (MacArthur, 1931; Burton et al. 1955), but it has not been cloned yet. The genetic and molecular basis of this locus has remained largely unknown.

To better utilize the *br* gene in a breeding program, the tomato breeding community needs genetic markers closely linked to the gene to improve selection efficiency. In addition, to understand the molecular mechanisms/functions of the gene, it needs to be cloned. Both of these efforts would benefit from determining the precise genetic intervals where the gene maps. The objective of this study was to locate *br* locus in tomato genome.

A mapping population used to map the *br* was developed from a cross between Fla 8044 and Fla 8834. The latter carries the *br*. Mapping of *br* was initiated by genotyping parents and 16 F_2 plants (8 normal genotype and 8 *br*) from this cross with genome-wide markers featured in the SolCAP single nucleotide polymorphism (SNP) array according to the method described by Sim et al. 2012. The association between the segregation of markers and the phenotypic data of plants was analyzed by the Fisher's exact test in R 3.3.2. In addition, the parental lines Fla 8834 and Fla 8044 used in the population development were included in the genotyping with the array.

Results mapped the *br* to a distal part on chromosome 1 (Table 1). Our mapping efforts were aided by the abundant SNPs obtained from the SolCAP SNP chip. The information should allow the better utilization of *br* in tomato breeding programs, as the locus can be more efficiently selected through marker assisted selection (MAS) with high confidence. The introduction of the *br* into diverse genetic backgrounds with important disease resistance and horticultural traits can then be used to create a new shift in fresh-market tomato production toward mechanical harvest.

DEFINITIONS

Allele - An alternative form of a gene at a locus

Array - A technology that allows users measure the relative abundance of sequence polymorphisms by binding labeled DNA probes from samples to a microchip with attached spots of DNA, with each spot representing a single target sequence. Tomato researchers have developed large SNPs genotyping array based on transcriptome sequence (Sim et al. 2012). The Solanaceae Coordinated Agricultural Project (SolCAP; http://solcap.msu.edu) is available for genetic and linkage studies in tomato. Two genetic maps with over 7000 SNP markers distributed across 12 linkage groups was developed for three interspecific populations. The maps had an average marker bin interval of 0.9 cM and 1.6 cM, respectively. Additionally, researchers have developed a microarray through the Affymetrix GeneChip® Consortia Program for gene expression study in tomato. The GeneChip® Tomato Genome Array (www.affymetrix.com) contains more than 10,000 *Solanum lycopersicum* probe sets to monitor gene expression for more than 9,200 *S. lycopersicum* genes and is commercially available for studying tomato genetics.

Cloning - Molecular DNA sequence characterization

Genetic variation - It has been estimated that the tomato genome contains approximately 900 million nucleotide positions. There is increasing evidence of high levels of such positions have common variation, from single nucleotide polymorphisms (SNPs) to insertions, deletions and copy number variation of DNA segments (CNV) between individual plants. Estimated divergence between the wild and domesticated genomes of tomatoes is 0.6% (5.4 million SNPs distributed along the chromosomes) (Tomato Genome Consortium, 2012). The interest in the genotyping originates that studies with SNPs may enable the identification of genetic variation that mediates traits. Those SNPs can be also used as markers to locate target gene(s).

Genotype - The term "genotype" refers to the genetic makeup of an organism. In a narrow sense, the term can be used to refer to the alleles. The process of determining a genotype is called genotyping.

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Table 1. Mapping the br (brachytic) on chromosome 1 using the tomato SolCAP array

	brachytic plants									normal plants									
Maker Identity[a]	**Fla 8834**	**139286-1**	**139286-2**	**139286-3**	**139286-4**	**139286-5**	**139286-6**	**139286-7**	**139286-8**	**Fla 8044**	**139286-9**	**139286-10**	**139286-11**	**139286-12**	**139286-13**	**139286-14**	**139286-15**	**139286-16**	**p-value** [b]
solcap_247	T[c]	-	C	Y	Y	C	-	Y	Y	T	Y	C	T	T	Y	Y	Y	T	0.5227
solcap_337	A	G	G	G	G	G	G	G	G	A	R	G	A	A	A	R	R	A	0.0034
solcap_247	G	A	A	A	A	A	A	A	A	G	R	G	A	A	A	R	R	A	0.0034
solcap_86	G	G	G	G	G	G	G	G	G	A	R	G	A	A	A	R	R	A	0.0004
solcap_866	C	C	C	C	C	C	C	C	C	T	Y	C	T	T	T	Y	Y	T	0.0004
solcap_8	C	C	C	C	C	C	C	C	C	T	Y	C	T	T	T	Y	Y	T	0.0004
solcap_24	A	A	A	A	A	A	A	A	A	T	W	A	T	T	T	W	W	A	0.0004
solcap_247	C	C	C	C	C	C	C	C	C	T	Y	C	T	T	T	Y	Y	T	0.0004
solcap_865	G	G	G	G	G	G	G	G	G	C	S	G	C	C	C	S	S	C	0.0004
solcap_861	G	G	G	G	G	G	G	G	G	A	R	G	A	A	A	R	R	A	0.0004
solcap_8_1	G	G	G	G	G	G	G	G	G	A	R	G	A	A	A	R	R	A	0.0004
solcap_8_2	A	A	A	A	A	A	A	A	A	G	R	A	G	G	G	R	R	G	0.0004
solcap_8_3	C	C	C	C	C	C	C	C	C	T	Y	C	T	T	T	Y	Y	T	0.0004
solcap_8_4	G	G	G	G	G	G	G	G	G	T	K	G	T	T	T	K	K	T	0.0004
solcap_8_5	A	A	A	A	A	A	A	A	A	T	W	A	T	T	T	W	W	T	0.0004
solcap_8_6	C	C	C	C	C	C	C	C	C	T	Y	C	T	T	T	W	W	T	0.0004
solcap_150	G	G	G	G	G	G	G	G	G	T	-	G	T	T	T	-	-	T	0.0020
solcap_204	A	G	G	G	G	G	G	G	G	A	A	R	A	A	A	A	A	A	0.0004
solcap_387	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	n/a
solcap_186 ▼[d]	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	n/a
solcap_18	T	T	T	T	T	T	T	T	T	C	C	C	C	C	C	C	C	Y	0.0001
solcap_181	A	A	A	A	A	A	A	A	A	T	T	T	T	T	T	T	T	W	0.0001
solcap_535 ▲	G	C	S	C	C	G	S	S	S	G	G	G	G	G	S	G	G	S	0.0200
solcap_128	T	T	Y	T	T	C	Y	Y	C	C	C	C	C	C	T	Y	Y	Y	0.4892

[a] Marker identity implemented in the tomato SolCAP Infinium array platform. (http://solcap.msu.edu/tomato_genotype_data.shtml) was abbreviated with the prefix solcap.
[b] Fisher's exact test; n/a means no difference between brachytic plants and normal ones in the test.
[c] International Union of Pure and Applied Chemistry nucleotide code. - represents missing genotypes.
[d] The arrows point in the direction that the br is located.

Tomato Compost Quality Use Guidelines

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In 2016, Florida continued to rank first in fresh-market tomato production with 27,988 acres harvested generating a production value of US$382 million [U.S. Department of Agriculture (USDA), 2017]. Nationally, Florida accounted for 34% and 36%, respectively, of total fresh-market tomato harvested area and production value (USDA, 2016). Florida fresh-tomato production mainly occurs in the central and southern regions (Ozores-Hampton et al., 2015) from November to January and April to May with well-defined growing seasons extending from October to June (Ozores-Hampton et al., 2007). The fresh-market tomatoes are normally grown on raised, polyethylene-mulched beds; fumigation, irrigation, and soluble fertilizer application in sandy soils having low organic matter, water-holding capacity and cation exchange capacity (Ozores-Hampton et al., 2015).

As a response to the Federal Total Maximum Daily Load mandate described in the Federal Clean Water Act (USEPA, 2002), the Florida legislature passed the Florida Watershed Restoration Act which gave the Florida Department of Agriculture and Consumer Services (FDACS) the authority to develop Best Management Practices (BMPs). Adopted by reference in rule 5M-8 of the Florida Administrative Code, the "Water quality/quantity best management practices for Florida vegetable and agronomic crops" is the document that describes the BMPs that apply to vegetable crops in Florida (FDACS, 2015). The current Florida Vegetable and Row Crop BMP manual (www.floridaagwaterpolicy.com) lists 49 approved BMPs.

Compost application is recognized as a tomato production BMP. Compost is defined as the product of a managed process through which microorganisms break down plant and animal materials into more available forms suitable for application in the soil. Feedstock for composting to be used by tomato producers in Florida can be generated from yard trimming wastes, food waste (pre and post-consumer), municipal solid waste, and animal manures (poultry, dairy, horse, swine, cattle with and without bedding), and other biodegradable waste by-products from urban or agricultural areas. There are no U.S. government restrictions on how and when compost can be used in tomato production, except compost derived from sewage sludge or biosolids in Florida (FDACS, 2012). To eliminate or reduce human and plant pathogens, nematodes, and weeds, the temperature during the composting process must remain between 131and 170ºF for 3 days in an in-vessel or static aerated pile; or 15 days in windrows, which must be turned at least 5 times during this period (USEPA, 1994, 1995 and 1999; DEP,2010).

Compost can directly affect soil bulk density, water holding capacity, soil structure, soil carbon content, macronutrients and micronutrients, pH, soluble salts, cation exchange capacity, and biological properties [(microbial biomass) Ozores-Hampton, 2012]. Compost can be used in conventional and organic tomato production. Tomato growers can use compost as a soil conditioner or as a nutrient source to supplement the fertility program in their production systems. Nutrients such as nitrogen, phosphorous, and potassium may be low. However, to lower the environmental impact of high compost application rates and protect water supplies from excessive nutrient runoff or leaching, or an excessive soil nutrient buildup, compost should be applied to match nutrient crop requirements. Compost is a dynamic system; hence, making recommendations for its use is more complicated than for standard fertilizer. Compost quality use guidelines in tomato production are limited, and this, together with the lack of knowledge of agricultural professionals, may result in a failure to use composts, or mistakes and problems with compost production and use. Therefore, the objective of this paper is to present compost quality guidelines to help growers determine the most appropriate compost quality to be used on tomato production.

The compost quality guidelines will promote the positive effects of compost on soil/crops and minimize the negative impacts on tomato production. Table 1 includes physical, chemical and biological compost parameters and Table 2 describes each parameter (Sources: Ozores-Hampton, M. 2017. HortTechnology 27:162-165). Compost quality guidelines for tomato production are still limited and non-comprehensive in addressing all the potential positive and negative effects of compost. However, the physical, chemical, and biological properties of compost presented here will promote the positive effects of compost, and minimize the negative ones, in organic and conventional vegetable production.

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Table 1. Optimal compost physical, chemical and biological property ranges for use in vegetable production and other production systems (Sources: Ozores-Hampton, M. 2017. HortTechnology 27:162-165).

Parameter (Unit)	Optimal range[z]	TMECC[z] methods no.
Physical		
Bulk density (lb/$yard^3$ wet basis)	740 – 980	3.03
Moisture (%)	30 (dry) - 60 (wet)	-
Organic matter (%)	40-60	5.07-A
Particle size	98% pass through 3/4-inch screen or smaller than 1 inch	2.02-B
Physical contaminants (%)	<2 %	3.08-A
Chemical		
pH	5.0-8.0	4.11-A
Electrical conductivity (mmho[x]/cm)	< 6	4.10-A
Stability (Carbon dioxide (CO_2) evolution rate or oxygen consumption)	CO2-C /unit volatile solid (VS)/day as < 2 = very stable; 2-8 = stable and > 8 = unstable. Oxygen (O2) uptake O2/VS/h < 0.5 as very stable; 0.5-1.5 = not stable and > 1.5 = not stable	5.08-B
Solvita maturity test (Woods End Research Laboratory, Mt Vernon, ME)	≥6	-
C/N (Carbon:nitrogen)	10-25	4.01 and 4.02
Nitrogen (%)	0.5-6.0	4.02
Phosphorous (%)	0.2-3.0	4.03
Potassium (%)	0.10-3.5	4.04

Parameter (Unit)	Optimal range[z]	TMECC[z] methods no.
Chemical		
Heavy metals	meet or exceed USEPA Class A standard, 40 CFR § 503.13 or DEP 62-709	
Arsenic (As) (ppmx)	< 41	4.06-As
Cadmium (Cd) (ppm)	< 15 (DEP)	4.06-Cd
Copper (Cu) (ppm)	< 450 (DEP)	4.06-Cu
Lead (Pb) (ppm)	< 300	4.06-Pb
Mercury (Hg) (ppm)	< 17	4.06-Hg
Molybdenum (Mo) (ppm)	< 75	4.06-Mo
Nickel (Ni) (ppm)	< 50 (DEP)	4.06-Ni
Selenium (Se) (ppm)	< 100	4.06-Se
Zinc (Zn) (ppm)	< 900 (DEP)	4.06-Zn
Biological		
Maturity (Seed emergence and seedling vigor)	>80% relative to positive control	5.05-A
Weed-free	No or very low weed seeds	-
Pathogen	[Meet or exceed US EPA Class A standard, 40 CFR § 503.32(a)]	
Fecal coliform (MPN[y]/g Total solids)	< 1,000	7.01
Salmonella (MPN/4 g)	< 3	7.02

[z] TMECC = Test Methods for the Examination of Composting and Compost.
[y] MPN = most probable number.
[x] 1 mmho/cm = 1 $mS.cm^{-1}$ and 1 ppm = 1 $mg{\cdot}kg^{-1}$,

Table 2. Compost guidelines: including physical, chemical and biological parameters for use in tomato production.

Bulk density: calculated as weight divided by volume. Lighter compost indicates less inorganic materials.

Moisture: water content in the compost and is expressed as a percentage of total dry weight. Moisture content lower than 30% will indicate dry compost and higher than 60% is wet compost, which will affect handling and transportation. Dry compost will be light and dusty and wet compost will be heavy and clumpy.

Organic matter (OM): Lower OM content indicates the presence of an inorganic component such as sand, clay, silt or man-made materials such as plastics and metals.

Particle size: is determined by passing the compost through a series of sieves. Large particle size will indicate poor quality or immature compost.

Physical contaminants (inert materials): Man-made materials that are aesthetically offensive and decrease the value of the finished compost.

pH: a measure of the acidity or alkalinity of the compost. Most composts have pH values between 5 and 8, with a preferred ranged of 6 to 7.5.

Electrical conductivity [(EC) (soluble salts]: Some specific salts (sodium and chloride) may be detrimental to vegetable crops. However, a higher EC in most compost is due to higher nutrient content, and at recommended field application rates do not contain sufficient levels of these salts to cause phytotoxicity.

Weed-free: Compost should not add weed seed or tubers into the soil. In order to produce weed-free compost the temperature must remain between 131 and 170 °F for 3 days in an in-vessel or static aerated pile; or 15 days in windrows, which must be turned at least five times during this period.

Human pathogens: The public health needs to be protected from potential pathogen content, such as fecal coliform and Salmonella. Therefore, all compost that contains regulated feedstocks must meet national, state and/or local safety standards to be marketable.

Maturity (growth screening): Is the degree to which the compost is free of phytotoxic substances such as high ammonia levels, organic acids, and other water soluble compounds that limit seed germination and plant growth and is determined empirically using bioassays. The testing should be performed on site after compost is been delivered to the vegetable producer.

Stability: Can be defined as the point at which easily degradable C decreases so that its decomposition rate is no longer controlling the overall rate of the decomposition of the feedstocks. If the compost consumes large amount of N and oxygen (O_2) to support biological activity (bacteria and fungi, etc.) that can cause plant stunting by "N-immobilization". Compost stability can be determined from respiration rate by measuring the rate at which carbon dioxide (CO_2) is released or O_2 consumed in optimal moisture and temperature conditions. Portable and easy to use compost stability tests such as the Solvita maturity test (Woods End Research Laboratory, Mt Vernon, ME) are available commercially. This is a color-coded test based on a two-tiered test system using respirometry (stability) and ammonia-gas emission (maturity). Very stable and mature compost will range between 7 and 8; mature 5 and 6, and immature < 5.

C:N ratio: this is the balance of the two elements for optimal performance of the compost once it is incorporated into the soil. Lower C:N ratio you may give compost an intense ammonium odor with significant losses of N and high C:N ratio may immobilize in the soil and cause plant stunting.

N-P-K: this is normally stipulated as a percentage of dry or wet weight. Compost N-P-K content is low compared to commercial fertilizer; however, when compost is applied at higher rates it can cause a soil nutrient buildup. The rate of N release or availability is especially important, since this nutrient moves readily through sandy soils. Evaluations of N mineralization in situ can be used to improve N use efficiency. However, the direct, quantitative measurement of N mineralization in situ is difficult due to the complex and dynamic nature of N transformations in the soil environment.

Heavy metals: trace elements whose concentration must meet national, state, and/or local safety standards to be marketable, due to the potential for toxicity to humans, animals, and plants.

Chemical and Biological Nematicide Testing in Tomato and Cucurbits

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INTRODUCTION

Since the phase-out of methyl bromide, nematode management in Florida agriculture has become much more challenging. Methyl bromide replacements often have not provided the same level of nematode control, and until recently, only one non-fumigant nematicide (Vydate, a.i oxamyl) and a few biological nematicides were available to growers. The loss of methyl bromide, however, coupled with an increase in nematode problems worldwide, has triggered the crop protection industry to initiate new nematicide discovery and research programs. As a result, several novel nematicides have recently entered the market, and more new products are expected in the near future. This is a welcome new trend for growers in Florida and elsewhere, who have been deprived of new (and safer) nematicides for decades. Unlike other products (herbicides, fungicides and insecticides), nematicides have received very little attention from crop protection companies in the past decades, and the new industry focus on nematicide discovery has been long overdue.

The new nematicides have a much better human and environmental safety profile (new products have a caution or warning label instead of a danger label) and they are more selective. Unlike the older nematicides, they often only target nematodes (fluensulfone and fluazaindolizine), or they can be considered fungicides/nematicides, such as fluopyram. Several biological nematicides are also available in Florida, including a new bacterial-based product (*Burkholderia* strain).

One of the priorities of the nematology group at the University of Florida's GCREC is to evaluate new nematicidal products, and integrate them into the current soil fumigant/management practices in Florida's fruits and vegetables. Four different trials were conducted in Florida between fall 2016 and spring 2017. The following products were evaluated: three new synthetic nematicides, Nimitz (fluensulfone, Adama), Velum (fluopyram, Bayer), Salibro (fluazaindolizine, Dupont, registration expected in 2019), and four biological nematicides Majestene (*Burkholderia* spp., Marrone Bio Innovations), Dazitol (capsaicin and allyl isothiocyanate, EngageAgro), NemaKill (cinnamon, clove and thyme essential oils, ExcelAg) and Melocon (*Paecilomyces lilicanus*, Certis).

METHODOLOGY

Tomato trials were done at the Gulf Coast Research and Education Center (GCREC) in Wimauma, FL (fall and spring, 2016-17), and cucurbit trials at 2 commercial farms near Dover, FL, spring 2017. Tomato trials were done on newly formed beds. Cucumber and cantaloupe trials were done on old beds (double-crops). Root-knot nematodes (*Meloidogyne* spp.) were the main target in all trials.

The experimental field at the GCREC research farm had been fallow for several years, and was known to have root-knot nematodes in the past. The root-knot nematode species in the field was identified as *Meloidogyne javanica*. The fall 2016 trial was conducted from September 2016 until January 2017, the spring trial from February until June 2017. Mulch was silver/metallic PE (polyethylene) in fall and white VIF (virtually impermeable film) in spring. There were two drip tapes per bed in both trials. Plots were 50 ft long x 2.5 ft wide in 2016 and 30 ft long x 2.5 ft wide in 2017. All compounds were drip-applied via 2 tapes (12" emitter spacing, 0.24 gal/hr/emitter). Beds were irrigated and were moist prior to application. Drip applications were done using stainless steel tanks pressurized with CO_2. Each plot was injected individually. Chemicals and biologicals were applied according to label recommendations. After nematicide applications supplemental irrigation was applied for 1.5 hr. Follow-up applications with nematicides (Vydate, Velum, Majestene, Melocon) were done about 3 weeks after planting using the same method as for the at plant applications.

Beds were sprayed with glyphosate one week before planting to knock back nutsedge growing through the mulch.

Nematicides in the 2016 fall trial were Nimitz, Velum, Salibro, Vydate and K-pam (Table 1). Raised beds were installed early September and K-pam was applied via drip on September 13, 2016. Nematicides were applied between September 22 (Nimitz, 7 days pre-plant) and September 28 (other products, at plant) and on October 20-21 (post plant) (Table 1).Tomato cv. HM1823 was planted on September 29, 2016 (24" spacing, 25 plants per plot) using a tractor-operated transplanter. Dinotefuron (Venom) was added to transplant water for insect control. Standard practices were followed for irrigation, fertigation and disease, insect and weed control. There were 6 replicates per treatment.

The spring 2017 trial consisted of 3 main (pre-plant fumigant) treatments (a reduced rate of Pic-Clor 60 (60% chloropicrin, 40% 1,3-D) at 150 lbs/A, a reduced rate of Tri-Pic 100 (99% chloropicrin) at 200 lbs/A, and no fumigant), and 7 sub (nematicide) treatments

Table 1 Treatments, rates and application timing for the fall 2016 tomato trial, Gulf Coast Research and Education Center in Wimauma, FL.

Treatment number	Nematicide	Rate/acre	Application timing
1	Nimitz	3.5 pt	7 days before planting
2	Nimitz	7 pt	7 days before planting
3	Nimitz + Vydate	3.5 pt + 1 Qt	7 days bp + 22 days pp
4	Velum + Vydate	6.5 oz + 1 Qt	At planting + 22 days pp
5	Vydate + Velum	2 Qt + 6.5 oz	At planting + 22 days pp
6	Salibro	1 lb ai	At planting
7	Salibro + Vydate	1 lb ai + 1 Qt	At planting + 23 days pp
8	Vydate + Vydate	2 Qt + 1 Qt	At planting + 23 days pp
9	K-Pam	62.5 gal	15 days before planting
10	None		

bp = before planting; pp = post planting

(Nimitz, Velum, Salibro, Vydate, Majestene and Melocon) (Table 2). Fumigants were applied and beds made on February 3, 2017. Nematicides were applied between March 17 and March 23 (at plant applications) and on April 12 and 19 (post plant applications) (Table 2). Tomato cv. FL47 was planted on March 24, 2017 (18" spacing, 20 plants per plot) using a tractor-operated transplanter. Dinotefuron (Venom) and propamocarb (Previcur) were added to the transplant water for early insect and disease control. Standard practices were followed for irrigation, fertigation and disease, insect and weed control. There were 4 replicates per treatment.

The on farm trials in spring 2017 were both done on old beds. The nematicides in these tests were Nimitz, Velum, Vydate and Majestene for the cantaloupe trial, and Nimitz, Velum, Vydate, Majestene, Dazitol and NemaKill for the cucumber trial (Table 3).

The cantaloupe trial was done on existing strawberry beds that had high population of northern root-knot nematode (*Meloidogyne hapla*). Prior to our trial, cantaloupes had been planted in between strawberries, but were severely stunted and showed very high incidence of root galls. The crop was a total loss and a new crop was planted after pulling strawberries and applying nematicide treatments. All nematicides were applied via the drip system (single tape). First Nimitz was applied (7 day pre-plant) via the grower's drip system to the entire field, except for certain rows where we had placed valves to prevent Nimitz from entering, in order to apply the other treatments. Other treatments were applied 1-3 days before planting to single plots according to recommendations using the same system as in the tomato trials at GCREC (Table 3). Plots were 100 ft long and consisted of separate rows. There were 4 rows (replicates) per treatment.

Table 2 Treatments, rates and application timing for the spring 2017 tomato trial, Gulf Coast Research and Education Center in Wimauma, FL.

Fumigant	Nematicide	Rate/acre	Application time
PicClor60	Nimitz	7 pt	7 Days before planting
@150 lbs/acre	Velum	6.5 oz	1-3 days before planting
	Salibro	1 lb ai	1-3 days before planting
	Vydate	2 + 1 Qt	At plant + at 21 days pp
	Majestene	2 +1 gal	At plant + 21 days pp
	Melocon	4 + 4 lbs	At plant + 28 days pp
	None		
Pic100	Nimitz	7 pt	7 Days before planting
@200 lbs/acre	Velum	6.5 oz	1-3 days before planting
	Salibro	1 lb ai	1-3 days before planting
	Vydate	2 + 1 Qt	At planting + 21 days pp
	Majestene	2 + 1 gal	At planting + 21 days pp
	Melocon	4 + 4 lbs	At planting + 28 days pp
	None		
No fumigant	Nimitz	7 pt	7 Days before planting
	Velum	6.5 oz	1-3 days before planting
	Salibro	1 lb ai	1-3 days before planting
	Vydate	2 + 1 Qt	At planting + 21 days pp
	Majestene	2 + 1 gal	At planting + 21 days pp
	Melocon	4 + 4 lbs	At planting + 28 days pp
	None		

bp = before planting; pp = post planting

Table 3. Treatments, rates and application timing for the on farm trials, spring 2017, Dover, FL.

Treatment number	Farm/crop	Nematicide	Rate/acre	Application timing
1	Cantaloupe	Nimitz	7 pt	7 days before planting
2		Velum	6.5 oz	At planting
3		Vydate	2 + 1 Qt	At planting + 40 days pp*
4		Majestene	2 + 1 gal	At planting + 40 days pp*
5		None		
1	Cucumber**	Nimitz	7 pt	7 days before planting
2		Velum	6.5 oz	At planting
3		Vydate	2 Qt	At planting
4		Majestene	2 gal	At planting
5		Dazitol	5.35 gal	5 days before planting
6		NemaKill	48 oz	At planting
7		None		

* Post plant applications were done after 40 days instead of the recommended 20 days.
** No post plant applications were done due to early trial termination.

The cucumber/pickle trial was done on old cucumber/pickle beds (3rd pickle crop). Similar to the field above, prior to our trial, cucumbers had been planted but were severely stunted and show very high incidence of root galls. Nematicide treatments were applied to individual plots of 100 ft long and there were 4 replicates per treatment (Table 3). Cantaloupes (March 17) and cucumbers (March 28) were re-planted (direct seeded) by the grower and the growers managed all irrigation, fertigation, disease, insect and weed control practices.

Nematode soil counts were done pre-treatment, shortly after planting and after final harvest. Root gall ratings were done throughout the growing season (early, mid and late season). During the season (4-8 weeks after planting) 4 plants/plot were sampled, and at the end of the season the remaining plants were sampled (~ 10 plants/plot). Root gall assessment was done using a 0–10 scale where 0 indicates no visible root galling and 10 representing 100% galled and no visible fibrous roots. Soil samples (1 cup of soil) were extracted using a modified Baermann method (salad spinner method) at the GCREC nematology lab. Soil samples were collected with a soil probe for pre-treatment and at plant soil samples (8 cores/subsamples per plot), or collected together with roots from plants that were uprooted for root gall assessments (4-10 subsamples per plot).

Crop vigor was recorded during the growing season with a handheld crop sensor (GreenSeeker, Trimble). The sensor functions by producing red and infrared light and it detects how much light is reflected back to it from the crop. These values are based upon the Normalized Difference Vegetation Index (NDVI, 0-1), and they indicate how healthy the crop currently is. The higher values represent healthier crops, while lower values indicate less healthy crops. NDVI was recorded by walking both sides of each plot, holding the crop sensor about 5 ft above ground level, and averaging both measurements.

Tomatoes were harvested by hand from the center 10 plants in both tests. Plots were picked 3 times, once a week for 3 weeks (during December 2016 for test 1, and during May-June 2017 for test 2). Fruits were graded according to size (small, medium, large, extra-large) using a mechanical grader.

For the spring 2017 tomato trial, only early and mid-season gall ratings and plant vigor (NDVI) data are given (no late season gall ratings and yield data were available, as the trial was still ongoing at the time of writing). For the on farm trials, cantaloupes were counted just prior to the grower's final harvest, and no cucumbers could be harvested as the grower finished the trial early.

RESULTS & DISCUSSION

Prior to installing the raised beds in fall 2016, plant-parasitic nematodes at the GCREC field site included lance *(Hoplolaimus* spp.) (10-20 per cup of soil), root-knot *(Meloidogyne* spp.), stubby root (Trichodoridae), lesion (*Pratylenchus* spp.) and sting (*Belonolaimus longicaudatus*) nematodes (1-5 per cup). Post-treatment (at plant) plant-parasitic nematode soil counts remained low and included some lance (0-10 per cup), and very few root-knot (<1 per cup), sting (<1 per cup), and lesion (<1 per cup) nematodes. No plant-parasitic nematodes could be detected following K-pam at that stage.

By the end of the season root-knot nematode soil counts had increased significantly in all plots (Fig. 1). Lowest root-knot nematode soil counts after final harvest were found for the high rate of Nimitz and the Vydate followed by Velum treatment. Highest root-knot nematode numbers were found in untreated plots (UTC). Also numbers of stubby root nematodes (24-97 nematodes per cup of soil) and lance nematodes (10-24 nematodes per cup) had increased during the season, but numbers were far too low to cause damage, and only minor differences were found.

Root gall ratings on fall-planted tomato were low early in the season, and increased significantly by the end of the season (Table 4). All nematicide treatments significantly reduced root gall ratings as compared to the control treatment by the end of the season, with almost 50% galls observed on untreated tomatoes, as compared to 10-20 % galled roots for Nimitz and Vydate and 10% galled roots for the K-pam treatment (Table 4). Root gall ratings are a direct measure of root-knot nematode damage and usually a more meaningful bioindicator than nematode soil counts.

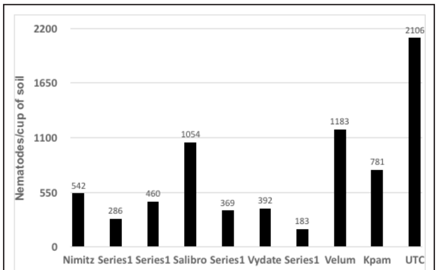

Figure 1. Root-knot nematodes (J2 and males) in soil after final tomato harvest for different nematicide treatments, January 2017, Gulf Coast Research and Education Center in Wimauma, FL (means followed by the same letter are not significantly different).

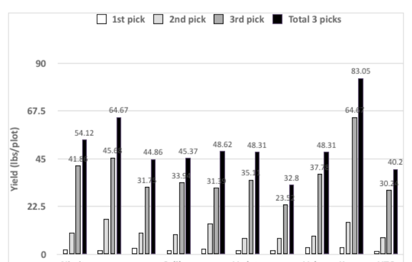

Figure 2. Tomato fruit yield for 3 separate picks and combined total for all picks, Fall 2016, Gulf Coast Research and Education Center in Wimauma, FL. (means followed by the same letter are not significantly different).

Table 4. Tomato root gall ratings (gall index at 4, 8 and 14 weeks) and plant vigor (NDVI at 4 and 8 weeks), fall 2016, Gulf Coast Research and Education Center in Wimauma, FL.

	Gall Index (GI, 0-10)*			Plant Vigor (NDVI)** (0-1)	
Treatment	**4 weeks**	**8 weeks**	**14 weeks**	**4 weeks**	**8 weeks**
Nimitz 3.5 pt	0.4 abz	0.5 b	1.3 cde	0.45	0.59 ab
Nimitz 7pt	0.1 b	0.3 b	1.4 cde	0.43	0.59 ab
Nimitz + Vydate	0.4 ab	0.3 b	2.1 bc	0.44	0.56 b
Velum + Vydate	0.3 b	0.6 b	2.0 bc	0.45	0.59 ab
Vydate + Velum	0.1 b	0.1 b	0.7 e	0.37	0.53 b
Salibro	0.2 b	0.4 b	2.4 b	0.39	0.55 b
Salibro +Vydate	0.2 b	0.2 b	2.6 b	0.41	0.61 ab
Vydate + Vydate	0.3 ab	0.1 b	2.1 bcd	0.45	0.56 b
K-Pam	0.2 b	0.6 ab	1.1 de	0.54	0.67 a
Control	0.7 a	1.5 a	4.9 a	0.41	0.57 b
F probability	0.01	0.01	0.01	ns (0.14)	0.01

[z] Means followed by the same letter are not significantly different; ns = no significant difference (P<0.10).

[*] Gall indices were rated on a 0-10 scale whereby, 0 = no galls, 1 = very few small galls, 2 = numerous small galls, 3 = numerous small galls of which some are grown together, 4 = numerous small and some big galls, 5 = 25% of roots severely galled, 6 = 50% of roots severely galled, 7 =75% of roots severely galled, 8 = no healthy roots but plant is still green, 9 = roots rotting and plant dying, 10 = plant and roots dead.

** NDVI = Normalized Difference Vegetation Index (0-1).

NDVI, which is a measure of plant vigor, was highest in K-pam plots, and few differences were noted among the other treatments (Table 4). By the end of the season (after 14 weeks) NDVI was the same for all treatments (data not given).

Root gall ratings on spring-planted tomato in 2017 were low early in the season, and increased significantly by 50 days after planting (Table 5). Root gall ratings were greatest in non-fumigated rows > Pic-Clor 60 rows > Tri-Pic 100 rows. Gall ratings were also significantly different for nematicide treatments. None of the nematicides significantly reduced root galls in the non-fumigated beds, only Nimitz showed a numeric reduction in galls. In the Tri-Pic 100 fumigated beds, and especially for the gall rating at 50 days, Nimitz, Velum, Salibro and Vydate all showed a reduction in root galls, compared to the control and the two biologicals. Nimitz and Vydate also significantly reduced root galls in the Pic-Clor 60 beds, with Salibro, Velum and Majestene showing a numerical reduction (Table 5). Melocon did not provide significant nematode control in this trial, regardless of the pre-plant fumigant treatment (Table 5).

NDVI (plant vigor) after 30 and 50 days was better in fumigated rows as compared to non-fumigated rows, but no difference in NDVI was noted between nematicide treatments (Table 5).

Not surprisingly, the different fumigant treatments significantly affected root-knot nematode infection and growth of tomato. Similar to the fall tomato trial, all of the synthetic nematicides showed potential to reduce root-knot nematode infection, but only or mostly so in the fumigated rows. Fumigant rates were deliberately reduced to allow for some nematode survival in order for nematicides to show additional effects. The lack of efficacy of the new nematicides in the non-fumigated rows indicates the new products may not be stand-alone nematicides, especially when nematode pressure is high, as seems to be the case in the spring 2017 trial.

Tomato fruit yields in the fall 2016 trial were low and not significantly different for the first 2 picks (Fig. 2). The third pick and the total for all 3 picks was greatest for the K-pam treatment, followed by the Nimitz treatments. Most fruits were large and extra-large, and no differences were noted for fruit size.

Better crop vigor and greater yields with K-pam in 2016 were probably due to the additional soil disease control that this treatment provided. *Sclerotium rolfsii* was observed throughout the trial, and probably other soil pathogens, such as *Fusarium oxysporum* L., were present as well. Also, soil fumigation will often result in an increased growth response, as a result of the nitrogen,

Table 5. Tomato root gall ratings (Gall index) and plant vigor (NDVI) after 30 and 50 days), spring 2017, Gulf Coast Research and Education Center in Wimauma, FL.

		Gall Index (0-10)*		NDVI (0-1)**	
Fumigant	**Nematicide**	**30 days**	**50 days**	**30 days**	**50 days**
PicClor60	Nimitz	1.0 bcz	2.0 b	0.47	0.74
@ 150 lbs/acre	Velum	1.6 abc	3.8 ab	0.47	0.72
	Salibro	2.2 ab	3.9 ab	0.46	0.71
	Vydate	0.5 c	1.4 b	0.46	0.71
	Majestene	1.7 abc	3.9 ab	0.40	0.72
	Melocon	3.2 a	5.9 a	0.39	0.68
	none	2.1 abc	4.7 a	0.41	0.73
		0.001	0.001	ns	ns
Pic100	Nimitz	0.5 c	0.6 b	0.41	0.69
@ 200 lbs/acre	Velum	1.0 bc	1.0 b	0.50	0.68
	Salibro	1.1 bc	1.4 b	0.48	0.69
	Vydate	1.3 bc	2.8 a	0.49	0.68
	Majestene	2.3 a	3.5 a	0.52	0.71
	Melocon	1.3 bc	3.7 a	0.48	0.69
	none	1.4 b	3.5 a	0.52	0.70
		0.001	0.001	ns	ns
No fumigant	Nimitz	1.1 c	3.6 c	0.42	0.64
	Velum	2.8 ab	5.4 bc	0.37	0.62
	Salibro	3.0 a	5.6 b	0.39	0.68
	Vydate	3.8 a	7.8 a	0.39	0.65
	Majestene	2.3 bc	5.3 bc	0.35	0.69
	Melocon	2.4 bc	5.0 bc	0.41	0.67
	none	2.0 bc	4.5 bc	0.34	0.68
		0.001	0.001	ns	ns
PicClor60		1.8 b	3.6 b	0.44 b	0.72 a
Pic100		1.3 c	2.3 c	0.48 a	0.69 b
No fumigant		2.5 a	5.3 a	0.38 c	0.66 c
		0.001	0.001	0.001	0.001

[z] *Means followed by the same letter are not significantly different; ns = no significant difference (P<0.10).*

[*] Gall indices were rated on a 0-10 scale whereby, 0 = no galls, 1 = very few small galls, 2 = numerous small galls, 3 = numerous small galls of which some are grown together, 4 = numerous small and some big galls, 5 = 25% of roots severely galled, 6 = 50% of roots severely galled, 7 =75% of roots severely galled, 8 = no healthy roots but plant is still green, 9 = roots rotting and plant dying, 10 = plant and roots dead.

**NDVI = Normalized Difference Vegetation Index (0-1).

Table 6. Root gall ratings for the on farm trials (cucumber and cantaloupe), spring 2017, Dover, FL.

		Gall Index (0-10)*	
Farm/crop	**Nematicide**	**30 -40 days****	**60 days**
Cantaloupe	Nimitz	1.5 bz	2.7 b
	Velum	1.8 ab	2.6 b
	Vydate	2.5 ab	3.9 ab
	Majestene	2.7 a	2.7 b
	None	2.7 a	5.1 a
F probability		0.03	0.001
Cucumber	Nimitz	6.9 a	
	Velum	5.5 b	
	Vydate	3.4 c	
	Majestene	7.1 a	
	Dazitol	6.4 ab	
	NemaKill	7.0 a	
	None	6.5 ab	
F probability		0.001	

[z] Means followed by the same letter are not significantly different; ns = no significant difference (P<0.10).

[*] Gall indices were rated on a 0-10 scale whereby, 0 = no galls, 1 = very few small galls, 2 = numerous small galls, 3 = numerous small galls of which some are grown together, 4 = numerous small and some big galls, 5 = 25% of roots severely galled, 6 = 50% of roots severely galled, 7 =75% of roots severely galled, 8 = no healthy roots but plant is still green, 9 = roots rotting and plant dying, 10 = plant and roots dead.

** Cucumber roots were evaluated after 30 days, cantaloupe roots after 40 days.

phosphorus, and other nutrients released from the microbial biomass killed by the fumigant.

Root-knot nematode pressure in the fall 2016 tomato trial was low to moderate. Low early levels of nematode infection, such as in this trial, usually allow tomato plants to outgrow the nematode infection and avoid significant yield loss. Yield differences in this trial were probably mostly due to the earlier mentioned effects of K-pam on soil pathogens and soil microbes.

Both on farm trials were done on fields that were heavily infected with root-knot nematodes. Root gall incidence in the cantaloupe trial was moderate (Table 6). Early gall ratings at 40 days were significantly reduced by Nimitz, with Velum showing a numerical reduction. Both products had significantly lower gall ratings at 60 days as compared to the control. Vydate showed a numerical, but no significant reduction in galls at both time points. Majestene did not reduce root galls at 40 days, but did show significantly less galls at 60 days, similar to Nimitz and Velum (Table 6). This seems to indicate that for Majestene a second application is essential. The 2nd application was done after 40 days (instead of the recommended 20 days), which may explain why no effect was observed for the 40-day gall ratings.

No effect on early growth (NDVI similar for all treatments up to 40 days) or number of fruits after 70 days (70-75 fruits per plot for all treatments) was seen (data not given). Cantaloupes were harvested in this trial, but due to foliar diseases that swept through the trial, the crop was terminated early.

Root-knot nematode infection in the cucumber (pickle) trial remained severe after applying treatments and replanting (Table 6). Vydate was the only product that significantly reduced root galls in this trial. Velum gave a small numeric reduction, but Nimitz, Majestene, Dazitol and Nemakill did not reduce root galls compared to the control. The pickle trial was terminated early by the grower as plants still did not grow well after replanting, probably due to continued high nematode infection. No yield was recorded for in this farm.

Higher root gall incidence in the pickle trial was probably due to the difference in root-knot nematodes. In the cantaloupe field the root-knot nematode species was *Meloidogyne hapla*, the northern root-knot nematode. This nematode prefers cooler soils and its infection potential was probably reduced as soil temperatures increased during the spring season. Also, *M. hapla* typically causes smaller galls as compared to the tropical root-knot species, such as *M. javanica*, which was the root-knot species present in the pickle field. This more aggressive nematode prefers warmer soils, and rapidly reproduced in this field as soil temperatures in spring increased.

SUMMARY

The new nematicides Nimitz, Velum and Salibro showed good potential for reducing root-knot nematode damage in both tomato trials. Two biological nematicides (Majestene and Melocon) that were evaluated in the second tomato trial showed no or minor effects on root-knot damage. Nimitz, Velum and Majestene were also tested on cucurbits in two on farm trials, and all products reduced root galls in the cantaloupe farm, but not in the pickle farm. Vydate was the only nematicide that reduced root-knot in the pickle farm. The other biological products were only tested once at the heavily infested pickle farm, and did not show any impact on root-knot nematodes.

Clearly, the new products are not fumigant replacements, but they do offer new options and more flexibility to vegetable growers that have nematode problems. More testing will be done in the next years to better understand the potential and limitations of these new nematicides and biologicals. Growers or stakeholders that are interested in helping to evaluate some of these products can contact the GCREC nematology lab.

1-MCP Nursery Treatment for Tomato Transplants to Minimize Stress Impact of Shipping, Handling, and Transplanting

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INTRODUCTION

Vegetable seedling are subjected to various types of abiotic stress during shipping and transplanting operations (Agehara and Leskovar, 2012; Vavrina, 2002). In particular, a high degree of mechanical stress can occur as seedlings are shaken, moved, pulled from trays, and planted into the soil (Cantliffe, 1993). This so-called transplant shock can result in seedling death, slow or non-uniform establishment, and subsequently, yield loss.

Mechanical stress stimulates ethylene synthesis (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). Common ethylene-induced responses 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; Druege, 2006).

Ethylene-induced responses can be mitigated by inhibiting either ethylene synthesis or ethylene perception. It is well documented that 1-methylcyclopropene (1-MCP) is highly efficient in inhibiting ethylene reception by blocking ethylene receptors. Therefore, if ethylene is a primary hormone responsible for shipping and transplanting induced stress responses in vegetable seeding, inhibiting ethylene perception by 1-MCP may reduce transplant shock and improve field establishment. In our previous study, 1-MCP treatment prior to transplanting promoted post-planting growth of tomato seedlings and increased fruit yield. The objective of this study was to confirm the stress control effects of 1-MCP using two tomato cultivars.

MATERIALS AND METHODS

One greenhouse experiment and two field experiments and were conducted at the Gulf Coast Research and Education Center in Balm, FL. In the greenhouse experiment (Expt. 1), treatments were: untreated, spray treatment of ethephon at 1,000 mg/L, and spray treatment of 1-MCP at 1 mg/L followed by ethephon at 1,000 mg/L. In the first field experiment (Expt. 2), treatments were factorial combinations of two cultivars (‘Florida 47’ and ‘SevenTY III’) and two 1-MCP concentrations (0 and 50 mg/L). In the second field experiment (Expt. 3), treatments were factorial combinations of two shipping methods (tray-packing and pull-packing) and two 1-MCP application rates (0 and 20 g/ha). In all experiments, tomato seedlings were grown in 128-cell plug trays at a commercial transplant nursery (Plants of Ruskin, Ruskin, FL). In Expt. 1 and 3, the cultivar used was ‘HM 1823’. Treatments of 1-MCP were performed 1 day before transplanting using a CO2-pressurized back-pack sprayer at 2 L per tray in Expt. 2 and a commercial irrigation boom at about 700 ml per tray in Expt. 1 and 3. A liquid formulation of 1-MCP, AF-XRD-038 (AgroFresh, Spring House, PA), was used to prepare the test solutions.

The soil at the experiment site is classified as a Myakka fine sand siliceous hyperthermic Oxyaquic Alorthod. At pre-planting, the surface (top 15 cm) soil had a pH of 6.8 and an organic matter content of 15 g/kg. Planting beds were 81 cm wide at the base, 71 cm wide at the top, 25 cm high, and spaced 152 cm apart on center. Raised beds were fumigated with Pic-Clor 60 at 336 kg/ha and covered with a black virtually impermeable mulch film. Standard cultural practices and pest management practices for commercial tomato production were followed.

There were four replicates in all experiments. Each replicate consisted of 5 plants in Expt. 1 and 14 plants in Expt. 2 and 3. Treatments were arranged in a randomized complete block design in Expt. 1 and in a split-plot design in Expt. 2 and 3. The main plot factor was cultivar in Expt. 2 and shipping method in Expt. 3, and the subplot factors was 1-MCP concentration in both experiments. All data were analyzed in SAS with the MIXED procedure.

RESULTS AND DISCUSSION

Several stress responses were induced by ethephon treatment in tomato seedlings in Expt. 1, including epinasty (Fig. 1), cholorosis, cotyledon absission, and inhibition in stem elongation and leaf growth (data not shown). These stress responses resemble common post-planting stress responses in vegetable seedlings, suggesting that ethylene plays an important role in transplant shock.

In both Expt. 2 and 3, a single spray treatment of 1-MCP prior to shipping accelerated shoot growth of tomato seedlings after transplanting (data not shown). In Expt. 2, 1-MCP treatment increased marketable yield by 13% for 'Florida 47' and by 20% for 'SevenTY III'. Similar results were observed previously (Agehara, 2015). In the previous study, 'Florida 47' was used, and 1-MCP treatment at 12.5 to 50 mg/L increased shoot biomass at the harvest by up to 19% and marketable yield by up to 25%. Therefore, the effectiveness of 1-MCP in improving post-planting growth and yield appears to be consistent for 'Florida 47'. However, the results also suggest that the effectiveness of 1-MCP is cultivar-specific.

Vegetable seedlings can be subjected to mechanical stress not only during transplanting but also during shipping. The two most common shipping methods are tray-packing and pull-packing. Mechanical stress is likely more severe for the pull-packing method compared to tray-packing, as seedlings are pulled and tightly packed in a box. Under such stressful conditions, ethylene accumulation may significantly increase and stimulate more severe stress responses. In Expt. 3, therefore, 1-MCP was tested using the two shipping methods. Marketable yield was unaffected by 1-MCP for tray-packing, but it shows a 6% increase by 1-MCP for pull-packing. 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). When stress-induced ethylene accumulation is minimal, therefore, it is likely that beneficial effects of 1-MCP can also be minimized. On the other hand, the result suggest that 1-MCP can exhibit more beneficial effects when seedlings are exposed to a higher magnitude of stress.

Importantly, no negative-side effects of 1-MCP were observed in all experiments. 1-MCP inhibits ethylene perception, not ethylene synthesis. This mode of action allows newly produced plant tissue to be responsive to ethylene, and therefore, 1-MCP treatment at the seedling stage does not appear to affect other important functions that involve ethylene, including fruit ripening. The results of this study suggest that 1-MCP has great potential use as a new stress management strategy to improve the productivity of vegetable crops.

Figure 1. Suppression of ethephon-induced epinasty by 1-MCP in tomato seedlings.

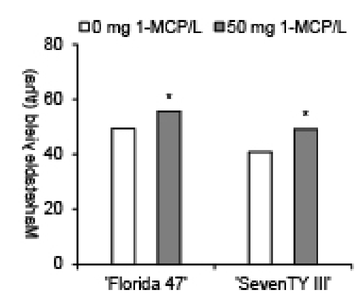

Figure 2. Marketable yield of two tomato cultivars as affected by 1-MCP spray application at the transplant nursery 1 day before shipping.

Table 1. Tomato (cv. HM 1823) marketable yield as affected by transplant shipping method and 1-MCP applied prior to shipping.

Shipping method	1-MCP rate (g/ha)	Fruit set (Number/plant)	Fruit size (g/fruit)	Yield (t/ha)		Marketability (%, wt/wt)
Tray-packing	0	36.5	223	115	ab[1]	95.6
	20	36.5	224	116	ab	95.2
Pull-packing	0	35.2	224	111	b	95.7
	20	37.3	224	118	a	96.1

[1] Means followed by the same letter are not significantly different at $P < 0.05$.

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The Use of Smart Phone Application (SmartIrrigation Vegetable) for Irrigation Scheduling in Tomato Production

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ABSTRACT

A study that focused on irrigation scheduling method and rates on open-field tomato (*Solanum lycopersicum*) production was conducted at the University of Florida Southwest Research and Education Center (SWFREC), Immokalee FL. The study was carried out during fall and spring seasons of 2015 and 2016 respectively. The main objective was to evaluate use of a smart phone application (SmartIrrigation Vegetable) on tomato productivity and water-use in comparison to University of Florida, Institute of Food and Agricultural Science (UF/IFAS) irrigation recommendation. Five irrigation rates (66% App, 100% App, 150% App, 66% UF/IFAS and 100% UF/IFAS) were evaluated in a randomized complete block design with four replicates per treatment. Plant biomass samples were taken at 30, 60 and 90 days after transplanting (DAT) and harvests were conducted at fruit maturity. For both seasons, no significant difference was observed among treatments for dry biomass accumulation at all sampling dates. Yields were significantly higher for 100% App in both seasons compared to other treatments. These results suggest SmartIrrigation vegetable (SI) app can be successfully used for irrigation scheduling in tomato production in Florida. Also, SI App can increase WUE by increasing water savings in tomato production and as a result can reduce nutrient leaching and increase yield.

INTRODUCTION

United States is one of the world largest tomato producing countries with more than $2 billion annual total farm cash receipts and about 403 thousand harvested acres in 2014 (USDA, 2015). Florida is a leading state in the production of fresh market tomatoes and pepper (*Capsicum annuum*) (Kokalis-Burelle, et al., 2002; Simonne and Ozores-Hampton 2009; Olson et al., 2010; Olson and Santos 2010). Tomato is the leading commodity of Florida vegetable production with 32,000 total harvested acres and total value of about $ 453 million in 2015 (USDA, 2016). Proper irrigation management is an important aspect of vegetable production to meet market quality demand. In vegetable production, irrigation can contribute up to a 200% yield increase (Doss et al., 1980; Locascio and Myers, 1974).

Maintaining adequate irrigation practice in crop production not only increases yield but also reduces production cost, minimizes nutrient and pesticide leaching into the ground water (Pulupol et al., 1996), and improves tomato fruit nutritional value (Dorais et al., 2008). Water supply is limited worldwide and research findings have intensified the necessity for improved water use efficiency (WUE) in agricultural production (Zegbe-Dominguez et al., 2003; Simonne et al., 2010). Considering that tomato has the highest acreage of any vegetable crop in the world (Ho, 1996), increases in WUE in tomato production can make a significant impact in the global agricultural water footprint.

There are many irrigation scheduling methods in tomato production, and one of the most recent scheduling methods is the use of SmartIrrigation (SI) applications. Presently, many SI applications have been published and used in crops such as citrus (*Citrus sinencis* L.), cotton (*Gossypium* spp L.), turf, strawberry (*Fragaria* spp) and recently avocado (*Persea americana*) (Migliaccio et al., 2014). The smartphone irrigation App has been proven efficient not only in reducing crop irrigation volume but also in significantly increasing cotton yields(Vellidis et al., 2014).

Published SI Apps are smart phone enabled irrigation decision support systems that provide users with irrigation schedules based on real-time, location specific weather data (Migliaccio et al., 2014). Smart phone apps for irrigation scheduling have the ability to reduce user calculation error or misplaced irrigation records and timing. They provide the opportunity to enter the necessary information anytime and anywhere with cellular network accessibility. In this publication, the SI Vegetable App was evaluated, using the FAO Penman-Monteith procedure for ETo calculation. Therefore, this project is designed with the main objective of evaluating a smart phone application (SmartIrrigation vegetable application) for irrigation scheduling in open-field fresh market tomato production.

MATERIALS AND METHODS

The study was conducted during the fall (September to December) and spring (February to May) seasons of 2015 and 2016 respectively at the SWFREC, Immokalee FL. The soil at the experiment site is a Spodosol classified as Immokalee soil series with nearly flat slope (USDA-NRCS, 2013).

Although, precipitation is high throughout the year, irrigation is a necessity due to very poor water holding capacity at the experimental site. Therefore, different daily irrigation rates based on the SI vegetable App were evaluated and compared to the irrigation recommendation by UF/IFAS. For both seasons, five irrigation treatments from two scheduling methods (App and IFAS) were evaluated (Table 1) using a randomized complete block design with four replications per treatment.

Standard bed size (6 ft bed centers) was used with the same fertilizer application for all treatments according to the current UF/IFAS recommendations (Liu et al., 2015). Nutrients were applied at 50 lbs.acre^{-1} (N

Table 1. Treatment specification for irrigation study in tomato production for spring and fall seasons, 2015 in Immokalee FL.

Treatments[z]	Irrigation schedule method	Drip line* (gal.hr^{-1})
1	100% IFAS rate	0.24
2	66% App rate	0.16
3	100% App rate	0.24
4	150% App rate	0.36
5	66 % IFAS rate	0.24

[z] IFAS = Irrigation based on University of Florida Institute of Food and Agricultural Sciences recommendation, App = Irrigation based on SmartIrrigation vegetable application. *All drip lines used were at 12-inch emitter spacing.

and K) pre-plant and 150 lbs.acre^{-1} (N and K) fertigation. Pre-plant dry fertilizer 19-0-19 (N-P-K) was applied as a bottom mix during bed preparation while water soluble fertilizer 20-0-20 (N-P-K) was applied through fertigation. During bed preparation Pic Clor 60 fumigant (Agrian. Fresno, CA. a.i chloropicrin and 1,3-Dichloropropene at 59.6% and 39% respectively) was applied to the beds at the rate of 200 lbs.acre^{-1} and immediately covered with polyethylene mulch. A 0.8 mil white/black polyethylene mulch (Berry Plastics. Washington, GA) was used throughout the experiment. All the beds had two drip lines (thinwall drip lines, 5 mil streamline Plus 630 series by Netafilm. Fresno, CA) under the polyethylene mulch for irrigation and fertigation. After bed preparation, tomato seedlings (variety Charger by Sakata. Morgan Hill, CA) were transplanted at 24 inch plant spacing in a single row 21 days after bed preparation.

Irrigation was scheduled weekly using UF/IFAS irrigation recommendations and the SI vegetable App. The volume of irrigation at every schedule was applied daily and changed every seven days. Irrigation water applied to each treatment was controlled by a flow meter (M 1 ½" size by Netafilm, Fresno. CA). Water along the drip lines was maintained at constant pressure by pressure regulators (15 PSI by Senninger Irrigation Inc. Orlando, FL). Based on irrigation volume, daily total irrigation time was divided into two to three irrigation events and the time of each event was controlled by a hose-end irrigation controller (model IZEHTMR by Rainbird. Azusa, CA). Irrigation time was the same for all treatments, however the desired irrigation volume for each treatment was determined based on different flow rates of the drip lines (Table 1). A total of 200 lbs.acre^{-1} each of N and K (pre-plant and fertigation) were applied for each season. Fertigation was conducted twice a week and each application was carried out at the last irrigation cycle of the day to ensure that nutrients were maintained within the root zone.

Biomass samples were taken for all treatments considering both above ground (leaves, stems and fruits) and below ground (roots) plant parts. Crop biomass samples were collected once every 30 days starting at 30 days after transplanting (DAT) except for fruit sampling that started about 60 DAT. All tissue samples were dried at 149^{o}F and corresponding dry biomass was recorded as total biomass (lbs.acre^{-1}) per treatment for each season. Harvest was conducted at fruit maturity (66 and 85 DAT during spring season and 86, 96 and 115 DAT during fall) and yields were recorded as total marketable yield (boxes per acre per treatment) for each season. Harvested fruits were graded based on USDA (1997) standards as small, medium, large and extra-large mature-green and colored fruits. All statistical analysis was realized with Statistical Analysis Software (SAS Institute Inc., Cary, NC) for the analysis of variance (ANOVA). Duncan's multiple range test was used to identify significant differences among treatments.

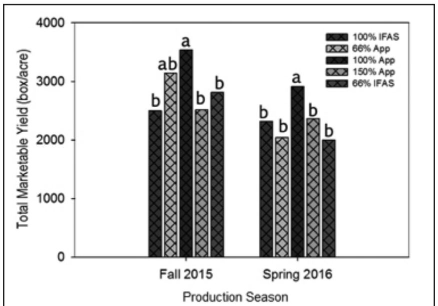

Figure 1. Effect of irrigation on total marketable yield during fall 2015 and spring 2016 seasons based on University of Florida Institute of Food and Agricultural Sciences (IFAS) recommendation and SmartIrrigation vegetable application (App) in Immokalee, FL.

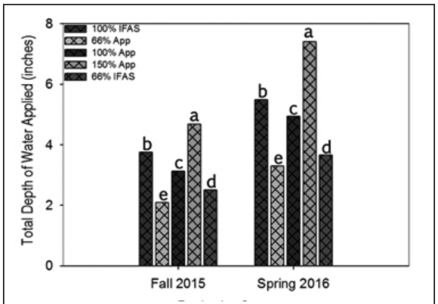

Figure 2. Total depth of irrigation for spring and fall seasons of 2015 based on University of Florida Institute of Food and Agricultural Sciences (IFAS) recommendation and SmartIrrigation vegetable application (App) in Immokalee, FL.

Table 2. Total biomass accumulation at different days after transplanting (DAT) during spring and fall seasons of 2015 in Immokalee, FL.

	Fall 2015 (lbs.acre^{-1})			Spring 2016 (lbs.acre^{-1})		
Treatment[z]	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT
100% IFAS	330.15	2748.31	2436.00	32.27	1756.15	2630.79
66% App	410.46	2864.31	3283.69	31.95	1596.07	2282.26
100% App	383.69	3078.46	3105.23	41.64	1602.14	2478.83
150% App	330.15	2498.46	2552.00	25.70	1488.10	2771.42
66% FAS	321.23	3497.85	2944.62	27.51	1484.09	2321.34
Sig. Level	ns	ns	ns	ns	ns	ns

[z] IFAS = Irrigation based on University of Florida Institute of Food and Agricultural Sciences recommendation, App = Irrigation based on SmartIrrigation vegetable application.

RESULTS AND DISCUSSIONS

Biomass Accumulation

No significant differences were observed among treatments in total biomass accumulation for both seasons at all sampling dates (Table 2). The possible reason for a similar biomass accumulation between the low and high irrigation rates could be as a result increase in tomato root volume under lower irrigation rates early in the season (Ngouajio et al., 2007).

Marketable Yield

Similar results with significant differences were observed in yield among treatments during both seasons. The 100% app treatment was significantly greater in total marketable yield compared to other treatments except during the fall season when yields were similar for 66% and 100% App (Fig. 1). Total marketable yield from 100% App was higher compared to 100% IFAS rate. The lower marketable yield for higher irrigation rates (100% IFAS and 150% App) is an indication that irrigation schedules from both irrigation rates were higher than plant water requirement hence potential leaching of nutrients below the root zone (Zotarelli et al., 2008). Total marketable yield obtained during the seasons was similar to reported yields in the literature (Hanson and May, 2004; Zotarelli et al., 2009; Ren et al., 2010; Ozores-Hampton et al., 2015).

Seasonal Irrigation Water Use

Irrigation was scheduled weekly at selected rates using both scheduling methods. Total water use was observed to be lower for the fall season compared to the spring season (Fig. 2) because of lower ET observed during the fall season. From lowest to highest irrigation rates, total seasonal irrigation depths ranged from 2.1 inches to 4.7 inches during fall season and 6.8 inches to 14.5 inches during spring. For both seasons, depth of irrigation water applied increased in the order of 66% App < 66% IFAS < 100% App < 100% IFAS < 150% App. For fall and spring seasons respectively, a total of 17% and 15% reduction in total irrigation volume was recorded for the App-based treatment (100% App) over the corresponding treatment based on UF/IFAS irrigation scheduling method (100% IFAS). These results suggest that irrigation schedule using real-time and location specific weather data (SI App) could be a more suitable irrigation scheduling method compared to schedules based on historic weather information (UF/IFAS) in open-field tomato production.

CONCLUSION

Although no significant differences were observed among treatments in total biomass accumulation, 100% SI App was significantly greater in total marketable yield compared to other treatments, with significant water savings compared to 100% IFAS. Yield data suggests that irrigation scheduled with 100% SI App was most adequate for tomato fruit production. Irrigation was most likely to be deficient for the 66% App and 66% IFAS treatments and excessive for 100% IFAS and 150% App. Thus, increase in yield for 100% App is an indication that irrigation scheduled using 100% App could be better suited for tomato production in south Florida as compared to UF/IFAS recommendations.

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Updated Information on the Thrips Vectors (Thysanoptera: Thripidae) of Tospoviruses in Tomatoes in South Florida

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INTRODUCTION

Tomato (*Solanum lycopersicum*), the second largest vegetable crop in acreage worldwide, is grown on 3.7 million hectares in 144 countries with an annual yield of 100 million tons of fresh fruit. The Unites States of America ranks second in tomato production with Florida ranking first among the states in total fresh market tomato production (42,000 acres in 2008). Tomato growers face serious challenges from biotic and abiotic factors (McAvoy and Hampton 2014). The most troublesome biotic factors include insects (whiteflies, thrips, leafminers, and worms) and pathogenic microbes (bacteria, fungi, and viruses).

Miami-Dade County, Florida has a long history of growing fresh market tomatoes during the winter and spring. Recently, tomato production is facing challenges from serious outbreaks of the tospoviruses, *Tomato chlorotic spot virus* (TCSV) and *Groundnut ring spot virus* (GRSV) (Londoño et al., 2012, Zhang et al. 2015). In 2014-2015, about 100% of Miami-Dade County tomato fields were infected by these tospoviruses, primarily TCSV, causing 30 -50% total yield loss. In addition, several growers abandoned their fields in the wake of this devastating TCSV infestation. Despite the weekly applications of commonly used insecticides, tomato growers did not receive any remedy to the virus problems because of inadequate control of the thrips vectors.

Tospoviruses are vectored by thrips belonging to the family Thripidae. Jones (2005) confirmed that at least 13 tospoviruses are transmitted by 10 species of thrips. Acquiring tospoviruses is dependent on thrips development stage. Only larval stages become infected when they feed on infected plants. Adults that develop from the infected larvae become viruliferous and transmit viruses when they feed on a non-infected plant. Thus secondary spread of virus in a tomato field takes place if adults reproduce in the infected field.

Common blossom thrips have been reported to efficiently transmit GRSV (Nijkamp et al., 1995; de Bordon et al., 2006; Nagata et al., 2004) and TCSV (Londoño et al., 2012; Funderburk et al., 2007; Wijkamp et al., 1995; Nagata et al., 2004). This thrips species has also been reported to transmit *Chrysanthemum stem necrosis virus* (Nagata and de Àévíla, 2000; Nagata et al., 2004) and *Groundnut bud necrosis virus* (Wijkamp et al., 1995).

Like common blossom thrips, Western flower thrips also transmit *Chrysanthemum stem necrosis virus* (Nagata and de Àévíla, 2000; Nagata et al., 2004), GRSV (Wijkamp et al., 1995; Nagata et al., 2004), *Impatiens necrotic spot virus* (De Angelis et al., 1993; Wijkamp et al., 1995; Sakurai et al., 2004), TCSV (Wijkamp et al., 1995; Nagata et al., 2004) and *Tomato spotted wilt virus* (TSW) (Medeiros et al., 2004; Wijkamp et al., 1995; Nagata et al., 2004).

The role of melon thrips in transmitting tospoviruses is not clear yet although it has been recorded in all tospovirus infected tomato fields. However, several researchers reported its potential in transmitting tospoviruses (Nagata et al., 2002; Chen et al., 2005; Lakshmi et al, 1995; Meena et al., 2005; Reddy et al., 1992; Kato et al., 2000; and Iwaki et al., 1984). However, there is no molecular level research information to support above reports on the transmission of TCSV by melon thrips. It is important to know the potential of this species in transmitting tospoviruses in tomatoes. This information will play an important role in developing an effective IPM program in managing TCSV in tomato.

Growers use insecticides of different modes of action to combat thrips and their transmitted tospoviruses in tomatoes. These insecticides, when applied alone, provided unsatisfactory results in controlling thrips. Efforts should be made to understand their non-tomato vegetable, ornamental and weed hosts, and their seasonal abundance. This information coupling with effective chemical rotation programs and cultural control practices will provide control of thrips and tospoviruses. Therefore, the objectives of this study were: a. to determine seasonal abundance of thrips in tomato and other simultaneously grown vegetable crops; b. to gather information on common weed hosts; and c. to evaluate insecticides to develop an effective rotation program.

MATERIALS AND METHODS

All studies were conducted in the Tropical Research and Education Center (TREC) research plots and three small commercial tomato fields located in Homestead, FL. The commercial fields were 2-3 acres each and the TREC field was 1 acre. In all studies the soil type was Krome gravelly loam (loamy-skeletal, carbonated hyperthermic Lithic Udorthents), which consisted of 33% soil and 67% pebbles (> 2 mm). Tomato (cv. `Sanibel') transplants were planted in all fields on raised beds (91 cm wide, 15 cm high) covered with 1.5 mm thick black-and-white polyethylene. Tomato seedlings were placed in 5-7 cm deep holes spaced 45.72 cm (18 in.) within the row and 1.83 meters (72 in.) between adjacent rows. A pre-plant herbicide, Halosulfuron methyl (Sandea®, Gowan Company LLC., Yuma, Arizona) was applied at 51.9 g / ha 21 days before planting to control weed emergence. Crops were fertilized by applying granular fertilizer 6:12:12 (N : P : K) at 1345 kg/ha in a 10 cm-wide band on both sides of the raised bed center and was incorporated before placement of plastic mulch. Additionally, liquid fertilizer 4: 0: 8 (N : P : K) was also applied at 0.56 kg N / ha / day through a drip system at 2, 3, 4, and 5 weeks after planting. Plants were irrigated every day for one hour using two parallel lines of drip tube (T-systems, DripWorks, Inc., Willits, California), spaced 30 cm apart parallel to the bed center, having an emitter opening for water every 13 cm. For managing fungal and bacterial pathogens, chlorothalonil (Bravo®, Syngenta Crop Protection, Inc., Greensboro, NC) at 1.75 l/ha and copper hydroxide (Kocide® 3000, BASF Ag Products, Research Triangle Park, NC) at 0.8 l/ha were sprayed every 2 weeks.

Seasonal abundance in tomato. The thrips population abundance study was conducted in 2014-15, 2015-16 and 2016-17 tomato growing seasons in the above mentioned four fields to assess generalized pattern of thrips seasonal abundance. For this purpose, a 9.1 square meter area (plot) containing 20 plants was selected from each corner of a field. 20 leaves were randomly collected: one full grown young leaf perplant, from each plot and placed in a one quart, thrips proof, plastic container which was marked with date of collection, field location and plot number. The leaves were washed with 70% ethanol to separate thrips adults from larvae. Thrips specimens in ethanol were checked using a binocular microscope at 10x magnification to record thrips numbers by species. Samples were collected on the second week of each month starting October and continued until June. In the instance when a field was destroyed before sampling was over, an adjacent field was selected to continue sampling. Thus from each field, we collected four sub samples each month and 36 sub samples in each study period. All sub samples from a specific field on a specific date were combined to consider as a sample of (20x4)=80 leaves and each field was considered as a replicate. We visually recorded TCSV infected plants from each sub plot at the time of sample collection for thrips.

Seasonal abundance in non-tomato vegetable crops. This study was conducted in five crops including snap bean (*Phaseolus vulgaris*), squash (*Cucurbita pepo*), `Jalapeno' pepper (*Capsicum annuum*), eggplant (*Solanum melongena L.*), and tomato (*Solanum lycopersicum* L.). The crops were planted in the same locations where tomatoes were planted. Planted area of each crop in each location varied from 1 – 2 acres. Each crop was planted on three dates- 2 October, 5 January and 5 April in season. All crops were planted and managed following recommendations as mentioned in the Vegetable Production Handbook of Florida. Plot design, sample collection and sample preparation were as discussed above for tomato.

Abundance of thrips in weeds. We conducted this study in 2015 and 2016 in the same locations where tomato and vegetable crop were planted. Seven different weed species including spiny amaranth (*Amaranthus spinosus*), Mexican poppy (*Argemone mexicana*), Aster flowers (*Aster* sp.), Varigated bauhinia (*Bauhinia varigata*), Spanish needle (*Bidens pilosa*) and red clover (*Trifolium pretense*) were sampled in the same time as discussed for tomato. Each time we collected 20 grams of flowers and leaves in four replications from each location. Samples were placed in one quart plastic cups which were marked with date, location and weed species. Weed contents in each cup were washed and processed following methods as discussed in the above studies.

Improved use of insecticides. Management of different species of thrips using chemical insecticides was conducted at the TREC research field. Treatment plots consisted of two beds each 12.19 m (40 ft.) long and 0.91 m (3 ft.) wide. Plots were arranged in a randomized complete block design replicated four times. A 1.52 m (5 ft.) planted space separated adjacent plots in a block. Thus, each block consisted of 161.5 m (530 ft.) long two beds. One planted bed separated each block from the next block. Various insecticides used in this study included spinetoram (Radiant®, Dow AgroSciences), abamectin (Agri-Mek® SC, Syngenta), sulfoxaflor (Closure® SC, Dow AgroSciences), tolfenpyrad (Apta™, Nichino America, Inc.), Clothianidin (Belay®, Valent USA), acetamiprid (Assail® 30 SG, United Phosphorous, Inc.), cyantraniliprole (Exirel®, Dupont) and an untreated check. Rotational sequence of each insecticide in a treatment, rate [oz]/ acre and application method is shown in Table 1.

Treatments were applied on five dates- 24 Feb., 4, 11, 18 and 25 March, 2016. Application of insecticides was performed by using a backpack sprayer delivering 50 – 70 GPA at 30 PSI. Evaluation of insecticide efficacy was accomplished by randomly collecting 10 full grown young leaves, one leaf/plant, from each treatment plot 24 h after each application. Sampled leaves were placed in a plastic bag by plot and treatment and were brought to the laboratory for washing them with 70% ethanol to separate thrips from leaves. Numbers of adults and larvae were identified and recorded by checking under a binocular microscope at 10 x magnification.

Statitistics. All data were square root transformed ($\sqrt{x}+0.25$) before analysis to normalize the error variance. Proc Mixed with Repeated measure function was conducted to determine interaction effects between years and months in tomato study, months and veg-

Table 1. Insecticides used in the study, rates applied, and application method.

Treatments	Rates (oz./acre)	Application method
Radiant, Closer, Assail, Belay	6.0, 4.5, 6.9, 6.0	Foliar
Radiant, closer, Exirel, Apta	6.0, 4.5, 20.5, 21.0	Foliar
Radiant, Closer, Radiant, Closer	6.0, 4.5, 6.0, 4.5	Foliar
Radiant+Ag, Closer, Radiant+Ag, Closer	6+16, 4.5, 6+16, 4.5	Foliar
Untreated check	-	-

Table 2. Mean numbers of thrips adults/10 leaf sample of tomato in different months of sampling in Homestead, FL.

	Mean numbers/10 leaf sample								
	Melon thrips			Western flower thrips			Common blossom thrips		
Months	2015	2016	2017	2015	2016	2017	2015	2016	2017
October	4.50cd[z]	4.25ab	3.75a	0.50a	1.00a	1.25b	1.00ab	1.25a	0.25a
November	5.75cd	5.50ab	4.00a	0.75a	0.75a	1.75b	0.50ab	1.00a	0.25a
December	8.75ac	7.50ab	4.00a	1.25a	2.50a	2.75ab	0.50ab	0.50a	1.25a
January	11.25ab	8.25ab	5.25a	0.50a	2.25a	3.00ab	1.25ab	1.25a	1.25a
February	12.50ab	7.75ab	6.75a	1.75a	2.25a	4.50a	1.75a	1.00a	0.75a
March	12.75ab	10.00a	6.25a	2.00a	2.25a	3.00ab	0.25b	1.50a	0.75a
April	13.50a	7.75ab	5.75a	2.50a	1.50a	2.00b	0.50ab	1.25a	1.25a
May	7.50bd	5.50ab	4.50a	1.75a	1.50a	2.50ab	1.00ab	1.25a	1.75a
June	3.75d	3.50b	3.50a	0.75a	1.50a	1.25b	1.75ab	1.00a	0.75a

[z] Means within a column followed by the same letter or no letter do not differ statistically, $P < 0.05$; Tukey's Studentized Range (HSD) Test.

Table 3. Mean numbers of TCSV infected tomato plants/30 feet long beds in three years of sampling.

	Mean numbers of TCSV infected plants		
Months	2015	2016	2017
October	0.83c[z]	0.33d	0.33d
November	1.17c	0.58cd	1.00cd
December	2.67bc	1.08bd	1.50bc
January	5.00ab	1.42bc	1.83bc
February	4.92b	1.92bd	2.33ab
March	5.42ab	1.83b	2.17ab
April	6.08a	3.33a	3.42a

[z] Means within a column followed by the same letter or no letter do not differ statistically, $P < 0.05$; Tukey's Studentized Range (HSD) Test.

etables species in vegetable study, year and month in TCSV study. When interactions were found significant, each factor of the interaction was analyzed separately by using linear model `Proc Anova' with `Repeated measure' option. Mean values for all levels under a specific factor were separated using the Tukey studentized range honestly significant difference (HSD) mean separation test ($\alpha = 0.05$) (SAS Institute Inc. 2013).

RESULTS AND DISCUSSION

During the present study, melon, western flower and common blossom thrips were recorded on tomato in all months (October to April) of sampling in 2015, 2016 and 2017 (Table 2). Melon thrips population abundance was higher in Dec. to April than other months in 2015 (F=2.91; df=8,27; P <0.01) and 2016 (F=2.99; df=8,27; P < 0.01). Mean number of melon thrips/sample did not differ among months in 2017 (F=2.86; df=8,27; P<0.01). Mean numbers of melon thrips varied from 3.75 to 13.50, 3.50 to 10.00 and 3.50 to 6.75 in 2015, 2016 and 2017, respectively.

Western flower thrips population abundance was low and the mean number of thrips/sample did not vary among different months during the sampling periods of 2015 (F=1.86; df=8,27; P<0.10), and 2016 (F-1.11; df=8,27, P<0.38) (Table 2). In 2017 (F=5.75; df=8,27; P < 0.0003), mean number of western flower thrips was higher (4.40/sample) in February than in other months.

Like western flower thrips, mean numbers of common blossom thrips/sample were low (0.25-1.75) during the entire study period of 2015, 2016 and 2017 (Table 2). In 2015 (F=2.91; df=8, 27; P<0.01), mean number of common blossom thrips was higher (1.75) in February than other months. Mean number of common blossom thrips / sample did not vary among months in 2016 (F=0.73; df=8, 27; P<0.66) and 2017 (F=2.48; df=8,27; P<0.03).

Tomato cholorotic spot virus incidence. Virus incidence was recorded at a low number in October shortly after planting tomatoes in all three years of the study (Table 3). In 2015, TCSV infected plants ranged from 0.83 (4.15%) in October to 6.08 (34%) in April. Mean number of infected plants varied significantly among various months (F=16.91; df=8,18; P<0.0001). In 2016 (F=19.97; df=8,18; P<0.0001), TCSV infected plants varied from 0.33 (1.65%) in October to 3.33 (16.65%) (Table 3). Like 2015 and 2016, mean number of infected plants varied significantly among different months (F=24.79; df=8,18; P<0.0001) with the highest number in April (3.42 plants or 17.1%) and the lowest in October (0.33 plants or 1.65%).

Thrips abundance in vegetable crops. Bean, squash, pepper, eggplant and tomato are grown in the same area in Miami-Dade County. Once one crop is infested with an insect pest, other crops become vulnerable to that pest and eventually become infested with the same pest. Thus, it is important to know the vegetable hosts of the TCSV vectoring thrips and their seasonal abundance. Melon thrips are a major feeding pest of bean, squash, pepper and eggplant and minor feeding pest of pepper and tomato (DRS; personal observations). It was recorded in all months of sampling with the highest numbers in bean, squash and eggplants followed by pepper and tomato (Table 4). Month and vegetable crop interactively (month* vegetable: F=2.18; df=24; P<0.003) influenced population abundance of melon thrips. In conducting one-way repeated measure ANOVA using month and vegetable type separately as main factor (one factor ANOVA), each factor was also found to be influencing thrips population (month: F=11.78; df=6; P<0.001; vegetable: F=117.86; df=4; P<0.0001).

Western flower thrips were recorded in all crops during this study (Table 5). However, population abundance was low (0.50-7.75) when all crops and months were considered together. Like melon thrips, month and Vegetable crop interactively (month * vegetable: F=3.53; df=24; P<0.0001; month: F=31.84; df=6; P<0.001; vegetables: F=15.37; df=4; P<0.0001) influenced population abundance of western flower thrips in this study.

Like the above two species of thrips, common blossom thrips were recorded in

Table 4. Mean number of melon thrips adults/10 leaf sample of five select vegetable crops in different months of sampling.

	Mean no. adults/10 leaf sample				
Month	Bean	Squash	Pepper	Eggplant	Tomato
October	16.00a[z]	14.00a	4.75b	9.75a	2.50b
November	15.75a	15.00a	7.50b	16.75a	2.50c
December	21.00a	18.25a	8.75b	19.25a	3.75c
January	29.25a	26.00a	7.25b	26.25a	4.25b
February	25.50a	27.25a	6.75b	28.50a	5.50b
March	25.50a	20.50a	4.50b	26.75a	2.50b
April	25.50a	20.50a	4.50b	26.75a	2.50b
April	22.75a	22.25a	7.25b	26.50a	3.50c

[z] Means within a row followed by the same letter or no letter do not differ statistically, P < 0.05; Tukey's Studentized Range (HSD) Test.

Table 5. Mean number of western flower thrips adults/10 leaf sample of five select vegetable crops in different months of sampling.

	Mean no. adults/10 leaf sample				
Month	Bean	Squash	Pepper	Eggplant	Tomato
October	1.00a[z]	0.50a	1.00a	1.00a	0.50a
November	0.75a	0.50a	0.50a	0.50a	0.75a
December	1.00a	0.50a	1.00a	0.75a	0.50a
January	3.00a	1.25b	1.50ab	0.75b	1.50ab
February	6.75a	0.75b	1.00b	1.00b	1.00b
March	3.00a	2.75a	2.50a	0.75b	2.25a
April	7.75a	5.50ab	5.50ab	2.25c	3.50bc

[z] Means within a row followed by the same letter or no letter do not differ statistically, P < 0.05; Tukey's Studentized Range (HSD) Test.

Table 6. Mean number of common blossom thrips adults/10 leaf sample of five select vegetable crops in different months of sampling.

Month	Mean no. adults/10 leaf sample				
	Bean	Squash	Pepper	Eggplant	Tomato
November	1.00a[z]	0.50a	0.75a	0.75a	0.25a
December	1.00a	1.50a	2.00a	1.50a	1.25a
January	1.00a	1.00a	0.75a	0.75a	0.75a
February	1.50a	1.50a	0.75a	0.50a	1.50a
March	1.00a	1.00a	0.50a	0.75a	0.25a
April	0.75a	1.00a	0.25a	0.25a	0.75a

[z] Means within a row followed by the same letter or no letter do not differ statistically, P < 0.05; Tukey's Studentized Range (HSD) Test.

all crops grown in various seasons (Table 6). Month and vegetable did not interactively (month * vegetable: $F = 0.62$; df=24; $P<0.91$) influence populations population abundance of common blossom thrips in this study. Vegetable crop species did not influence population abundance of common blossom thrips (F=1.02; df=4; $P<0.40$). Month at which plants were sampled was an important factor to influence (F=3.61; df=6; $P<0.002$) population abundance of common blossom thrips.

Abundance of thrips in weeds. Melon, western and common blossom thrips were recorded on all six weed hosts in low numbers during the present study (Table 7). Although the numbers were low in all months of sampling, it is important that vector thrips were maintaining their populations on these weeds and move to different vegetable crops shortly after planting. Efforts are being made to combat thrips and their transmitted tospoviruses by avoiding their presence in the weed hosts near tomato fields and other crops.

Rotational use of insecticides. Melon thrips population abundance was medium on tomato plants during this study (Table 8). Treatment effects were inconsistent across the study period. Radiant + Agrimek and Closer weekly rotation program significantly reduced melon thrips adults on the last two sampling dates when compared with the untreated check. Other treatments did not reduce melon thrips.

Common blossom and western flower thrips populations were low in tomato during this study. This trend of western and common blossom thrips abundance was observed in all commercial tomato fields in Miami-Dade County, FL. The effect of various treatments in controlling flower thrips was not statistically different as compared to the untreated control (data not shown). This might be due to the movement of thrips from weeds and other vegetable hosts.

TCSV infected tomato plants were not recorded on the first sampling date in any of the treatment plots (Table 9). On the second sampling date, only a few untreated check plants were infected with TCSV. On the third and fourth sampling dates all treatment plots had TCSV infected plants which did not differ statistically from the untreated check plot. Insecticide application was discontinued on the fourth sampling date which suddenly increased the mean numbers of TCSV infected plants in each treatment plot.

Table 7. Abundance of melon thrips and flower thrips (western flower thrips + common blossom thrips) on different weed species in tomato ecosystem at Homestead, FL.

Weed species	Mean no. of melon thrips	Mean no. of Flower thrips (western + common blossom thrips)
Spiny amaranth	1.75a[z]	1.20a
Mexican poppy	0.20a	0.20a
Aster	1.80a	0.10a
Bauhinia	1.20a	0.20a
Spanish needle	1.50a	0.10a
Red clover	0.80a	0.50a

[z] Means within a row followed by the same letter or no letter do not differ statistically, P < 0.05; Tukey's Studentized Range (HSD) Test.

Table 8. Effectiveness of Radiant-Closer rotation in controlling Melon thrips adults in tomato

Treatments	Rate [oz.]/acre	Mean numbers of melon thrips adults				
		25 Feb.	5 Mar.	12 Mar.	9 Mar.	26 Mar.
Radiant-Closer-Assail-Belay	6.0-4.5-6.9-6.0	5.75a[z]	1.75b	3.75ab	4.50ac	2.50a
Radiant-closer-Exirel-Apta	6.0-4.5-20.5-21.0	7.25a	3.50a	3.00b	5.25ab	2.00ab
Radiant-Closer-Radiant-Closer	6.0-4.5-6.0-4.5	4.50a	3.25ab	4.75ab	4.25bc	1.50ab
Radiant + Ag-Closer-Radiant+Ag - Closer	6+16-4.5-6+16-4.5	4.50a	3.00ab	4.00ab	3.25c	0.75b
Untreated check	6.0-4.5-6.9-6.0	6.75a	4.00a	5.50a	6.50a	3.25a

[z] Means within a row followed by the same letter or no letter do not differ statistically, P < 0.05; Tukey's Studentized Range (HSD) Test.

Table 9. Effectiveness of Radiant-Closer rotation in controlling TCSV incidence in tomato

Treatments	Rate [oz.]/acre	Mean numbers of TCSV plants				
		25 Feb.	5 Mar.	12 Mar.	9 Mar.	26 Mar.
Radiant-Closer-Assail-Belay	6.0-4.5-6.9-6.0	0.00a[z]	0.00a	3.25a	6.00a	11.75a
Radiant-closer-Exirel-Apta	6.0-4.5-20.5-21.0	0.00a	0.00a	5.00a	5.25a	9.00a
Radiant-Closer-Radiant-Closer	6.0-4.5-6.0-4.5	0.00a	0.00a	5.50a	4.75a	12.25a
Radiant+Ag-Closer-Radiant+Ag - Closer	6+16-4.5-6+16-4.5	0.00a	0.00a	4.25a	6.00a	13.50a
Untreated check	6.0-4.5-6.9-6.0	0.00a	0.25a	5.75a	8.00a	10.25a

[z] Means within a row followed by the same letter or no letter do not differ statistically, P < 0.05; Tukey's Studentized Range (HSD) Test.

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From Seed to Fork: Advancing Integrated Practices for Managing Tomato Bacterial Spot

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BACKGROUND

Bacterial diseases pose a major challenge to vegetable production, and are a constant menace to Florida's lucrative fresh market tomato industry valued at $453 million in 2015. Bacterial spot of tomato (BST), caused by the bacterium *Xanthomonas perforans* race T4, is a common disease in Florida that affects all aerial portions of the plant (leaves, stems and fruit) and can lead to dramatic reductions in yield. Impacts from BST are greatest during late summer plantings, when weather conditions favor rapid disease development. VanSickle et al. (2009) estimated that monetary losses attributed to BST at nearly $3,000 per an acre. Such losses are unacceptable in the face of narrowing profit margins.

Although host resistance offers the most economical and effective means of managing BST, resistance breeding efforts have been hindered by changes in the *Xanthomonas* pathogen population. Prior to 1990, resistance derived from Hawaii 7998 to the prevalent *X. euvesicatoria* race T1 was overcome by the introduction of *X. perforans* race T3 in Florida. Resistance to *X. perforans* race T3 derived from PI 128216 was then overcome by *X. perforans* race T4 (Stall 2009). Statewide surveys of BST causing xanthomonads in Florida also reflected these changes. A 2006-2007 survey of 377 strains identified *X. perforans* as the sole cause of BST in Florida with a 1:2 ratio of race 3 to race 4 strains (Horvath et al. 2012). A subsequent survey of 144 strains in 2011-2012 found that *X. perforans* race 4 displaced race 3 throughout Florida (Vallad et al. 2013). Most troubling, these shifts in the BST pathogen population occurred in the absence of any commercially deployed resistance. This suggests that these population changes are not due to host selection, but instead are likely due to the introduction of novel strains with a competitive advantage over the established population. Interestingly, whole genome sequencing has identified the existance of at least 2 genetic lineages (group 1 and 2) among *X. perforans* race 4 strains, with evidence that group 2 strains emerged from the genetic exchange between *X. perforans* (race T3) with *X. euvesicatoria* (race T1) (Timilsina et al. 2015).

In the absence of host resistance, growers have relied on copper-based fungicides for the management of BST over the last 60 years, including for transplant production. Surveys of *X. perforans* strains recovered from tomato transplant and field production areas revealed that copper-tolerant strains are ubiquitous throughout the state and have compromised the efficacy of copper-based fungicides (Horvath et al. 2012; Vallad et al. 2013 & 2014). Even more alarming, 86% of the strains collected from transplant facilities were resistant to the antibiotic streptomycin, compared to only 14% for field strains (Vallad et al. 2013). Many tomato growers have transitioned away from copper or limited copper applications during field production, adopting copper-alternatives, such as the plant defense elicitor Actigard (Huang et al. 2012; Louws et al. 2001). Unfortunately, while alternatives like Actigard and other copper-alternatives exist, they only provide limited control of BST under field conditions in Florida. Identifying and addressing inoculum sources of *X. perforans* would limit the introduction of inoculum into commercial production fields.

Commercial transplant facilties provide an ideal environment for bacterial diseases, like BST. High plant density, frequent overhead irrigation, high temperatures and humidity are conducive for the rapid development and spread of bacterial pathogens. Disease outbreaks have large implications for commercial transplant operations and more importantly, infected seedlings introduce the bacterial pathogen to the field. The overall goal of the project was to develop integrated management strategies to limit transplant losses to BST and the spread of *X. perforans* in commercial transplant facilities; and further demonstrate the benefit of these approaches to limit the introduction of *X. perforans* into production fields.

MATERIALS & METHODS

Bactericide evaluations. A series of six trials was established at the Gulf Coast Research and Education Center (GCREC) to evaluate the effectiveness of 15 bactericides for managing BST on seedlings (Table 1). Trials used 128-cell Speedling trays (26.6" length x 13.6" width) with 2 week old tomato seedlings (FL 47) that were initiated at a local transplant operation. Each tray of seedlings was treated using a small boom fitted to a CO_2 backpack sprayer. A total of 4 trays per a treatment, including a non-treated control, were arranged in a randomized complete block design. One day after treatment, plants were inoculated with a copper tolerant strain of *X. perforans* at 10^5 CFU/ml. Trays were maintained under greenhouse conditions, using a portable overhead boom system to provide regular watering and fertilization of seedlings during the four week trial period. Several bactericide treatments were reapplied at least twice following inoculation. After four weeks, plants in each tray were rated for disease severity (proportion of seedlings in each tray exhibiting BST symptoms).

Movement of X. perforans during transplant production. A series of three trials were established at the GCREC and two trials at a commercial transplant facility to evaluate the movement of *X. perforans* on tomato seedlings during transplant production. Trials at GCREC used 128-cell Speedling trays with 2 week old tomato seedlings (FL 47) that were initiated at a local transplant operation. Trays were arranged into 6 groups, each group consisiting of 2 rows of three trays arranged lengthwise. Eight individual seedlings from one end of each group of seedling trays was dip-inoculated with a rifampicin resistant strain of *X. perforans* at 10^6 CFU/ml. Two groups of four trays were included as non-inoculated controls. A portable overhead boom system was used to provide regular watering and fertilization of seedlings during the four week trial period; however, boom movement was limited to only one direction across seedlings. Sampling zones were established at specific distances of 3.0, 9.5, 16.0, 24.8, 33.0, 41.0, 51.5, 61.0, and 70.5 inches from the inoculated row, from which 10-12 leaves were randomly sampled 5 times over a 4 week period. *Xanthomonas perforans* was enumerated by plating leaf washings from each distance (6 reps per a distance) onto rifampicin-amended media.

Trials at the commercial transplant facility were conducted in a similar manner to those at GCREC, except plants were 4 weeks old when inoculated. Trials used 242-cell Speedling trays with 6 groups of 20 trays, arranged in 4 rows of 5 trays (lengthwise). Six additional groups of non-inoculated control trays were included adjacent to inoculated trays with a 3 foot buffer to assess background BST levels. End trays in each group were spray inoculated with a 10^6 CFU/ml of rifampicin resistant *X. perforans* strain. The overhead boom system was used to provide regular watering and fertilization of seedlings as necessary during trials; however, boom movement was limited to only one direction across seedlings. Sampling zones were established at specific distances (1.2, 13.0, 26.0, 39.0, 52.0, 65.0, 78.0, 91.0, and 104.0 inches from the inoculated tray, from which 10-12 leaves were randomly sampled up to 4 times over a four week period. *Xanthomonas perforans* was enumerated by plating leaf washings from each distance (6 reps per a distance) onto rifampicin-amended media.

RESULTS AND DISCUSSION

Bactericide evaluations: In Trials 1 and 2, Kocide 3000 alone statistically reduced BST severity by 92 and 51%, respectively, compared to the non-treated control (Table 2). Only Actigard (96 and 79% reduction in Trial 1 and 2, respectively) and Cueva (79% reduction in Trial 2) was as effective as Kocide 3000. Other notable products included Innovotech B, which reduced disease severity by 62 and 56% in Trials 1 and 2, respectively, compared to the control. Quintec applications also statistically reduced BST severity by 58% compared to the control in Trial 2, but higher application rates caused severe phytotoxicity. Other products, such as Sil-Matrix, Innovotech A, and Tanos + Kocide 3000, only performed well in one of the two trials.

For Trials 3 and 4, Kocide 3000 was statistically equivalent to the control based on disease severity (Table 3). Similar to previous trials, Actigard (52 and 73% reduction in Trial 3 and 4, respectively), Cueva (57% reduction in Trial 3), and Quintec (65 and 61% reduction in Trial 3 and 4, respectively) statistically reduced the severity of BST compared to the control. Combined applications of either Tanos + Actigard + Agriphage or Tanos + K-Phite + Cueva also provided a significant reduction of BST compared to the control in both trials, but were statistically equivalent to either Actigard or Cueva alone, respectively. Combined applications consist-

Table 1. List of chemical product names, active ingredients, manufacturers used in trials.

Product name	Active ingredient	Manufacturer
Actigard	acibenzolar-s-methyl	Syngenta
Agri-mycin	streptomycin sulfate	Nufarm
Agriphage	bacteriophage cocktail	OmniLytics, Inc.
Cueva	10% copper octanoate	Certis USA
Cuprofix 40D	copper sulfate	United Phosphorous, Inc.
Double Nickel 55	*Bacillus amyloliquefaciens*	Certis USA
Innovotech A	*proprietary*	Innovotech
Innovotech B	*proprietary*	Innovotech
KleenGrow	ammonium chloride	Pace 49, Inc.
Kocide 3000	46.1% copper hydroxide	DuPont
K-Phite	mono- & di- sodium phosphoric acid	Plant Food Systems, Inc.
Mycoshield	oxytetracycline	Nufarm
Milstop	pottasium bicarbonate	BioWorks Inc.
Penncozeb 75DF	mancozeb	United Phosphorous, Inc.
Quintec	quinoxyfen	Dow AgroSciences
Sil-matrix	potassium silicate	Certis USA
Serenade Opti	*Bacillus subtilis* 'QST 713'	Bayer Crop Science
Tanos	famoxodone and cymoxanil	DuPont
USF2018A	*proprietary*	Bayer Crop Science

ing of either Tanos + K-Phite + Agriphage or Double Nickel + Cueva statistically reduced BST, relative to the control, in only one out of the two trials.

In Trials 5 and 6, Kocide 3000 reduced disease severity in both trials, but only to levels that were of statistical significance in Trial 5 (Table 4). As in previous trials, Actigard provided a significant 81 and 84% reduction in disease severity compared to the non-treated control. All combined applications that contained either Cueva or Actigard also performed well, statistically reducing disease severity compared to the non-treated control. Combined applications of Tanos + Actigard and Tanos + Cueva + Actigard, statistically performed better than Actigard alone in at least one out of the two trials. Similarly, mixed treatments of either Tanos + Cueva + Serenade Opti + Milstop or Tanos + Cueva + Agriphage + K-Phite performed statistically better than a mixture of Tanos + Cueva in at least one of two trials. Innovotech B failed to statistically reduce disease severity compared to the control. However, Innovotech A statistically reduced disease severity by 88.3 and 79% compared to the control in Trials 5 and 6, respectively.

Overall, repeated foliar applications of Kocide 3000 were statistically ineffective at reducing BST, relative to the control in half of the trials. What variables account for the difference in Kocide 3000 performance among trials remains unknown. Temperature and relative humidity can have a profound impact on *in planta* bacterial growth and may account for the differences in the performance of Kocide 3000. However, the *X. perforans* strain used was a characterized copper tolerant strain that was isolated in 2012, and caused fairly consistent levels of BST across the non-treated controls of all 6 trials. Products such as Actigard and Cueva performed better than copper. A single 0.33 oz/100 gal. application of Actigard statistically reduced disease severity in 6 separate trials. Cueva is a copper soap containing only 1.8% metallic copper equivalent, which is extremely low compared to the 30% metallic copper equivalent for Kocide 3000. Innovotech A and B also did well; although the efficacy of the two products varied across trials (compare results in trials 1 and 2 versus trials 5 and 6). Innovotech A and B both contain a proprietary active ingredient that disrupts biofilm formation. Some of the differences observed may be linked to the specific formulations, as it was difficult to solubilize products at the time of application. Quintec also offered effective BST control at the 1 floz/100 gal. rate. However, phytotoxicity was problematic at higher rates and likely poses an unacceptable risk even at the lower rate evaluated here. Treatments that contained Actigard and Cueva combined with other products typically were as effective as Actigard or Cueva alone, but in some cases control was statistically improved.

Movement of X. perforans during transplant production. During trials conducted in January and February of 2016, inoculated plants exhibited water-soaked lesions 5 days post-inoculation (dpi) and well-defined, visible lesions by 10 dpi. However, no symptoms developed on any plants neighboring inoculated plants and *X. perforans* was only recovered at the point of inoculation, and never from any of the other sampling zones or the control trays for the 4 week duration of the trial.

Trial 3 was conducted in April 2017, and symptoms developed along the same timeline as observed in the first 2 trials. No *X. perforans* was recovered 5 dpi at any distance. However, by 7 dpi, *X. perforans* could be recovered at 3 and 9 inches from the source, as well as sporadic recovery at distances of 24.8, 41.0 and 61.0 inches from the inoculum source; in the absence of any symptoms on non-inoculated plants. Symptoms of *X. perforans* were not observed on neighboring plants (3 inches from the inoculum source) until 2 weeks after initial inoculation; at which time *X. perforans* was recovered 51.5

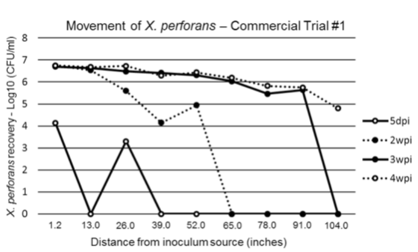

Figure 1. Movement of *X. perforans* on trays of tomato seedlings based on the recovery a rifampicin resistant *X. perforans* strain grown under commercial conditions.

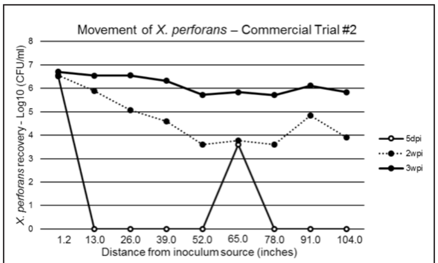

Figure 2. Movement of *X. perforans* on trays of tomato seedlings based on the recovery a rifampicin resistant *X. perforans* strain grown under commercial conditions.

Table 2. Treatments evaluated for controlling bacterial leaf spot in the greenhouse during summer and early fall 2015.

	Disease Severity (%) [z]	
Treatment, rate/100 gal [y]	Trial 1	Trial 2
Non-treated control	45.8 a[x]	88.8 a
Actigard, 0.33 oz [w]	2.0 de	28.8 fe
USF2018A 200SC, 0.01 lb, 0.02 lb, 0.04 lb[v]	58.8 a	76.3 ab
Tanos, 8 oz + Kocide, 1lb	2.0 de	67.5 ab
Kocide 3000, 1lb	3.5 d	43.8 b-e
Mycoshield, 445 g	23.8 bc	50.0 a-c
Agri-Mycin, 445 g	1.5 e	66.3 ab
KleenGrow, 6 oz	38.8 ab	63.8 a-c
Sil-Matrix, 4 qt	13.8 c	51.3 a-d
Innovotech A, 378 g	55.0 a	33.8 de
Innovotech B, 530 g	17.5 c	38.8 c-e
Quintec, 5 floz[u]	-	NT [t]
Quintec, 3 floz[u]	NT	-
Quintec, 1 floz	NT	37.5 def
Cueva, 2 qt	NT	18.8 f
Agri-Phage, 4 pt	NT	73.8 ab
P=	0.0001	0.0001

[z] The severity of bacterial spot was assessed as the percentage of trays affected. The disease rating percentages were subjected to a log-normal transformation prior to statistical analyses.

[y] Listed treatment rates are on a per 100 gal basis unless noted otherwise; foliar treatments were applied on 18 Aug, 25 Aug, and 1 Sept for Trial 1 and 29 Sept, 6 Oct for Trial 2 (corresponding to 3 and 2 applications, respectively).

[x] Means followed by the same letter are not significantly different according to Fisher's LSD test (α = 0.05).

[w] Actigard was applied once before inoculation in both trials.

[v] USF2018A 200SC rate increased with repeat applications.

[u] Plants treated with Quintec showed severe leaf curling and phytotoxicity at rates exceeding 1 floz/100 gal and were not rated '-'.

[t] NT: non-tested.

inches away from the source. By 3 weeks post-inoculation (wpi), *X. perforans* was recovered 70.5 inches from the incoulum source, although maximum recovery was limited to 61 inches by 4 wpi. No *X. perforans* was recovered on selective media from non-inoculated control trays during the trial.

Trials at the commercial transplant facility conducted in May and June 2016 yielded similar results, with *X. perforans* recovered at 1 and 26.0 inches from the inoculated source in Trial 1 and at 1 and 65.0 inches in Trial 2 at 5 dpi; with no recovery at other sampled distances (Figure 1 and Figure 2). By 2 wpi, *X. perforans* recovery was consistent from 1 to 65.0 inches from the inoculum source in Trial 1 and from 1 to 104 inches (the furthest sampling distance) in Trial 2. For Trial 1, *X. perforans* was not recovered from the furthest sampling distance of 104 inches until 4 wpi. Observed foliar symptoms were confined to only those seedlings in the tray nearest to the source of inoculum, encompassing sampling distances of 1.2, 13.0 and 26.0 inches from the inoculum source. Rifampicin resistant *X. perforans* was not initially recovered from the non-inoculated control trays. However, by the end of both trials, rifampicin resistant *X. perforans* was recovered, along with observed symptomatic seedlings on the very ends of non-inoculated control trays nearest to inoculated trays.

Results demonstrate that under favorable conditions of high temperature and relative humidity (typical of late-spring and summer transplant production), *X. perforans* can spread rapidly from an inoculum source with overhead irrigation. Not surprisingly, a 4 to 10-day lag in symptom development from the time of infection (with a known level of inoculum) can provide ample time for *X. perforans* to spread. The removal of trays containing diseased transplants can be an effective means of removing a potential inoculum source, as long as dispersal distances is taken into consideration, which can vary depending on environmental conditions. By not removing symptomatic plants these trials were obviously biased to favor maximum bacterial spread. Interestingly, no movement was detected during the first GCREC trials, even from plants neighboring inoculated seedlings that developed BST. Future trials will address the effect of roguing and *in planta* growth on the spread of *X. perforans*, as well as how bactericidal treatments influence spread and *in planta* growth. Based on these results, it is advisable to rogue at least one tray on each side of a symptomatic tray. However, if environmental conditions are favorable, it may be necessary to rogue two or more trays that surround each side a symptomatic tray. Additional studies are neccessary to further define environmental parameters governing the development of BST and movement of *X. perforans*.

Table 3. Treatments evaluated for controlling bacterial leaf spot in the greenhouse during fall 2015.

	Disease Severity (%)z	
Treatment, rate/100 gal[y]	**Trial 3**	**Trial 4**
Non-treated control	76.3 a[x]	82.5 a
[w]Actigard, 0.33 oz	36.3 b-e	22.5 d
Kocide 3000, 1lb	52.5 abc	57.5 ab
Quintec,1 floz	26.7 g	32.5 cd
Cueva, 2 qt	32.5 c-f	NT[v]
K-Phite, 3 qt	46.3 a-d	70.0 a
Agriphage, 4 pt	50.0 abc	56.3 ab
Double Nickel, 1 qt + Cueva, 2 qt	45.0 a-e	26.3 cd
K-Phite, 3 qt + Agriphage, 4 pt	30.0 c-f	68.8 a
Tanos, 8 oz + Actigard, 0.33 oz + Agriphage, 4 pt	18.8 def	28.8 cd
Tanos, 8 oz + K-Phite, 3 qt + Agriphage, 4 pt	25.0 d-g	52.5 abc
Tanos, 8 oz + K-Phite, 3 qt + Cueva, 2 qt	16.3 gf	32.5 bcd
P=	0.0001	0.0001

[z] The severity of bacterial spot was assessed as the percentage of trays affected. The disease rating percentages were subjected to a log-normal transformation prior to statistical analyses.

[y] Listed treatment rates are on a per 100 gal basis unless noted otherwise; foliar treatments were applied on 17 Nov and 24 Nov for Trial 3; and 2 Dec and 9 Dec for Trial 4 (corresponding to 2 applications).

[x] Means followed by the same letter are not significantly different according to Fisher's LSD test (α = 0.05).

[w] Actigard was applied only once before inoculation in both trials.

[v] NT: non-tested.

Table 4. Treatments evaluated for controlling bacterial leaf spot in the greenhouse during fall 2016 and spring 2017.

	Disease Severity (%): [a]	
Treatment, rate/100 gal (appl. no.)[b]	**Trial 5 [e]**	**Trial 6**
Non-treated control	71.3 a	70.0 a
Actigard, 0.33 oz (1)[c]	13.3 cd	11.5 f
Actigard, 0.33 oz (1)[d]	58.8 a	67.5 a
Tanos 8 oz (1, 3); Cueva 2 qt (1, 3)	11.8 cd	30 cd
Kocide 1lb. (2-3)	22.5 b	50.0 abc
Innovotech A 378 g (2-3) [f]	8.3 de	15.0 f
Innovotech B 530 g(2-3)	71.3 a	56.3 ab
Tanos 8 oz. (1, 3); Cueva 2 qt (1, 3); Serenade Opti 14 oz. (1-3); Milstop 2 lb (1-3)	7.5 e	32.5 cde
Tanos 8 oz. (1, 3); Cueva 2 qt (1, 3); Double Nickel 55 0.5 lb (1-3)	19.3 bc	38.5 bcd
Tanos 8 oz. (1, 3); Cueva 2 qt (1, 3); Agriphage 4 pt (1-3)	20.5 bc	35.0 bcd
Tanos 8 oz. (1, 3); Cueva 2 qt (1, 3); Agriphage 4 pt (1-3); K-Phite 3 qt (1-3)	6.0 e	27.5 cde
Tanos 8 oz. (1, 3); Agriphage 4 pt (1-3); Actigard 0.33 oz (1)[c]	8.0 cd	21.3 def
Tanos 8 oz. (1, 3); Actigard 0.33 oz (1)[c]	7.0 e	16.3 ef
Tanos 8 oz. (1, 3); Cueva 2 qt (1, 3); Actigard 0.33 oz (1)[c]	4.8 e	20.0 def
P=	<.0001	<.0001

[a] The severity of bacterial spot was assessed as the percentage of trays affected. The disease rating percentages were subjected to a log-normal transformation prior to statistical analyses.

[b] Listed treatment rates are on a per 100 gal basis unless noted otherwise; foliar treatments were applied on 11 Nov, 23 Nov, 29 Nov and 22 Feb, 1 March, 8 March for Trial 5 and 6, respectively (corresponding to 3 applications).

[c] Actigard was applied once before inoculation in each trial.

[d] Actigard was applied once at three weeks after inoculation.

[e] Means followed by the same letter are not significantly different according to Fisher's LSD test (α = 0.05).

[f] Plants showed slight phytotoxicity.

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Copper Nanomaterials Against Copper-Tolerant Strains of *Xanthomonas perforans* and Bacterial Spot of Tomato

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This article is a short review of nanomaterials developed, tested, evaluated in vitro, greenhouse and in field conditions and preliminary data on copper nanomaterials against copper-tolerant *Xanthomonas perforans*, the causal agent of bacterial spot of tomato in Florida. The experiments were conducted at the University of Florida, North Florida Research and Education Center and Gulf Coast Research and Education Center from 2010-2016.

Photocatalytic nanomaterials: Photocatalytic means "light-activated" nanomaterials like titanium dioxide (TiO_2), which absorbs energized photons from light (ultraviolet or visible) creating free electrons and positively charged holes that migrate to the structure of the crystal. This leads to interaction with water molecules forming hydroxyl radicals and oxygen forming superoxide anions, which are highly antibacterial in nature. This process has been demonstrated using commercially formulated TiO_2 (TiO_2/Zn) doped to Zinc and Silver (TiO_2/Ag) against a copper-tolerant *Xanthomonas perforans* strain in the presence of visible light, and no activity was found in the dark (Paret et al., 2013). Both of these materials were also shown to significantly reduce bacterial spot disease severity in greenhouse and field studies compared to non-treated controls and activity was similar to copper-mancozeb (Paret et al., 2013). However, a significant bottleneck in the commercialization of photocatalytic nanomaterials for bacterial spot management is the phytoxicity on tomatoes after 6 weekly applications, which is potentially due to the over accumulation of the nanomaterials on tomato leaves and higher release of superoxide anions and hydroxyl radicals to levels detrimental to tomatoes. Studies on developing a slow-release photocatalysis approach may be an alternative method in resolving this issue, but needs to be tested.

Bio-nanomaterial: One of the major limitations in the development and design of the silver (Ag) nanomaterials which are highly antibacterial in nature is the agglomeration of the particles in suspension leading to loss of the antibacterial activity. To resolve this issue Ag was bound to synthesized dsDNA and

Graphene oxide (Ag-dsDNA-GO), which led to high antibacterial activity against copper-tolerant and sensitive *X. perforans* strains than bare Ag nanomaterials (Ocsoy et al., 2013, Strayer et al., 2016). Ag-dsDNA-GO was also shown to significantly reduce bacterial spot disease severity compared to the non-treated control in greenhouse trials and the activity was significantly better than copper-mancozeb (Strayer et al., 2016). Phytoxicity to tomatoes was only observed at high concentrations of 200 – 500 µg/ml. This bio-nanomaterial has potential, but the cost is high due to the dsDNA matrix. Possibilities on changing ds-DNA with other low-cost materials are currently being evaluated.

Copper nanomaterials: Three new copper nanomaterials were designed including core-shell copper (CS-Cu), multi-valent copper (MV-Cu), and fixed quaternary ammonium copper (FQ-Cu) and were tested against copper-tolerant *X. perforans*. In vitro, 100 µg/ml of metallic copper from CS-Cu and FQ-Cu killed a copper-tolerant *X. perforans* strain within 1 h of exposure (data not shown). All copper nanomaterials significantly reduced bacterial spot disease severity compared to non-treated and copper-mancozeb controls in the greenhouse, and significantly reduced disease severity compared to the non-treated in field studies. These nanomaterials did not cause any phytoxicity to tomatoes in field trials and are in evaluation for commercialization. While specific modes of action of these copper nanomaterials are not known at this point, the unique structural design and multivalent properties may be providing unique bactericidal properties to these nanomaterials which are currently being studied.

A comparative assessment of the copper nanomaterials to other nanomaterials discussed above are listed below (Table 1)

ACKNOWLEDGEMENTS

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Table 1. Comparison of three new copper-nanomaterials with other nanomaterials evaluated against bacterial spot of tomato caused by ***Xanthomonas perforans*** in vitro, in greenhouse and under field conditions in Florida.

	Photocatalytic nanomaterials	**Bio-nanomaterial**	**Copper nanomaterials**
Nanomaterials	TiO_2/Zn TiO_2/Ag (Paret et al., 2013)	Ag-dsDNA-GO (Ocsoy et al., 2013, Strayer et al., 2016)	Core Shell Copper Multi-valent copper Fixed Quaternary Ammonium Copper (Strayer et al., In Review)
Antibacterial property against *Xanthomonas perforans* (*In vitro*)	High	High	High
Ability in reducing bacterial spot disease severity (In greenhouse and in the field)	High	High (Only tested in the greenhouse)	High
Proposed Mode of Action	Generation of superoxide anions and hydroxyl radicals upon light activation leading to bacterial cell death	Toxicity to bacterial cells from silver ions and nano-silver itself and minimal agglomeration of nanomaterials	Toxicity to bacterial cells from copper ions in multiple valent states, nano-copper by itself and unique structural designs
Phytotoxicity	Moderate (Some field trials indicated leaf damage starting at the 5th weekly applications)	Observed at concentrations of >200 ppm under greenhouse conditions	None noticed in the field trials
Expected cost of production	Moderate	High	Low-Moderate
Availability of formulation for testing	Available for non-agricultural applications	Not available	Commercial grade in the process of development

Managing Irregular Ripening and Secondary Spread of TYLCV

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Irregular ripening is a disorder of tomato caused by the silverleaf whitefly, *Bemisia tabaci* biotype B (MEAM1). The disorder is associated with feeding by nymphal rather than adult whiteflies. The symptoms of irregular ripening are longitudinal sections of incomplete ripening on the exterior of the fruit, and increased white, unripened tissue on the interior of the fruit. Irregular ripening is associated with a delayed ethylene climacteric in fruit left on the plant, and the absence of an ethylene climacteric in harvested fruit (McCollum et al. 2004). Levels of lycopene, the carotenoid pigment, are significantly lower in symptomatic fruit than healthy fruit (Masuda et al. 2016). The specific mechanism by which nymphal feeding causes irregular ripening is not known. Irregular ripening should not be confused with yellow shoulder or grey wall, ripening disorders that are not related to whiteflies. Yellow shoulder is most common in tomato varieties with dark green shoulders, and is caused by exposure of fruit to high temperatures and extended direct sunlight during maturation. Grey wall can be caused by several factors, including high nitrogen, low potassium, high soil moisture, high humidity, temperature fluctuations and low light intensity.

Irregular ripening can occur when whitefly nymphal densities surpass five nymphs per ten terminal leaflets (Schuster 2001). This is a very conservative number, and in practical terms means that all measures must be taken to prevent the colonization of the crop by whiteflies. In this way management of irregular ripening and *Tomato yellow leaf curl virus* (TYLCV) are similar. TYLCV is a begomovirus transmitted by the silverleaf whitefly. The symptoms of TYLCV include stunted, curled, bright yellow leaves, shortened petioles and stunted plants. The earlier a plant is infected with TYLCV, the greater the impact on yield. For this reason management of TYLCV focuses on reducing colonization of the crop during the first five week treatment window, when infection can result in complete loss of yield. Primary infection is the term used to describe transmission of virus to the crop by vectors, in this case whiteflies, migrating into the crop from outside the field. Secondary infection refers to transmission of virus by the generation of whiteflies developing in the crop that acquire the virus as nymphs and increase its spread within the crop while dispersing as adults. It is the nymphal feeding of whiteflies developing in the crop that can also result in irregular ripening of fruit. While management of primary transmission of TYLCV focuses on reducing damage caused by whiteflies migrating into the crop during the first five week treatment window, management of irregular ripening and secondary spread of TYLCV focuses on the extension of management tactics into the second five-week treatment window.

Crop hygiene. Prompt destruction of harvested tomato fields is necessary to reduce TYLCV inoculum. Prompt destruction of any whitefly-infested crop, not only tomato, is important for management of irregular ripening. Relatively high numbers of whiteflies may be tolerated in some crops, for example certain brassicas, because they do not transmit viruses or induce disorders in those crops. Tomato fields that are adjacent to fields where high numbers of whiteflies originate may be at a higher risk for irregular ripening if large numbers of whiteflies migrate into the tomato crop. It is unlikely that whiteflies originating from a crop other than tomato will carry TYLCV; however whiteflies can acquire TYLCV from infected plants in the tomato field and increase transmission as they disperse through the crop.

Metalized plastic mulches can repel whitefly adults and reduce numbers of whiteflies colonizing the crop compared to tomatoes grown in white or black plastic mulches. Figure 1 illustrates season-long whitefly nymph densities on metalized versus white plastic mulch from trials carried out at the Gulf Coast Research and Education Center in 2013, 2014 and 2015. The 2013 and 2014 trials were carried out in the fall, when whitefly numbers were high. The 2015 trial was carried out in the spring, when whitefly numbers were low. Metalized mulch provided a clear advantage in reducing whitefly numbers during the two fall trials.

Insecticidal control is an important component to managing irregular ripening and secondary spread of TYLCV. The Insecticide Resistance Action Committee Mode of Action (IRAC MoA) group 4 insecticides play an important role in protection of the tomato crop during early stages of growth, including in the plant house, at planting, and during the first five week treatment window. The group 4 insecticides are nicotinic acetylcholine agonists and include the neonicotinoid insecticides imidacloprid (Admire Pro), thiamethoxam (Platinum) and dinotefuran (Venom), as well as the butenolide insecticide flupyradifurone (Sivanto Prime). These insecticides are systemic and are most effective when applied through the soil. Another useful systemic tool for managing whiteflies in tomato is the group 28 insecticide cyazypyr, which interferes with ryanodine receptor function. Cyazypyr has a soil (Verimark) and foliar (Exirel) formulation. Cyazypyr is also effective for managing caterpillars and leafminers. Insecticides that specifically target the egg and nymphal stages of whitefly are the insect growth regulators buprofezin (Courier, IRAC MoA 16) and pyriproxifen (Knack, IRAC MoA 7C), and the lipid biosynthesis inhibitor spirotetramat (Movento, IRAC MoA 23). Biopesticides, including insecti-

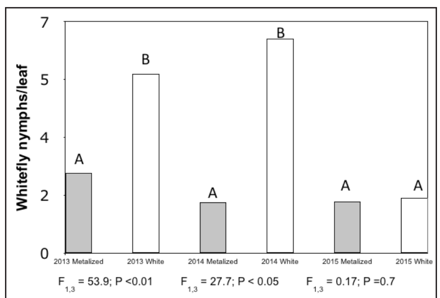

Figure 1. Season-long whitefly nymph densities on metalized vs white plastic mulch from tomato field trials, Gulf Coast Research and Education Center (Balm, FL), fall 2013, fall 2014 and spring 2015. Whitefly nymphs densities were significantly lower on metalized than white mulch in 2013 and 2014, when overall whitefly numbers were high, but not in 2015, when whitefly numbers were low. Columns labeled with a different letter within a given year/trial are statistically different according to Tukey's mean separation test. Separation comparisons (A vs B) are within, not across, years.

cidal soaps (i.e. M-Pede), *Beauvaria bassiana* products (Botanigard, Mycotrol), and stylet oils (Suffoil-X, others) can contribute to the suppression of whitefly populations. Many biopesticides have not been assigned a mode of action number. Most biopesticides can be used repeatedly without concerns regarding the development of resistance. Phytotoxicity, specifically burning of foliage, is a greater concern with many biopesticides. For a fuller list of insecticides registered for use on Florida tomato, please consult the insecticide appendix in these proceedings, or the 2017-2018 Florida Vegetable Production Handbook.

There are many unknowns regarding the irregular ripening of tomato. It is clearly associated with feeding by whitefly nymphs, however it is unknown if other environmental factors contribute to the development of symptoms. For example, two farms that experienced irregular ripening in the spring of 2017 also had concerns regarding potassium deficiency. Please contact Hugh Smith with any questions or observations that you may have regarding irregular ripening in your tomato fields.

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Mexican Competition and Trade Policy

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INTRODUCTION

The United States is the world's second largest producer of tomatoes. California and Florida are the leading tomato-producing states in the country and account for more than 70 percent of all commercially produced tomatoes in the United States annually. Over the past decade, however, the domestic tomato industry has declined. The total production of fresh tomatoes dropped from 3.9 billion pounds in 2000 to 2.7 billion pounds in 2015. In 2000 Florida produced 1.57 billion pounds of fresh-market tomatoes, whereas in 2015, the fresh-market tomato production in Florida dropped to 0.95 billion pounds (Figure 1). The harvested acreage in Florida also dropped from 39,000 acres in 2000 to 33,000 acres in 2015 (Figure 2). California also showed a similar declining trend during the same period. One major reason behind this decline in the U.S. production of fresh tomatoes is the increased competition from Mexico. Total tomato imports from Mexico have increased substantially, from 1.3 billion pounds in 2000 to 3.1 billion pounds in 2015.Mexico accounts for almost 90 percent of the total tomato imports by the U.S. (USDA, 2017). The inverse trends of fresh-market tomato production in Florida and imports from Mexico are shown in figure 3.

Favorable weather conditions and government support give Mexican growers a competitive edge over their U.S. counterparts. In particular, large investment by the Mexican government in protected culture (Victoria et al., 2011) promoted industry growth. It also allows Mexican growers to supply tomatoes year round to the U.S. market by extending the regular growing season. Meanwhile, lower labor costs also give Mexican tomato growers a comparative advantage over US growers.

Trade policies also paved the road for growing Mexican export to the U.S. market. Historically, there were tariffs and quota restrictions on imports of Mexican tomatoes. But the North American Free Trade Agreement (NAFTA) that took effect in 1994 gradually eliminated tariffs and quota. Not long after NAFTA took effect, trade disputes occurred in 1996 and the domestic industry filed an antidumping investigation against Mexican tomato industry. To resolve the conflict, the suspension agreement between the U.S. and Mexico was signed. These trade policies have significantly affected tomato imports from Mexico and changed the market position of US tomatoes relative to imported tomatoes. Next we discuss these policies and analyze their effects.

NAFTA AND TARIFFS

The North American Free Trade Agreement (NAFTA) has been a focal point of debate in the industry since it was introduced in 1994. The NAFTA gradually abolished many tariff and non-tariff barriers to trade through January 2008. There were three major provisions under the NAFTA related to tomato trade: (1) eliminating tariffs over the ten-year transition period, (2) liberalizing the transportation sector, (3) removing barriers to investment. Before the NAFTA, initial high tariff rates on Mexican tomatoes were imposed for the seasons when US tomatoes were harvested. Under the NAFTA, tariffs were eliminated during the periods between July 15 to August 31 and September 1 to November 14 over the four-year period that ended in January 1998. The US also eliminated tariffs gradually over a period of nine years for Mexican tomatoes imported during March 1 to July 14 and November 15 to the end of February (Table 1).

The phase-out in tariffs on imports under the NAFTA has increased the volume of imports from Mexico and squeezed market shares of the US fresh tomatoes. There have been proposals to dismantle the NAFTA and impose 20 to 35 percent tariff on all imports from Mexico. Tariff makes imported goods expensive relative to domestic products. Higher prices of Mexican tomatoes will discourage domestic consumers from buying imported tomatoes and encourage higher demand for U.S. grown tomatoes, thus motivating domestic producers to supply more. Therefore, imposing tariffs on Mexican imports will benefit U.S. tomato growers.

Although most countries are now opening their borders for foreign goods, there are examples of countries protecting domestic industries by imposing tariffs on imports. For example, Japan's agriculture is highly protected. Japan currently uses tariffs as a tool to support beef farming and protect its beef industry from foreign competition (USDA, 2017). Also, Japan protects sectors like vegetable oil and oranges from foreign competition by imposing high tariffs on imports.

SUSPENSION AGREEMENTS

The U.S. and Mexican fresh tomato producers have engaged in trade conflict historically (Bredahl et al., 1987; VanSickle et al., 2003). To resolve this conflict between the trading partners, policy makers have introduced renegotiable suspension agreements. Under the suspension agreement, minimum sale prices or floor prices for Mexican tomatoes in the U.S. market are set. The latest suspension agreement between the U.S. and Mexico was signed on March 4, 2013, which raised the reference prices of Mexican tomatoes by 43% (2013 suspension agreement).

The US tomato industry has relied on the agreements to prevent dumping and undercutting of price. The recent study (Wu et al., 2017) shows that the average expected price for Mexican tomatoes without the agreement (i.e., assuming the 2008 reference prices were still in effect) was \$0.469 per pound, while it increases to \$0.497 per pound with the 2013 agreement, resulting in a 5.5% increase . For the U.S. tomatoes, the average prices with and without the agreement were \$0.469 per pound and \$0.475 per pound, respectively, which represent an increase of 1.3%, smaller than a 5.5% increase in the Mexican tomato price.

QUOTAS ON MEXICAN IMPORTS

Import quotas control the volume of various commodities that can be imported during a specified period. Most countries in the world apply quota or quantitative restrictions to the import of certain goods or services in order to limit its access. Limiting access to imports will shift consumer demand from imported goods to domestic commodities. Import quotas in the United States are divided into two categories: absolute quota and tariff-rate quota. Under absolute quota, the quantity of goods that may enter the U.S. for a specific period is strictly limited. Under tariff-rate quota, for commodities imported within the quota limit a lower tariff is imposed, while for imports outside the quota limit higher tariffs are imposed, which indirectly prohibits trade.

During the transition period of the NAFTA, tomato imports from Mexico to the United States were restricted by maintaining a tariff-rate quota with a prohibitive over-quota tariff. There were quotas on imports of Mexican tomatoes during two periods, November 15 through February 28 and March 1 through July 14. Any imports in excess of the quota were subject to pre-NAFTA tariffs. For example, within-quota tariffs for fresh winter tomato imports from Mexico are 1.18 cents/lb while over-quota tariffs are 1.5 cents/lb for tomatoes during the November 15 through February 28, 1996 period. Tariffs for the March 1 through July 14, 1996 period were 1.68 and 2.09 cents for within and over-quota imports, respectively. In the first year of NAFTA (1994), the quota for March 1 to July 14 was 165,000 metric tons and the quota for

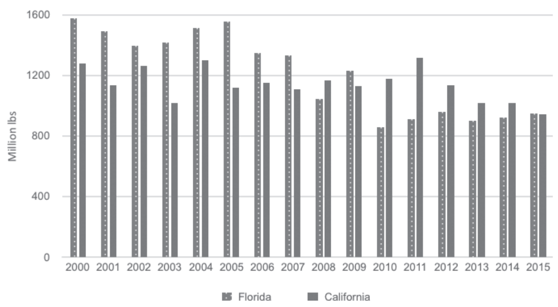

Figure 1. Fresh Tomato Production in Florida and California, 2000 to 2015.

Source: USDA and NASS.

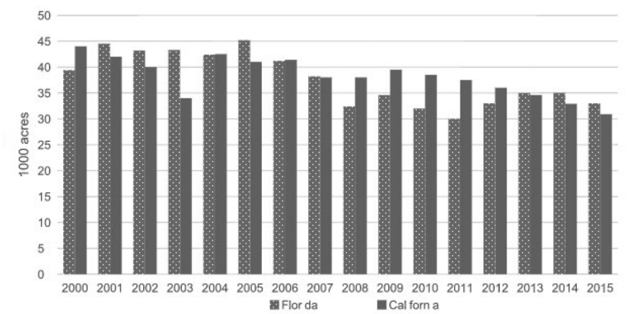

Figure 2. Fresh Tomato Acreage in Florida and California, 2000 to 2015.

Source: USDA and NASS.

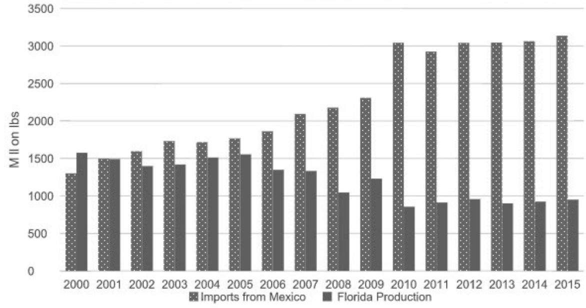

Figure 3. FL Production & Imports from Mexico, 2000-2015.

Source: U.S. Department of Commerce.

Table 1. The U.S. tariff on fresh tomatoes and phase-out schedule under NAFTA.

Commodity	Season	Base tariff	Phase-out
Fresh Tomatoes	March 1-July 14	2.09 cents/pound	9
Fresh Tomatoes	July 15-August 31	1.5 cents/pound	4
Fresh Tomatoes	September 1-November 1	2.09 cents/pound	4
Fresh Tomatoes	November 15- February 28/29	1.5 cents/pound	9

Source: HTSUSA (2000), FAS, ERS, and USDA.

November 15 to the last day of February was 172,300 metric tons. These quotas increase at a compound rate of 3 percent during the 10-year transition.

CONCLUSION

Over the past fifteen years, the US tomato industry has been declining due to the competition from Mexico. The NAFTA has played a role in the decline of the market share and profitability of the U.S. growers. Although the 2013 suspension agreement has supported the US tomato price by raising the Mexican tomato price, the market trend shows that the suspension agreement alone may not be enough to make the industry sustainable. Now the discussion of renegotiating the NAFTA is on the table. The current U.S. administration is proposing to impose tariffs on Mexican imports. At the same time, the U.S is planning to impose quota restrictions on certain imports from Mexico. Both tariff and quota restrictions will limit the quantity of Mexican commodities in the U.S. market, raise the price of Mexican products, and shift consumer demand from Mexican products to home-grown commodities.

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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 made 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 in south and central Florida and Tomato spotted wilt 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. FL 47 which long dominated the industry has been supplanted by several newer cultivars which possess superior disease resistance.

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 VARIETIES

1. LARGE FRUITED AND BEEFSTAKE TYPES

BHN 602. Early midseason maturity. Determinate. Fruit are globe shaped but larger than BHN 640 and green shouldered.

BHN 730. Strong determinate plant with good cover, uniform, firm fruit. Sets good size fruit up to the top of plant for second and third harvests.

Camaro. Early midseason maturity. Determinate**.** Medium plant with limited to no pruning. Like Charger with better quality extra-large globe shaped fruit.

Florida 47. Late midseason maturity. Determinate. Jointed hybrid. Uniform green, globe shaped fruit.

Florida 91. Midseason maturity. Determinate. Uniform green fruit borne on jointed pedicels. Good fruit setting ability under high temperatures

Grand Marshall. Midseason maturity. Determinate. Vigorous plant with hot set and extra-large to large oblate fruits.

HM 1823. Early season maturity. Determinate. Round tomato with strong plant habit. Strong plant and large to extra-large round fruit.

HM 8849 CR. Early season maturity. Determinate. Strong plant and good leaf cover. Fruit extra-large, smooth and slightly flattened globe shape.

Phoenix. Early midseason maturity. 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.

Quincy. Full season maturity. Determinate. Fruit are large to extra-large, excellent quality, firm, deep oblate shaped fruit, and uniformly colored.

Red Bounty. Determinate round tomato with vigorous, strong plant with good foliage cover, heat set, and high yields. It produces uniform, extra-large, smooth fruit.

Sanibel. Main season. Determinate. Large, firm, smooth fruit with light green shoulder and a tight blossom end.

Skyway 687. Main season maturity. Determinate. Strong plant. Extra-large globe shaped fruit.

Southern Ripe. Full season. Determinate. Large quality fruit.

SV 7631TD. Midseason maturity. Determinate. Medium to strong plant with extra-large to large oblate fruits.

Tasti-Lee. Midseason maturity. Determinate. Jointed hybrid with moderate heat-tolerance. 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.

Winterhaven. Suited for winter planting in Manatee/Ruskin, and for cold night production in other areas.

2. PLUM TYPE VARIETIES

BHN 685. Midseason maturity. Determinate. Vigorous bush with no pruning recommended. Large to extra-large, deep blocky fruit, globe shape fruit.

Daytona. Widely adapted determinate variety with productive medium compact plants which produce smooth extra-large fruit, with good color, firmness and shelf life. Daytona is similar to Mariana with the addition of IR: TYLCV

Mariana. Midseason maturity. 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.

3. CHERRY TYPE VARIETIES

BHN 268. Early to midseason maturity. Determinate. Small to medium bush with high yields an extra firm cherry tomato that holds, packs and ships well.

BHN 762. Improved red color, firmness and uniformity of size and shape over BHN 268, from first to last harvest.

4. GRAPE TOMATOES

BHN 784. Early-midseason maturity. Determinate. Heat tolerant.

BHN 785. Midseason maturity. Determinate. Hybrid with a strong set of very uniform size and shape fruit on a vigorous bush with good cover.

Felicity. Midseason maturity. Indeterminate. Globe shaped fruit with high brix.

Sweethearts. Early to mid-season. Indeterminate. Bush with intermediate internodes, Brilliant red, firm, elongated grape-shaped fruit. Matures between 70 and 75 days. Crack resistance and high brix.

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

Table 1. Tomato varieties grown in Florida

Large and Beefsteak	Disease Resistance[z]	Large and Beefsteak	Disease Resistance[z]
BHN 602	R to F-R (1, 2, 3), TSW, and V (1)	Tasti-Lee	R to F-R (1, 2, 3), V (1), and S
BHN 730	R to FCR, F-R (1, 2), and V (1)	Winterhaven	R to F-R (1-3), FCR, and V1, IR to TSW, and TYLC
Camaro	R to ASC, F-R (1, 2, 3), V (1), IR to S and TYLC	**Plum**	
Florida 47	R to F-R (1, 2), V (1), ASC, and S	BHN 685	R to F-R (1, 2, 3), TSW, and V (1)
Florida 91	R to F-R (1, 2), V (1), ASC, and S	Daytona	R to ASC, F-R (1, 2), N, and V (1), IR to S, and TYLCV
Grand Marshall	R to ASC, F-R (1, 2), IR to S and TYLC	Mariana	R to ASC, F-R (1, 2), N, and V (1), and IR to S
HM 1823	R to FCR, F-R (1, 2), and V (1) and IR to S	Cherry	
HM 8849 CR	R to FCR, F-R (1, 2), S, and V (1)	BHN 268	R to F-R (1), and V (1)
Phoenix	R to ASC, F-R (1, 2), S, and V (1)	BHN 762	R to F-R (1), and V (1)
Quincy	R to ASC, F-R (1,2), S, and TSW	**Grape**	
Red Bounty	R to ASC, F-R (1, 2), S, TSW, and V (1)	BHN 784	R to F-R (1)
Sanibel	R to ASC, F-R (1, 2), N, S, and V (1)	BHN 785	R to F-R (1)
Skyway 687	R to F-R (1, 2) IR to N, TSW, TYLC	Felicity	R TYLCV. IR to F-R (1, 2, 3), N, ToM, and V (1)
Southern Ripe	R to FCR, F-R (1, 2, 3), TSW, and IR to N	Sweethearts	R to C, CLS, F-R (1), and TM, and IR to S
SV 7631TD	R to ASC, F-R (1, 2), TSW, V (1) IR to N		

[z] CMV = ASC – Alternaria stem canker = *Alternaria alternata* f.sp. *lycopersici*; C – Cracking; CLS - Cladosporium leaf mold - *Cladosporium fulvum*; F-R 1, 2, 3 - Fusarium wilt race 1, 2, 3 - *Fusarium oxysporum* f.sp. *lycopersici* races 1, 2, 3; FCR – Fusarium crown rot - *Fusarium oxysporum* f.sp. *radicis-lycopersici*; N – Root knot nematode - *Meloidogyne arenaria, M. Incognita,* and M. *javanica*; S – Gray leaf spot - *Sylium solani*; ToM = Tomato mosaic virus; TM = Tobacco mosaic virus; TSW = Tomato spotted wilt; TYLC – Tomato yellow leaf curl; V (1) - Verticillium wilt - *Verticillium albo-atrom* and *Verticillium dahliae* race 1; R = Resistant; IR = Intermediate Resistance; T = Tolerant.

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 liming 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 preplant.

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

Production system	Nutrient	Recommended base fertilization[z]								Recommended supplemental fertilization[z]		
		Total (lbs/acre)	Preplant[y] (lbs/acre)	Injected[x] (lbs/acre/day) Weeks after transplanting[w] 1-2	3-4	5-11	12	13	Leaching rain[r,s]	Measured > low = plant nutrient content[u,s]	Extended harvest season[s]
Drip irrigation, raised beds, and polyethyleneMulch	N	200	0-50	1.5	2.0	2.5	2.0	1.5	n/a	1.5 to 2 lbs/acre/day for 7days[t]	1.5-2 lbs/acre/day[p]
	K_2O	220	0-50	2.5	2.0	3.0	2.0	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 polyethyleneMulch	N	200	200[v]	0	0	0	0	0	30 lbs/A[q]	30 lbs/acre[t]	30 lbs/acre[p]
	K_2O	220	220[v]	0	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 preplant. 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.

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.

Stage of growth	Sap concentration (ppm) 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 called the 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

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

Typical CF values for fully-grown tomato should not exceed 0.75 (Locascio and Smajstrla, 1996). A third method for estimating tomato crop water requirement is to use modified Bellani plates also known as atmometers. A common model of atmomter used in Florida is the $ET_{gage.}$ This device consists of a canvas-covered ceramic evaporation plate mounted on a water reservoir. The green fabric creates a diffusion barrier that controls evaporation at a rate similar to that of well watered 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

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.

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

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 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 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 2 2 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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Weed Control in Tomato

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

Active ingredient lb. a.i./acre	Trade name product/acre	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 up to 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 up to 0.128	(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.

Weed Control in Tomato (continued)

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

Active ingredient lb. a.i./acre	Trade name product/acre	MOA Code	Weeds controlled / remarks
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.
Sulfentrazone 0.094 - 0.125	(Spartan) 4F 3 - 4 oz	14	Broadleaves, grasses and nutsedge. Apply under the plastic mulch or in row middles. Do not use on soils with less than 1% organic matter.
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.
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_2$0) 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.

Weed Control in Tomato (continued)

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

Active ingredient lb. a.i./acre	Trade name product/acre	MOA Code	Weeds controlled / remarks
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.
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 (continued)

Conventional fungicides are sorted by disease 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 separe table for convenience. (Updated June 2017).

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. Biopesticides and other alternative products labeled for disease management can be found in the next table.

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]
Anthracnose	M1	**(copper compounds)** **Many brands available:** Americop 40 DF, 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, Copper Count N, Cueva, Cuprofix Ultra 40D, Cuproxat, Kentan DF, Kocide 2000, Kocide 3000, Kocide DF, KOP-Hydroxide, KOP-hydroxide 50W, Mastercop, Nordox, Nordox 75WG, Nu-Cop 50WP, Nu-Cop 3L, Nu-Cop 30 HB, Nu-Cop 50DF, Nu-Cop HB, Nu-Cop XLR, Previsto	**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 Max, Manzate Pro-Stik, Penncozeb 4FL, Penncozeb 75DF, Penncozeb 80WP, Protect DF, Roper DF Rainshield	**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, Orondis Opti B, Praiz	SEE INDIVIDUAL LABELS		0	0.5	Use higher rates at fruit set and lower rates before fruit set.
	3	Rhyme (flutriafol)	7 fl oz	28 fl oz	0	0.5	Limit is 4 applications per season.
(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.
(suppression)	7 & 11	Luna Sensation (fluopyram + trifloxystrobin)	7.6 fl oz	27.3 fl oz	3	0.5	No more than 2 sequential applications before rotating with another effective fungicide from a different FRAC group. Limit of 5 apps per a year.
	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	**(azoxystrobin)** **Many brands available:** Aframe, Azoxystar, Azoxystrobin 100 ST, Azoxyzone, Dynasty, Equation SC, Heritage, Quadris, Satori, Tetraban, Trevo, Willowood Azoxy 2SC	SEE INDIVIDUAL LABELS		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.

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	11	Flint Gem 500 SC (trifloxystrobin)	4 oz 3.8 floz	16 oz 16 fl oz	3 3	0.5 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.
	11 & 3	Topguard EQ (azoxystrobin + flutriafol)	8 fl oz	32 fl oz	0	0.5	Limit is 4 applications per season. Do not use adjuvants or EC formulated tank mix partners. The addition of silicone or oil based additives may cause injury at high temperatures. Do not exceed 0.125% (v/v) adjuvant levels.
	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 compat-ibility 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.
	27 & M5	Ariston (cymoxanil + chlorothalonil)	1.9 pt	30.2 pt	3	0.5	Check copper manufacturer's label for spe-cific precautions and limitations for mixing with this product.
(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.
	U15 & M5	Oronidis Opti (oxathiapiprolin + chlorothalonil)	2.5 pt	10 pt	0	12 hr	Do not combine foliar apps of Orondis with soil apps of Orondis for disease control. 6 apps/A/year; no more than 2 sequential apps. 7 day minimum app. interval; Appli-cations should not exceed more than 33% of the total foliar fungicide apps or 4 apps per a crop, whichever is fewer.
Bacterial canker	M1	**(copper compounds)** **Many brands available:** Americop 40 DF, 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, Copper Count N, Cueva, Cu-profix Ultra 40D, Cuproxat, Kentan DF, Kocide 2000, Kocide 3000, Kocide DF, KOP-Hydroxide, KOP-hydroxide 50W, Mastercop, Nordox, Nordox 75WG, Nu-Cop 50WP, Nu-Cop 3L, Nu-Cop 30 HB, Nu-Cop 50DF, Nu-Cop HB, Nu-Cop XLR, Previsto	**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:** Americop 40 DF, 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, Copper Count N, Cueva, Cu-profix Ultra 40D, Cuproxat, Kentan DF, Kocide 2000, Kocide 3000, Kocide DF, KOP-Hydroxide, KOP-hydroxide 50W, Mastercop, Nordox, Nordox 75WG, Nu-Cop 50WP, Nu-Cop 3L, Nu-Cop 30 HB, Nu-Cop 50DF, Nu-Cop HB, Nu-Cop XLR, Previsto	**SEE INDIVIDUAL LABELS**		1	Varies by product from 4 hr to 2 days.	Mancozeb enhances the bactericidal effect of fix copper compounds.

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	M3	(mancozeb) **Many brands available:** Dithane DF, Dithane F45, Dithane M45, Kover-all, Manzate Max, Manzate Pro-Stik, Penncozeb 4FL, Penncozeb 75DF, Penncozeb 80WP, Protect DF, Roper DF Rainshield	**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.
	25	Agri-mycin 17 Ag Streptomycin Bac-Master FireWall 17 WP or 50 WP (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	Rhyme (flutriafol)	7 fl oz	28 fl oz	0	0.5	Limit is 4 applications per season.
	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.
	3 & 9	Chairman (propiconazole + fludioxonil)	32 floz /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. Lower rates for small diameter fruit. 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 usage.
	7 & 9	Luna Tranquility (fluopyram + pyrimethanil)	11.2 fl oz	54.7 fl oz	1	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 usage.
	7 & 11	Luna Sensation (fluopyram + trifloxystrobin)	7.6 fl oz	27.1 fl oz	3	0.5	No more than 2 sequential applications before rotating with another effective fungicide from a different FRAC group. Limit of 5 apps per a year.
	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	**(azoxystrobin)** **Many brands available:** Aframe, Azoxystar, Azoxystrobin 100 ST, Azoxyzone, Dynasty, Equation SC, Heritage, Quadris, Satori, Tetraban, Trevo, Willowood Azoxy 2SC	**SEE INDIVIDUAL LABELS**		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.

TOMATO FUNGICIDES (continued)

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	11 & 3	Topguard EQ (azoxystrobin + flutriafol)	8 fl oz	32 fl oz	0	0.5	Limit is 4 applications per season. Do not use adjuvants or EC formulated tank mix partners. The addition of silicone or oil based additives may cause injury at high temperatures. Do not exceed 0.125% (v/v) adjuvant levels.
	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.
	27 & M5	Ariston (cymoxanil + chlorothalonil)	1.9 pt	30.2 pt	3	0.5	Check copper manufacturer's label for specific precautions and limitations for mixing with this product.
	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.
	U15 & M5	Oronidis Opti (oxathiapiprolin + chlorothalonil)	2.5 pt	10 pt	0	12 hr	Do not combine foliar apps of Orondis with soil apps of Orondis for disease control. 6 apps/A/year; no more than 2 sequential apps. 7 day minimum app. interval; Applications should not exceed more than 33% of the total foliar fungicide apps or 4 apps per a crop, whichever is fewer.
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, Orondis Opti B, Praiz	**SEE INDIVIDUAL LABELS**		0	0.5	Use higher rates at fruit set and lower rates before fruit set.
	3 & 9	Chairman (propiconazole + fludioxonil)	32 floz /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. Lower rates for small diameter fruit. See label for details.
	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 usage.
(*suppression*)	7	Endura (boscalid)	12.5 oz	25 oz	0	0.5	Alternate with non-FRAC code 7 fungicides.
	7	Luna Privelege	6.84 fl oz	13.7 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.
	7 & 9	Luna Tranquility (fluopyram + pyrimethanil)	11.2 fl oz	54.7 fl oz	1	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.
	7 & 11	Luna Sensation (fluopyram + trifloxystrobin)	7.6 fl oz	27.3 fl oz	3	0.5	No more than 2 sequential applications before rotating with another effective fungicide from a different FRAC group. Limit of 5 apps per a year.
(suppression)	7 & 11	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.
	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.

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	12	Emblem (fludioxonil)	7 fl oz	28 fl oz	0	0.5	Transplant and Greenhouse use only. Limit to 4 applications per year. No more than 2 sequential applications before rotating to a different mode of action for 2 applications.
	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.
	17	Decree 50 WDG (fenhexamid)	1.5 lb	6 lb	0	0.5	Transplant and Greenhouse use only. Do not make more than 2 consecutive applications.
	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.
	27 & M5	Ariston (cymoxanil + chlorothalonil)	1.9 pt	30.2 pt	3	0.5	Check copper manufacturer's label for specific precautions and limitations for mixing with this product.
	U15 & M5	Oronidis Opti (oxathiapiprolin + chlorothalonil)	2.5 pt	10 pt	0	12 hr	Do not combine foliar apps of Orondis with soil apps of Orondis for disease control. 6 apps/A/year; no more than 2 sequential apps. 7 day minimum app. interval; Applications should not exceed more than 33% of the total foliar fungicide apps or 4 apps per a crop, whichever is fewer.
Buckeye rot **Phytophthora fruit rot** **(*Phytophthora* spp.)**	4	Orondis Gold B (mefenoxam)	1 pt	3 pt	28	0	Do not apply more than 1.5 lb mefenoxam/A per crop to the soil.
	M1 + 4	Ridomil Gold Copper (copper hydroxide + mefenoxam)	2 lb	6 lb	14	2	Limited to 3 apps per season. Tankmix with mancozeb.
	11	**(azoxystrobin)** **Many brands available:** Aframe, Azoxystar, Azoxystrobin 100 ST, Azoxyzone, Dynasty, Equation SC, Heritage, Quadris, Satori, Tetraban, Trevo, Willowood Azoxy 2SC	**SEE INDIVIDUAL LABELS**		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
	U15 & M5	Oronidis Opti (oxathiapiprolin + chlorothalonil)	2.5 pt	10 pt	0	12 hr	Do not combine foliar apps of Orondis with soil apps of Orondis for disease control. 6 apps/A/year; no more than 2 sequential apps. 7 day minimum app. interval; Applications should not exceed more than 33% of the total foliar fungicide apps or 4 apps per a crop, whichever is fewer.
	U15	Orondis Opti A Orondis Ultra A (oxathiapiprolin)	4.8 fl oz 4.8 fl oz	19.2 fl oz 19.2 fl oz	0 0	4 hr 4 hr	Do not combine foliar apps of Orondis with soil apps of Orondis for disease control. 6 apps per season; no more than 2 sequential apps. 5 day minimum app. interval; Applications should not exceed more than 33% of the total foliar fungicide apps. See Orondis Ultra A label for greenhouse use.

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Early blight	M1	**(copper compounds)** **Many brands available:** Americop 40 DF, 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, Copper Count N, Cueva, Cuprofix Ultra 40D, Cuproxat, Kentan DF, Kocide 2000, Kocide 3000, Kocide DF, KOP-Hydroxide, KOP-hydroxide 50W, Mastercop, Nordox, Nordox 75WG, Nu-Cop 50WP, Nu-Cop 3L, Nu-Cop 30 HB, Nu-Cop 50DF, Nu-Cop HB, Nu-Cop XLR, Previsto	**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 Max, Manzate Pro-Stik, Penncozeb 4FL, Penncozeb 75DF, Penncozeb 80WP, Protect DF, Roper DF Rainshield	**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, Orondis Opti B, Praiz	**SEE INDIVIDUAL LABELS**		0	0.5	Use higher rates at fruit set and lower rates before fruit set.
	3	Rhyme (flutriafol)	7 fl oz	28 fl oz	0	0.5	Limit is 4 applications per season.
	3	Tebuzol 3.6F Toledo 3.6F (tebuconazole)	8 fl oz	48 fl oz	7	0.5	Limit is 6 appl./crop. Minimum appl. interval of 7 days.
	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 usage.
	7	Luna Privelege	6.84 fl oz	13.7 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 usage.
	7 & 9	Luna Tranquility (fluopyram + pyrimethanil)	11.2 fl oz	54.7 fl oz	1	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 usage.
	7 & 11	Luna Sensation (fluopyram + trifloxystrobin)	7.6 fl oz	27.3 fl oz	3	0.5	No more than 2 sequential applications before rotating with another effective fungicide from a different FRAC group. Limit of 5 apps per a year.
	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 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.

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	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	(azoxystrobin) **Many brands available:** Aframe, Azoxystar, Azoxystrobin 100 ST, Azoxyzone, Dynasty, Equation SC, Heritage, Quadris, Satori, Tetraban, Trevo, Willowood Azoxy 2SC	**SEE INDIVIDUAL LABELS**		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 Gem 500 SC (trifloxystrobin)	4 oz 3 floz	16 oz 16 fl oz	3 3	0.5 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 & 3	Topguard EQ (azoxystrobin + flutriafol)	8 fl oz	32 fl oz	0	0.5	Limit is 4 applications per season. Do not use adjuvants or EC formulated tank mix partners. The addition of silicone or oil based additives may cause injury at high temperatures. Do not exceed 0.125% (v/v) adjuvant levels.
	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.
	12	Emblem (fludioxonil)	7 fl oz	28 fl oz	0	0.5	<u>Transplant and Greenhouse use only</u>. Limit to 4 applications per year. No more than 2 sequential applications before rotating to a different mode of action for 2 applications.
	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	
	22 & M5	Zing! (zoaximide + chlorothalonil)	36 fl oz	288 fl oz	5	0.5	Limit is 8 apps per season. No more than 2 sequential applications before alternating to a different mode of action.
	27 & M5	Ariston (cymoxanil + chlorothalonil)	3.0 pt	30.2 pt	3	0.5	Check copper manufacturer's label for specific precautions and limitations for mixing with this 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.

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	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.
	U15 & M5	Oronidis Opti (oxathiapiprolin + chlorothalonil)	2.5 pt	10 pt	0	12 hr	Do not combine foliar apps of Orondis with soil apps of Orondis for disease control. 6 apps/A/year; no more than 2 sequential apps. 7 day minimum app. interval; Applications should not exceed more than 33% of the total foliar fungicide apps or 4 apps per a crop, whichever is fewer.
Late blight	M1	**(copper compounds)** **Many brands available:** Americop 40 DF, 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, Copper Count N, Cueva, Cuprofix Ultra 40D, Cuproxat, Kentan DF, Kocide 2000, Kocide 3000, Kocide DF, KOP-Hydroxide, KOP-hydroxide 50W, Mastercop, Nordox, Nordox 75WG, Nu-Cop 50WP, Nu-Cop 3L, Nu-Cop 30 HB, Nu-Cop 50DF, Nu-Cop HB, Nu-Cop XLR, Previsto	**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 Max, Manzate Pro-Stik, Penncozeb 4FL, Penncozeb 75DF, Penncozeb 80WP, Protect DF, Roper DF Rainshield	**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, Orondis Opti B, Praiz	**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	**(azoxystrobin)** **Many brands available:** Aframe, Azoxystar, Azoxystrobin 100 ST, Azoxyzone, Dynasty, Equation SC, Heritage, Quadris, Satori, Tetraban, Trevo, Willowood Azoxy 2SC	**SEE INDIVIDUAL LABELS**		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 Gem 500 SC (trifloxystrobin)	4 oz 3.8 floz	16 oz 16 fl oz	3 3	0.5 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.

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	11 & 3	Topguard EQ (azoxystrobin + flutriafol)	8 fl oz	32 fl oz	0	0.5	Limit is 4 applications per season. Do not use adjuvants or EC formulated tank mix partners. The addition of silicone or oil based additives may cause injury at high temperatures. Do not exceed 0.125% (v/v) adjuvant levels.
(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	
	22 & M5	Zing! (zoaximide + chlorothalonil)	36 fl oz	288 fl oz	5	0.5	Limit is 8 apps per season. No more than 2 sequential applications before alternating to a different mode of action.
	27	Curzate 60DF (cymoxanil)	5 oz	30 oz per year	3	0.5	Must tank mix with another effective product.
	27 & M5	Ariston (cymoxanil + chlorothalonil)	3.0 pt	30.2 pt	3	0.5	Check copper manufacturer's label for specific precautions and limitations for mixing with this product.
	28	Previcur Flex 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
	40	Orondis Ultra B Revus (mandipropamid)	8 fl oz 8 fl oz	32 fl oz 32 fl oz	1 1	4 hr 4 hr	No more than 2 sequential appl. Rotate with another effective fungicide; See label.
	40	Micora (mandipropamid)	8 fl oz/ 5,000 sq ft	16 fl oz/ 5,000 sq ft	n.a.	4 hr	Micora is only labeled for transplant and retail sale to consumers.
	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.
	U15 & M5	Oronidis Opti (oxathiapiprolin + chlorothalonil)	2.5 pt	10 pt	0	12 hr	Do not combine foliar apps of Orondis with soil apps of Orondis for disease control. 6 apps/A/year; no more than 2 sequential apps. 7 day minimum app. interval; Applications should not exceed more than 33% of the total foliar fungicide apps or 4 apps per a crop, whichever is fewer.

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	U15	Orondis Opti A Orondis Ultra A (oxathiapiprolin)	4.8 fl oz 4.8 fl oz	19.2 fl oz 19.2 fl oz	0 0	4 hr 4 hr	Do not combine foliar apps of Orondis with soil apps of Orondis for disease control. 6 apps per season; no more than 2 sequential apps. 5 day minimum app. interval; Applications should not exceed more than 33% of the total foliar fungicide apps. See Orondis Ultra A label for greenhouse use.
Leaf mold	M3	**(mancozeb)** **Many brands available:** Dithane DF, Dithane F45, Dithane M45, Koverall, Manzate Max, Manzate Pro-Stik, Penncozeb 4FL, Penncozeb 75DF, Penncozeb 80WP, Protect DF, Roper DF Rainshield	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, Orondis Opti B, Praiz	**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.
	U15 & M5	Oronidis Opti (oxathiapiprolin + chlorothalonil)	2.5 pt	10 pt	0	12 hr	Do not combine foliar apps of Orondis with soil apps of Orondis for disease control. 6 apps/A/year; no more than 2 sequential apps. 7 day minimum app. interval; Applications should not exceed more than 33% of the total foliar fungicide apps or 4 apps per a crop, whichever is fewer.
Grey leaf spot (*Stemphyllium* spp.)	M1	**(copper compounds)** **Many brands available:** Americop 40 DF, 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, Copper Count N, Cueva, Cuprofix Ultra 40D, Cuproxat, Kentan DF, Kocide 2000, Kocide 3000, Kocide DF, KOP-Hydroxide, KOP-hydroxide 50W, Mastercop, Nordox, Nordox 75WG, Nu-Cop 50WP, Nu-Cop 3L, Nu-Cop 30 HB, Nu-Cop 50DF, Nu-Cop HB, Nu-Cop XLR, Previsto	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 Max, Manzate Pro-Stik, Penncozeb 4FL, Penncozeb 75DF, Penncozeb 80WP, Protect DF, Roper DF Rainshield	**SEE INDIVIDUAL LABELS**		5	1	
	M3 & M1	ManKocide (mancozeb + copper hydroxide)	5 lb	112 lb	5	2	

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			Applic.	Season	Harvest	Reentry	
	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, Orondis Opti B	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 (mefenoxam + chlorothalonil)	3 lb	12 lb	14	2	Limit is 4 apps./crop.
	7 & 9	Luna Tranquility (fluopyram + pyrimethanil)	11.2 fl oz	54.7 fl oz	1	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.
	7 & 11	Luna Sensation (fluopyram + trifloxystrobin)	7.6 fl oz	27.3 fl oz	3	0.5	No more than 2 sequential applications before rotating with another effective fungicide from a different FRAC group. Limit of 5 apps per a year.
	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 Gem 500 SC (trifloxystrobin)	4 oz 3.8 floz	16 oz 16 fl oz	3 3	0.5 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	
	27 & M5	Ariston (cymoxanil + chlorothalonil)	3.0 pt	30.2 pt	3	0.5	Check copper manufacturer's label for specific precautions and limitations for mixing with this product.
	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.
	U15 & M5	Oronidis Opti (oxathiapiprolin + chlorothalonil)	2.5 pt	10 pt	0	12 hr	Do not combine foliar apps of Orondis with soil apps of Orondis for disease control. 6 apps/A/year; no more than 2 sequential apps. 7 day minimum app. interval; Applications should not exceed more than 33% of the total foliar fungicide apps or 4 apps per a crop, whichever is fewer.
Phytophthora crown rot, Phytophthora root rot (*Phytophthora* spp.)	4	Orondis Gold B Ridomil Gold SL Ultra Flourish (mefenoxam)	1 pt 1 pt 2 pt	3 pt 3 pt 6 pt	28 28 7	0* 2* 2*	Do not apply more than 1.5 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.

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	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.
	U15	Orondis Gold 200 (oxathiapiprolin)	19.2 fl oz	38.6 fl oz	0	4 hr	Soil applications cannot be combined with foliar applications of Orondis Opti A or Orondis Ultra A. 4 apps per season; no more than 2 sequential apps. 7 day minimum app. interval; Applications should not exceed more than 33% of the total soil fungicide apps. See label for soil application instructions.
	U15	Orondis Opti A Orondis Ultra A (oxathiapiprolin)	4.8 fl oz 4.8 fl oz	19.2 fl oz 19.2 fl oz	0 0	4 hr 4 hr	Do not combine foliar apps of Orondis with soil apps of Orondis for disease control. 6 apps per season; no more than 2 sequential apps. 5 day minimum app. interval; Applications should not exceed more than 33% of the total foliar fungicide apps. See Orondis Ultra A label for greenhouse use.
Powdery mildew	M2	**(sulfur)** **Many brands available:** Bio-Sul, Cosavet DF, Kumulus DF, Micro Sulf, Microfine Sulfur, Microthiol Disperss, Suffa, Sulfur 6L, Sulfur 90W, Sulfur DF, That Flowable Sulfur, Tiolux, Wettable Sulfur, Yellow Jacket Dusting Sulfur, Yellow Jacket Flowable Sulfur, Yellow Jacket Wettable Sulfur	SEE INDIVIDUAL LABELS		1	1	Follow label closely, may cause leaf burn if applied during high temperatures.
	3	Rhyme (flutriafol)	7 fl oz	28 fl oz	0	0.5	Limit is 4 applications per season.
	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.
	3	Terraguard SC Trionic 4SC (triflumizole)	4 fl oz/ 100 gal	16 fl oz	1 1	0.5 0.5	Greenhouse use only. Limit is 4 applications per season.
	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.
	7	Luna Privelege Velum Prime (fluopyram)	6.84 fl oz	13.7 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. See Velum Prime label for soil applications.

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	7 & 9	Luna Tranquility (fluopyram + pyrimethanil)	11.2 fl oz	54.7 fl oz	1	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.
	7 & 11	Luna Sensation (fluopyram + trifloxystrobin)	7.6 fl oz	27.3 fl oz	3	0.5	No more than 2 sequential applications before rotating with another effective fungicide from a different FRAC group. Limit of 5 apps per a year.
	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	**(azoxystrobin)** **Many brands available:** Aframe, Azoxystar, Azoxystrobin 100 ST, Azoxyzone, Dynasty, Equation SC, Heritage, Quadris, Satori, Tetraban, Trevo, Willowood Azoxy 2SC	**SEE INDIVIDUAL LABELS**		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 Gem 500 SC (trifloxystrobin)	4 oz 3.8 floz	16 oz 16 fl oz	3 3	0.5 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 & 3	Topguard EQ (azoxystrobin + flutriafol)	8 fl oz	32 fl oz	0	0.5	Limit is 4 applications per season. Do not use adjuvants or EC formulated tank mix partners. The addition of silicone or oil based additives may cause injury at high temperatures. Do not exceed 0.125% (v/v) adjuvant levels.
	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.
	12	Emblem (fludioxonil)	7 fl oz	28 fl oz	0	0.5	Transplant and Greenhouse use only. Limit to 4 applications per year. No more than 2 sequential applications before rotating to a different mode of action for 2 applications.
	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.
	U8	Vivando (metrafenone)	15.4 fl oz	46.2 fl oz	0	0.5	3 apps per season; no more than 2 sequential apps. Do not mix with horticultural oils.

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]
Pythium diseases (*Pythium spp.*)	4	Orondis Gold B Ridomil Gold GR Ridomil Gold SL Ultra Flourish (mefenoxam)	1 pt 20 lb 2 pt 2 pt	3 pt 40 lb 3 pt 6 pt	28 28 7 7	0* 2* 2* 2	Do not apply more than 1.5 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	28	2	Soil applied by drip injection.
	14	Terramaster 4EC (etridiazole)	7 fl oz	27.4 fl oz	3	0.5	Greenhouse use only.
	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, Orondis Opti B, Praiz	**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.
	27 & M5	Ariston (cymoxanil + chlorothalonil)	1.9 pt	30.2 pt	3	0.5	Check copper manufacturer's label for specific precautions and limitations for mixing with this product.
	U15 & M5	Oronidis Opti (oxathiapiprolin + chlorothalonil)	2.5 pt	10 pt	0	12 hr	Do not combine foliar apps of Orondis with soil apps of Orondis for disease control. 6 apps/A/year; no more than 2 sequential apps. 7 day minimum app. interval; Applications should not exceed more than 33% of the total foliar fungicide apps or 4 apps per a crop, whichever is fewer.
Rhizopus rot	3 & 9	Chairman (propiconazole + fludioxonil)	32 floz /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. Lower rates for small diameter fruit. See label for details.

Conventional fungicides are sorted by disease 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 Applic.	Max. Rate/acre Season	Min. Days to Harvest	Min. Days to Reentry	Remarks[2]
Septoria leaf spot	M1	**(copper compounds)** **Many brands available:** Americop 40 DF, 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, Copper Count N, Cueva, Cuprofix Ultra 40D, Cuproxat, Kentan DF, Kocide 2000, Kocide 3000, Kocide DF, KOP-Hydroxide, KOP-hydroxide 50W, Mastercop, Nordox, Nordox 75WG, Nu-Cop 50WP, Nu-Cop 3L, Nu-Cop 30 HB, Nu-Cop 50DF, Nu-Cop HB, Nu-Cop XLR, Previsto	**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 Max, Manzate Pro-Stik, Penncozeb 4FL, Penncozeb 75DF, Penncozeb 80WP, Protect DF, Roper DF Rainshield	**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, Orondis Opti B, Praiz	**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.
	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 usage.
	7	Luna Privelege	6.84 fl oz	13.7 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 usage.
	7 & 9	Luna Tranquility (fluopyram + pyrimethanil)	11.2 fl oz	54.7 fl oz	1	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 usage.
	7 & 11	Luna Sensation (fluopyram + trifloxystrobin)	7.6 fl oz	27.3 fl oz	3	0.5	No more than 2 sequential applications before rotating with another effective fungicide from a different FRAC group. Limit of 5 apps per a year.
	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	**(azoxystrobin)** **Many brands available:** Aframe, Azoxystar, Azoxystrobin 100 ST, Azoxyzone, Dynasty, Equation SC, Heritage, Quadris, Satori, Tetraban, Trevo, Willowood Azoxy 2SC	**SEE INDIVIDUAL LABELS**		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.

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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]
	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	Topguard EQ (azoxystrobin + flutriafol)	8 fl oz	32 fl oz	0	0.5	Limit is 4 applications per season. Do not use adjuvants or EC formulated tank mix partners. The addition of silicone or oil based additives may cause injury at high temperatures. Do not exceed 0.125% (v/v) adjuvant levels.
	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.
	22 & M3	Gavel 75DF (zoaximide + mancozeb)	2.0 lb	16 lb	5	2	
	27 & M5	Ariston (cymoxanil + chlorothalonil)	3.0 pt	30.2 pt	3	0.5	Check copper manufacturer's label for specific precautions and limitations for mixing with this product.
	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.
	U15 & M5	Oronidis Opti (oxathiapiprolin + chlorothalonil)	2.5 pt	10 pt	0	12 hr	Do not combine foliar apps of Orondis with soil apps of Orondis for disease control. 6 apps/A/year; no more than 2 sequential apps. 7 day minimum app. interval; Applications should not exceed more than 33% of the total foliar fungicide apps or 4 apps per a crop, whichever is fewer.
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.
	3 & 9	Chairman (propiconazole + fludioxonil)	32 floz /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. Lower rates for small diameter fruit. 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.

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]
(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.
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, Orondis Opti B, Praiz	**SEE INDIVIDUAL LABELS**		0	0.5	Use higher rates at fruit set and lower rates before fruit set.
	3	Rhyme (flutriafol)	7 fl oz	28 fl oz	0	0.5	Limit is 4 applications per season.
	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.
	7 & 9	Luna Tranquility (fluopyram + pyrimethanil)	11.2 fl oz	54.7 fl oz	1	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.
	7 & 11	Luna Sensation (fluopyram + trifloxystrobin)	7.6 fl oz	27.3 fl oz	3	0.5	No more than 2 sequential applications before rotating with another effective fungicide from a different FRAC group. Limit of 5 apps per a year.
	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.
	9 & 12	Switch 62.5WG (cyprodinil + fludioxonil)	14 oz	56 oz per year	0	0.5	See 2 (ee) label. 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	**(azoxystrobin)** **Many brands available:** Aframe, Azoxystar, Azoxystrobin 100 ST, Azoxyzone, Dynasty, Equation SC, Heritage, Quadris, Satori, Tetraban, Trevo, Willowood Azoxy 2SC	**SEE INDIVIDUAL LABELS**		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	Topguard EQ (azoxystrobin + flutriafol)	8 fl oz	32 fl oz	0	0.5	Limit is 4 applications per season. Do not use adjuvants or EC formulated tank mix partners. The addition of silicone or oil based additives may cause injury at high temperatures. Do not exceed 0.125% (v/v) adjuvant levels.

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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	
	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.
	27 & M5	Ariston (cymoxanil + chlorothalonil)	3.0 pt	30.2 pt	3	0.5	Check copper manufacturer's label for specific precautions and limitations for mixing with this product.
	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.
	U15 & M5	Oronidis Opti (oxathiapiprolin + chlorothalonil)	2.5 pt	10 pt	0	12 hr	Do not combine foliar apps of Orondis with soil apps of Orondis for disease control. 6 apps/A/year; no more than 2 sequential apps. 7 day minimum app. interval; Applications should not exceed more than 33% of the total foliar fungicide apps or 4 apps per a crop, whichever is fewer.
Timber Rot, Sclerotinia stem rot, or White mold (*Sclerotinia sclerotiorum*)	7	Endura (boscalid)	12.5 oz	25 oz	0	0.5	Alternate with non-FRAC code 7 fungicides.
(suppression)	7 & 11	Luna Sensation (fluopyram + trifloxystrobin)	7.6 fl oz	27.3 fl oz	3	0.5	No more than 2 sequential applications before rotating with another effective fungicide from a different FRAC group. Limit of 5 apps per a year.
(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 2017; 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 2017).

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]
Actinovate, Actinovate STP (*Streptomyces lydicus* WYEC 108), NC	*Alternaria* spp., Anthracnose, Botrytis, *Erwinia* spp., *Fusarium* spp., 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.
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.
BlightBan A506 (*Pseudomonas fluorescens* A506)	Frost protection	0	4 hr	No	Begin applications at 2-leaf stage; Repeat 2-3 applications as needed.
Botector (*Aureobasidium pullulans* strains DSM 14940 + DSM 14941)	Botrytis	0	4 hr	Yes	See label for application recommendations, especially for compatibility to other fungicides.
Brandt Organics Aleo (garlic oil)	*Xanthomonas* spp., *Pseudomonas* spp., *Ralstonia* spp., *Alternaria* spp., Botrytis, *Phytophthora infestans, Rhizoctonia solani, Sclerotinia sclerotiorum.*	0	0	Yes	See label for application recommendations.
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.
Fracture (Banda de Lupinus albus doce; BLAD), NC	Botrytis and Powdery mildew	1	4 hr	No	No more than 2 sequential applications before alternating with another effective fungicide with a different mode of action. No more than 5 applications per season. Product requires 2 to 4 hours dry time for maximum adhesion to foliage.
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.

TOMATO BIOPESTICIDES AND OTHER DISEASE CONTROL PRODUCTS (continued)

Ordered alphabetically by commercial name. (Updated June 2017).

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]
Kaligreen (potassium bicarbonate), NC	Powdery mildew	0	4 hr	Yes	See label for specific rates and application recommendations.
Lifeguard (*Bacillus mycoides* isolate J)	Broad spectrum fungicide		4 hr	Yes	See label for specific rates and application recommendations.
Mildew Cure (cotton oil, cottonseed oil, garlic oil)	Broad spectrum fungicide	0	0	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 **Oxidate 2.0** (mono- and di-potassium salts of phosphorous acid + hydrogen peroxide), 33 + NC	*Alternaria* spp., Anthracnose, Bacterial diseases, Botrytis, Early blight, Fusarium spp., Late blight, *Phytophthora* spp., Powdery mildew, *Pythium* spp., Rhizoctonia.	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.
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.
Procidic (Citric acid), NC	Broad spectrum fungicide	0	0	No	See label for specific rates, application recommendations, and precautions regarding use with other pesticides.
Purespray Green (Oil, petroleum), NC	Powdery mildew, Rust	0	4 hr	Yes	See label for specific rates, application recommendations, and precautions regarding use.
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.
Rendition **ZeroTol 2.0** (Hydrogen peroxide + peroxyacetic acid), NC	Broad spectrum fungicide	0	1 hr for enclosed areas; until spray dries in open field areas.	No	See label for specific rates, application recommendations, and precautions regarding use with other pesticides. Can be used as a soil drench at transplant and periodically throughout the season. Can also be used as a seed treatment.
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** **Serenade Opti** **Serenade Optimum** (*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.

TOMATO BIOPESTICIDES AND OTHER DISEASE CONTROL PRODUCTS (continued)

Ordered alphabetically by commercial name. (Updated June 2017).

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]
Serifel **Subtilex NG** (*Bacillus amyloliquefaciens* strain MBI 600), NC	Anthracnose, Botrytis, Buckeye Rot, Early Blight, Late Blight, Powdery mildew	0	4 hr	Yes	Begin applications early and continue on a 5 - 10 day interval as needed. Not labelled for greenhouse or transplant production.
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 Gl-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.
Sanidate 5.0 **Sanidate 12.0 Microbiocide** (hydrogen peroxide; peroxyacetic acid)	For sanitation and disinfection of non-porous surfaces	-	-	No	See label for specific rates and application recommendations.
StorOx 2.0 (hydrogen peroxide; peroxyacetic acid)	Postharvest disease control and sanitation and disinfection of non-porous surfaces	-	-	No	See label for specific rates and application recommendations.
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.
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.
Thyme Guard	Broad spectrum bactericide and fungicide	-	-	Yes	See label for specific rates and application recommendations.
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.

Insecticides and Miticides for Management of Tomato Pests

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INSECTICIDES LABELED FOR MANAGEMENT OF ARTHROPOD PESTS ON TOMATO.

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

Insect	MOA Code[1]	Trade name (Active Ingredient) *Restricted	Rate (Product/acre)	Rate per Season	Days to Harvest	REI (hours)	Remarks
Aphids (including aphid transmitted viruses, green peach aphid, potato aphid)	1A	***Lannate LV** (methomyl)	**LV:** 1.5-3.0 pt	Do not apply more than 21 pt LV/acre/crop (15 for tomatillos) or 7 lb SP /acre/crop (5 lb for tomatillos).	1	48	
	1A	***Lannate SP** methomyl)	SP: 0.5-1.0 lb		1	48	
	1A	***Vydate L** oxamyl)	**foliar:** 2.0-4.0 pt	Do not apply more than 32 pts/A per season.	3	48	
	1B	**Dimethoate 4 EC** dimethoate)	0.5-1.0 pt	Maximum total rate per year is 1 lb ai/A.	7	48	Minimum 6 day reapplication interval.
	1B	**Malathion 5** malathion)	1.0-2.5 pt	10 pints	1	12	8F can be used in greenhouse.
	1B	**Malathion 8 F**	1.5 pt				
	3A	***Asana XL (0.66EC)** esfenvalerate)	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.	1	12	
	3A	***Baythroid XL** beta-cyfluthrin)	1.6-2.8 fl oz	Do not apply more than 16.8 fl oz per acre per season.	0	12	
	3A	***Danitol 2.4 EC** fenpropathrin)	7-10.67 fl oz	Do not exceed 42.67 fl. oz. total application /A per season.	3	24	
	3A	**Karate with Zeon*** (lambdacyhalothrin)	0.96-1.92 fl. oz.	Do not apply more than 23.04 fl. oz. /A per season.	5	24	
	3A	***Mustang** zeta-cypermethrin)	2.4-4.3 oz	Do not apply more than 25.8 fl. oz./A per season.	1	12	Do not make applications less than 7 days apart.
	3A	**Pyganic Crop Protection EC 5.0 II** pyrethrins)	4.5-18.0 fl oz	11.25 pints.	0	12	Pyrethrins degrade rapidly in sunlight. Thorough coverage is important. OMRI-listed. Do not apply more than 10 times per season.
	3A & 4A	**Leverage*** 360 beta-cyfluthrin & imidacloprid)	3.8-4.1		0	12	
	3A & 6	**Gladiator*** avermectin B1 & zeta-cypermethrin)	10-19 fl. oz.	Do not apply more than 57 fl. oz./A per 12 month cropping year.	7	12	
	3A & 28	***Voliam Xpress** lambda-cyhalothrin & chlorantraniliprole)	5.0-9.0 fl oz	Do not apply more than 31.0 fl oz /A per season.	5	24	
	3A	***Brigade 2EC** bifenthrin)	2.1-5.2 fl oz	Make no more than 4 applications per season.	1	12	Do not make applications less than 10 days apart.
	3A	***Proaxis Insecticide** gamma-cyhalothrin)	1.92-3.84 fl oz	Do not apply more than 2.88 pints per acre per season.	5	24	
	3A	***Warrior II** (lambda-cyhalothrin)	0.96-1.92 fl oz	Do not apply more than 23.04 fl. oz/A per season.	5	24	
	3A & 4A	***Endigo ZC** lambda-cyhalothrin & thiamethoxam)	4.0-4.5 fl oz	Do not exceed a total of 19.0 fl oz per acre per season.	5	24	See label for limits on each active ingredient.
	4A	**Actara** thiamethoxam)	2.0-5.5 oz	Do not exceed a total of 11.0 oz/Acre per acre per growing season.	0	12	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. Minimum interval between applications is 5 days.

INSECTICIDES LABELED FOR MANAGEMENT OF ARTHROPOD PESTS ON TOMATO. (continued)

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

Insect	MOA Code[1]	Trade name (Active Ingredient) *Restricted	Rate (Product/acre)	Rate per Season	Days to Harvest	REI (hours)	Remarks
	4A	**Admire Pro** imidacloprid)	7-10.5 fl oz	Maximum allowed on tomato is 10.5 fl. oz/A.	21	12	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.
	4A	**Admire Pro** imidacloprid)	0.6 fl oz per 1000 plants		0 (soil)	12	Greenhouse use: 1 application to mature plants, see label for cautions.
	4A	**Admire Pro** imidacloprid)	0.44 fl oz per 10,000 plants		21	12	Planthouse: 1 application. See label.
	4A	**Assail 70WP** acetamiprid)	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.	7	12	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.
	4A	**Belay 50 WDG** clothianidin)	1.6-2.1 oz (foliar application)	Do not apply more than 6.4 oz per acre per season.	7	12	Do not use an adjuvant. Toxic to bees. Do not release irrigation water from the treated area.
	4A	**Belay 50 WDG** clothianidin)	4.8-6.4 oz (soil application)	Do not apply more than 6.4 oz per acre per season.	Apply at planting	12	See label for application instructions. Do not release irrigation water from the treated area.
	4A	**Platinum** (thiamethoxam)	5-11 fl oz	Do not exceed a total of 11 fl. oz. Platinum/A per growing season.	30	12	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.
	4A	**Platinum 75 SG** (thiamethoxam)	1.66-3.67 oz	Do not exceed a total of 3.67 Platinum 75 SG/A per growing season.	30	12	
	4A	**Provado 1.6F** imidacloprid)	3.8-6.2 fl oz	Maximum per crop per season 19.2 fl oz/A.	0	12	Do not apply to crop that has been already treated with imidacloprid or thiamethoxam at planting.
	4A	**Safari 20 SG** dinotefuran)	7.0-14.0 oz		1	12	For transplant production only. Can be applied as foliar spray or soil drench.
	4A	**Scorpion** dinotefuran)	**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.	1	12	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.
	4A	**Venom 20 SG** dinotefuran)	**foliar:**0.44-0.895 lb	Do not apply more than 1.34 lb./A per season.	1	12	Use only one application method (soil or foliar). Limited to three applications per season. Toxic to honeybees.
	4A	**Venom 20 SG** dinotefuran)	**soil:** 1.13-1.34 lb	Do not apply more than 2.68 lb/A per season.	21	12	Use only one application method (soil or foliar). Must have supplemental label for rates over 6.0 oz/acre.
	4A & 28	**Durivo** thiamethoxam & chlorantraniliprole)	10-13 fl oz	Do not exceed a total of 13.0 fl. oz./A per growing season.	30	12	Several methods of soil application – see label.
	4A & 28	**Voliam Flexi** thiamethoxam & chlorantraniliprole)	4.0-7.0 oz	Do not exceed 14 oz/A per season.	1	12	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.
	4C	**Closer SC** (sulfoxaflor)	1.5 - 2.0 fl oz	Do not exceed 17 fl oz Closer per acre per year.	1	12	DO NOT APPLY UNTIL AFTER PETAL FALL.
	4D	**Sivanto Prime** (flupyradifurone)	**soil:** 21.0 - 28.0 fl oz **foliar:** 7.0 -14.0 fl oz	Do not apply more than 28.0 fl oz per acre per year.	soil application: 45 days; foliar: 1 day	4	Minimum interval between applications: 7 days.
	9B	**Fulfill** pymetrozine)	2.75 oz	Do not apply more than 5.5 oz/ acre per crop.	0	12	(FL-040006) 24(c) label for growing transplants also (FL-03004).
	23	**Movento** spirotetramat)	4.0-5.0 fl oz	Maximum of 10 fl oz/acre per season.	1	24	

INSECTICIDES LABELED FOR MANAGEMENT OF ARTHROPOD PESTS ON TOMATO. (continued)

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Insect	MOA Code[1]	Trade name (Active Ingredient) *Restricted	Rate (Product/acre)	Rate per Season	Days to Harvest	REI (hours)	Remarks
	28	**Exirel** cyantraniliprole)	7-20.5 fl. oz.	Do not apply a total of more than 0.4 lb ai/A per crop.	1	12	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 treatments is 5 days.
	28	**Verimark** cyantraniliprole)	5-13.5 fl. oz.	Do not apply more than 0.4 lb ai/A per crop.	1	4	
	29	**Beleaf 50 SG** flonicamid)	2.0-2.8 oz	Do not apply more than 8.4 oz per acre per season.	0	12	Begin applications before pests reach damaging levels. Do not apply more than 2 applications per season. Allow a minimum of 7 days between applications.
	-	**Aza-Direct** azadirachtin)	1-2 pts, up to 3.5 pts, if needed		0	4	Antifeedant, repellant, insect growth regulator. OMRI-listed.
	-	**Azatin XL** azadirachtin)	5-21 fl oz		0	4	Antifeedant, repellant, insect growth regulator.
	-	**Botanigard ES** (*Beauvaria bassiana* strain GHA)	0.25 - 1 quart per acre. Apply in sufficient water to cover foliage, typically 5 - 100 gallons per acre.		0	4	
	-	**Grandevo** *Chromobacterium subtsugae*)	1.0-3.0 lb		0	4	Thorough coverage is necessary for effective control.
	-	**Mycotrol ESO** (*Beauvaria bassiana* strain GHA)	0.25 - 1 quart per acre. Apply in sufficient water to cover foliage, typically 5 - 100 gallons per acre.		0	4	OMRI Listed
	-	**Neemix 4.5** azadirachtin)	4.0-16.0 fl oz		0	12	IGR, feeding repellant. OMRI-listed.
	-	**PFR-97** *Isaria fumosorosea* Apopka strain 97)	1.0-2.0 lbs		0	4	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.
	-	**Requiem 25EC** extract of *Chenopodium ambrosioides*)	2-4 qt	Limited to 10 applications per crop cycle.	0	4	Begin applications before pests reach damaging levels.
	-	**SuffOil-X** unsulfonated residue of petroleum oil)	1-2 gallons per 100 gallons of water.			4	OMRI listed.
	-	**M-Pede 49% EC** Soap, insecticidal)	1-2% V/V		0	12	OMRI-listed
	-	**Ultra Fine Oil, Saf-T-Side, others**	1.0-2.0 gal/100 gal		0	4	Do not exceed four applications per season.
	-	**JMS Stylet-Oil** (oil, insecticidal)	3.0-6.0 qt/100 gal water				Organic Stylet-Oil and Saf-T-Side are OMRI-listed.
Beetles (including beetle larvae, blister beetles, Colorado potato beetle, cucumber beetle, cucumber beetle adults, flea beetles)	1A	**Sevin 80S; XLR; 4F** (carbaryl)	**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.	3	12	Do not apply more than seven times.
	1A	***Vydate L** **(**oxamyl)	**foliar:** 2.0-4.0 pt	Do not apply more than 32 pts/A per season.	3	48	
	3A	***Ambush 25W** (permethrin)	3.2-12.8 oz	Do not apply more than 76.8 oz/A per season.	up to day of harvest	12	**Do not use on cherry tomatoes.**
	3A	***Asana XL (0.66EC)** (esfenvalerate)	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.	1	12	
	3A	***Baythroid XL** beta-cyfluthrin)	1.6-2.8 fl oz	Do not apply more than 16.8 fl oz per acre per season.	0	12	
	3A	***Hero** bifenthrin & zeta-cypermethrin)	4.0-10.3 oz	Do not apply more than 43.26 fl. oz./A per season.	1	12	Do not make more than 4 applications per season. Do not make applications less than 10 days apart.

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

Insect	MOA Code[1]	Trade name (Active Ingredient) *Restricted	Rate (Product/acre)	Rate per Season	Days to Harvest	REI (hours)	Remarks
	3A	**Karate with Zeon*** (lambdacyhalothrin)	0.96-1.92 fl. oz.	Do not apply more than 23.04 fl. oz. /A per season.	5	24	
	3A	***Mustang** zeta-cypermethrin)	2.4-4.3 oz	Do not apply more than 25.8 fl. oz./A per season.	1	12	Do not make applications less than 7 days apart.
	3A	***Pounce 25 WP** (permethrin)	3.2-12.8 oz		0	12	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.
	3A	**Pyganic Crop Protection EC 5.0 II** pyrethrins)	4.5-18.0 fl oz	11.25 pints.	0	12	Pyrethrins degrade rapidly in sunlight. Thorough coverage is important. OMRI-listed. Do not apply more than 10 times per season.
	3A & 4A	**Leverage*** 360 beta-cyfluthrin & imidacloprid)	3.8-4.1		0	12	
	3A & 6	**Gladiator*** avermectin B1 & zeta-cypermethrin)	10-19 fl. oz.	Do not apply more than 57 fl. oz./A per 12 month cropping year.	7	12	
	3A & 28	***Voliam Xpress** (lambda-cyhalothrin & chlorantraniliprole)	5.0-9.0 fl oz	Do not apply more than 31.0 fl oz /A per season.	5	24	
	3A	***Brigade 2EC** (bifenthrin)	2.1-5.2 fl oz	Make no more than 4 applications per season.	1	12	Do not make applications less than 10 days apart.
	3A	***Proaxis Insecticide** (gamma-cyhalothrin)	1.92-3.84 fl oz	Do not apply more than 2.88 pints per acre per season.	5	24	
	3A	***Warrior II** (lambda-cyhalothrin)	0.96-1.92 fl oz	Do not apply more than 23.04 fl. oz/A per season.	5	24	
	3A & 4A	***Endigo ZC** lambda-cyhalothrin & thiamethoxam)	4.0-4.5 fl oz	Do not exceed a total of 19.0 fl oz per acre per season.	5	24	See label for limits on each active ingredient.
	4A	**Actara** thiamethoxam)	2.0-5.5 oz	Do not exceed a total of 11.0 oz/Acre per acre per growing season.	0	12	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. Minimum interval between applications is 5 days.
	4A	**Admire Pro** (imidacloprid)	7-10.5 fl oz	Maximum allowed on tomato is 10.5 fl. oz/A.	21	12	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.
	4A	**Assail 70WP** (acetamiprid)	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.	7	12	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.
	4A	**Belay 50 WDG** (clothianidin)	1.6-2.1 oz (foliar application)	Do not apply more than 6.4 oz per acre per season.	7	12	Do not use an adjuvant. Toxic to bees. Do not release irrigation water from the treated area.
	4A	**Belay 50 WDG** (clothianidin)	4.8-6.4 oz (soil application)	Do not apply more than 6.4 oz per acre per season.	Apply at planting	12	See label for application instructions. Do not release irrigation water from the treated area.
	4A	**Platinum** (thiamethoxam)	5-11 fl oz	Do not exceed a total of 11 fl. oz. Platinum/A per growing season.	30	12	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
	4A	**Platinum 75 SG** (thiamethoxam)	1.66-3.67 oz	Do not exceed a total of 3.67 Platinum 75 SG/A per growing season.			
	4A	**Provado 1.6F** (imidacloprid)	3.8-6.2 fl oz	Maximum per crop per season 19.2 fl oz/A.	0	12	Do not apply to crop that has been already treated with imidacloprid or thiamethoxam at planting.
	4A	**Scorpion** dinotefuran)	**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.	1	12	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.

INSECTICIDES LABELED FOR MANAGEMENT OF ARTHROPOD PESTS ON TOMATO. (continued)

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

Insect	MOA Code[1]	Trade name (Active Ingredient) *Restricted	Rate (Product/acre)	Rate per Season	Days to Harvest	REI (hours)	Remarks
	4A	**Venom 20 SG** dinotefuran)	**foliar:** 0.44-0.895 lb	Do not apply more than 1.34 lb./A per season.	1	12	Use only one application method (soil or foliar). Limited to three applications per season. Toxic to honeybees.
		Venom 20 SG dinotefuran)	**soil:** 1.13-1.34 lb	Do not apply more than 2.68 lb/A per season.	21	12	Use only one application method (soil or foliar). Must have supplemental label for rates over 6.0 oz/acre.
	4A & 28	**Durivo** thiamethoxam & chlorantraniliprole)	10-13 fl oz	Do not exceed a total of 13.0 fl. oz./A per growing season.	30	12	Several methods of soil application – see label.
	4A & 28	**Voliam Flexi** (thiamethoxam & chlorantraniliprole)	4.0-7.0 oz	Do not exceed 14 oz/A per season.	1	12	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.
	4D	**Sivanto 200 SL** (flupyradifurone)	7.0-14.0 fl. oz.	Do not apply more than 28.0 fl. oz./A per year.	1	4	Minimum interval between applications: 7 days.
	5	**Entrust** spinosad)	0.5-2.5 oz	Do not apply more than 9 oz per acre per crop.	1	4	OMRI-listed. For thrips, rotate to other class of effective insecticide after 2 applications of a Group 5 insecticide for at least 2 applications.
	6	***Proclaim** emamectin benzoate)	2.4-4.8 oz	No more than 28.8 oz/A per season.	7	12	Do not use in greenhouses, nurseries, plant propagation houses, or on any plants grown for use as transplants.
	15	**Rimon 0.83EC** (novaluron)	9.0-12.0 fl oz	Do not apply more than 36 fl oz per acre per season.	1	12	Minimum of 7 days between applications.
	17	**Trigard** cyromazine)	2.66 oz	Do not apply more than 15.96 oz./A per season.	0	12	No more than 6 applications per crop. Does not control CPB adults. Most effective against 1st & 2nd instar larvae.
	28	**Coragen** (chlorantraniliprole/ rynaxypyr)	3.5-7.5 fl oz	Do not apply more than 15.4 fl oz per acre per crop.	1	4	Can be applied by drip chemigation or as a soil application at planting. See label for details.
	28	**Exirel** cyantraniliprole)	7-20.5 fl. oz.	Do not apply a total of more than 0.4 lb ai/A per crop.	1	12	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 treatments is 5 days.
	28	**Verimark** (cyantraniliprole)	5-13.5 fl. oz.	Do not apply more than 0.4 lb ai/A per crop.	1	4	
	-	**Aza-Direct** (azadirachtin)	1-2 pts, up to 3.5 pts, if needed		0	4	Antifeedant, repellant, insect growth regulator. OMRI-listed.
	-	**Azatin XL** (azadirachtin)	5-21 fl oz		0	4	Antifeedant, repellant, insect growth regulator.
	-	**Neemix 4.5** (azadirachtin)	4.0-16.0 fl oz		0	12	IGR, feeding repellant. OMRI-listed.
	-	**SuffOil-X** unsulfonated residue of petroleum oil)	1-2 gallons per 100 gallons of water.			4	OMRI listed.
	-	**Surround WP** kaolin)	12.5-50 lbs		0	4	OMRI listed.
	-	**Ultra Fine Oil, Saf-T-Side, others**	1.0-2.0 gal/100 gal		0	4	Do not exceed four applications per season.
	-	**JMS Stylet-Oil** (oil, insecticidal)	3.0-6.0 qt/100 gal water		0	4	
Caterpillars: including cabbage looper, corn earworm, garden webworm, hornworms, imported cabbageworm, loopers, saltmarsh caterpillar, tobacco budworm, tomato fruitworm; armyworms (beet armyworm, fall armyworm, southern armyworm, true armyworm, yellowstriped armyworm); cutworms (black cutworm, granulate cutworm).	1A	***Lannate SP** (methomyl)	SP: 0.5-1.0 lb		1	48	
	1A	**Sevin 80S; XLR; 4F** (carbaryl)	**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.	3	12	Do not apply more than seven times.
	1A	**10% Sevin Granules** (carbaryl)	20 lb		3	12	Maximum of 4 applications, not more often than once every 7 days.
	1B	***Diazinon AG500; *50 W** (diazinon)	**AG500:** 1-4 qt **50W:** 2-8 lb	Do not make more than one soil applicationper year regrardless of target pest.	preplant	48	Incorporate into soil - see label.
	3A	***Ambush 25W** (permethrin)	3.2-12.8 oz	Do not apply more than 76.8 oz/A per season.	up to day of harvest	12	**Do not use on cherry tomatoes.**

INSECTICIDES LABELED FOR MANAGEMENT OF ARTHROPOD PESTS ON TOMATO. (continued)

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

Insect	MOA Code[1]	Trade name (Active Ingredient) *Restricted	Rate (Product/acre)	Rate per Season	Days to Harvest	REI (hours)	Remarks
	3A	***Asana XL (0.66EC)** (esfenvalerate)	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.	1	12	
	3A	***Baythroid XL** beta-cyfluthrin)	1.6-2.8 fl oz	Do not apply more than 16.8 fl oz per acre per season.	0	12	
	3A	***Danitol 2.4 EC** (fenpropathrin)	7-10.67 fl oz	Do not exceed 42.67 fl. oz. total application /A per season.	3	24	
	3A	***Hero** (bifenthrin & zeta-cypermethrin)	4.0-10.3 oz	Do not apply more than 43.26 fl. oz./A per season.	1	12	Do not make more than 4 applications per season. Do not make applications less than 10 days apart.
	3A	***Karate with Zeon** (lambdacyhalothrin)	0.96-1.92 fl. oz.	Do not apply more than 23.04 fl. oz. /A per season.	5	24	
	3A	***Mustang** zeta-cypermethrin)	2.4-4.3 oz	Do not apply more than 25.8 fl. oz./A per season.	1	12	Do not make applications less than 7 days apart.
	3A	***Pounce 25 WP** (permethrin)	3.2-12.8 oz		0	12	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.
	3A	**Pyganic Crop Protection EC 5.0 II** (pyrethrins)	4.5-18.0 fl oz	11.25 pints.	0	12	Pyrethrins degrade rapidly in sunlight. Thorough coverage is important. OMRI-listed. Do not apply more than 10 times per season.
	3A & 4A	**Leverage*** 360 (beta-cyfluthrin & imidacloprid)	3.8-4.1		0	12	
	3A & 6	**Gladiator*** (avermectin B1 & zeta-cypermethrin)	10-19 fl. oz.	Do not apply more than 57 fl. oz./A per 12 month cropping year.	7	12	
	3A & 28	***Voliam Xpress** (lambda-cyhalothrin & chlorantraniliprole)	5.0-9.0 fl oz	Do not apply more than 31.0 fl oz /A per season.	5	24	
	3A	***Brigade 2EC** (bifenthrin)	2.1-5.2 fl oz	Make no more than 4 applications per season.	1	12	Do not make applications less than 10 days apart.
	3A	***Proaxis Insecticide** (gamma-cyhalothrin)	1.92-3.84 fl oz	Do not apply more than 2.88 pints per acre per season.	5	24	
	3A	***Warrior II** (lambda-cyhalothrin)	0.96-1.92 fl oz	Do not apply more than 23.04 fl. oz/A per season.	5	24	
	3A & 4A	***Endigo ZC** (lambda-cyhalothrin & thiamethoxam)	4.0-4.5 fl oz	Do not exceed a total of 19.0 fl oz per acre per season.	5	24	See label for limits on each active ingredient.
	4A	**Platinum** (thiamethoxam)	5-11 fl oz	Do not exceed a total of 11 fl. oz. Platinum/A per growing season.	30	12	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
	4A	**Platinum 75 SG** (thiamethoxam)	1.66-3.67 oz	Do not exceed a total of 3.67 Platinum 75 SG/A per growing season.			
	4A & 28	**Durivo** (thiamethoxam & chlorantraniliprole)	10-13 fl oz	Do not exceed a total of 13.0 fl. oz./A per growing season.	30	12	Several methods of soil application – see label.
	4A & 28	**Voliam Flexi** (thiamethoxam & chlorantraniliprole)	4.0-7.0 oz	Do not exceed 14 oz/A per season.	1	12	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.
	5	**Entrust** (spinosad)	0.5-2.5 oz	Do not apply more than 9 oz per acre per crop.	1	4	OMRI-listed. For thrips, rotate to other class of effective insecticide after 2 applications of a Group 5 insecticide for at least 2 applications.
	5	**Radiant SC** (spinetoram)	5-10 fl oz.	Do not apply more than 34 fl. oz./A per calendar year.	1	4	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.
	6	***Proclaim** (emamectin benzoate)	2.4-4.8 oz	No more than 28.8 oz/A per season.	7	12	Do not use in greenhouses, nurseries, plant propagation houses, or on any plants grown for use as transplants.
	11A	**Agree WG** (*Bacillus thuringiensis* subspecies *aizawai*)	0.5-2.0 lb		0	4	Apply when larvae are small for best control. Can be used in greenhouse. OMRI-listed.

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Insect	MOA Code[1]	Trade name (Active Ingredient) *Restricted	Rate (Product/acre)	Rate per Season	Days to Harvest	REI (hours)	Remarks
	11A	**Biobit HP** (*Bacillus thuringiensis* subspecies *kurstaki*)	0.5-2.0 lb		0	4	Treat when larvae are young. Good coverage is essential. Can be used in the greenhouse. OMRI-listed.
	11A	**Crymax WDG** (*Bacillus thuringiensis* subspecies *kurstaki*)	0.5-2.0 lb		0	4	Use high rate for armyworms. Treat when larvae are young.
	11A	**Deliver** (*Bacillus thuringiensis* subspecies *kurstaki*)	0.25-1.5 lb		0	4	Use higher rates for armyworms. OMRI-listed.
	11A	**DiPel DF** (*Bacillus thuringiensis* subspecies *kurstaki*)	0.25-2.0 lb		0	4	Treat when larvae are young. Good coverage is essential. Can be used for organic production.
	11A	**Javelin WG** (*Bacillus thuringiensis* subspecies *kurstaki*)	0.12-1.5 lb		0	4	Treat when larvae are young. Thorough coverage is essential. OMRI-listed[2].
	11A	**Xentari DF** (*Bacillus thuringiensis* subspecies *aizawai*)	0.5-2.0 lb		0	4	Treat when larvae are young. Thorough coverage is essential. May be used in the greenhouse. Can be used in organic production. OMRI-listed.
	15	**Rimon 0.83EC** (novaluron)	9.0-12.0 fl oz	Do not apply more than 36 fl oz per acre per season.	1	12	Minimum of 7 days between applica-tions.
	18	**Confirm 2F** (tebufenozide)	6-16 fl oz	Do not apply more than 64 fl. oz./A per season.	7	4	Product is a slow-acting IGR that will not kill larvae immediately.
	18	**Intrepid 2F** (me-thoxyfenozide)	4-16 fl oz	Do not apply more than 64 fl oz per acre per season.	1	4	Product is a slow-acting IGR that will not kill larvae immediately.
	22	**Avaunt** indoxacarb)	2.5-3.5 oz	Do not apply more than 14 ounces of product per acre per crop. Minimum spray interval is 5 days.	3	12	
	28	**Coragen** (chlorantra-niliprole/rynaxypyr)	3.5-7.5 fl oz	Do not apply more than 15.4 fl oz per acre per crop.	1	4	Can be applied by drip chemigation or as a soil application at planting. See label for details.
	28	**Exirel** cyantraniliprole)	7-20.5 fl. oz.	Do not apply a total of more than 0.4 lb ai/A per crop.	1	12	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 treatments is 5 days.
	28	**Verimark** (cyantraniliprole)	5-13.5 fl. oz.	Do not apply more than 0.4 lb ai/A per crop.	1	4	
	-	**Aza-Direct** (azadirachtin)	1-2 pts, up to 3.5 pts, if needed		0	4	Antifeedant, repellant, insect growth regulator. OMRI-listed.
	-	**Azatin XL** (azadirachtin)	5-21 fl oz		0	4	Antifeedant, repellant, insect growth regulator.
	-	**CheckMate TPW-F** (pheromone)	1.2-6.0 fl oz		0	0	For mating disruption of tomato pin-worm- See label for details.
	-	**Grandevo** (*Chromo-bacterium subtsugae*)	1.0-3.0 lb		0	4	Thorough coverage is necessary for effective control.
	-	**MBI-203 EP** (*Chromobacterium subtsugae*)	4.0-12.0 quarts		0	4	OMRI listed. Can be used in the green-house.
	-	**Neemix 4.5** (azadirachtin)	4.0-16.0 fl oz		0	12	IGR, feeding repellant. OMRI-listed.
Fire Ants	7A	**Extinguish** ((S)-methoprene)	1.0-1.5 lb		0	4	Slow-acting IGR (insect growth regula-tor). 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.
	7C	**Esteem Ant Bait** (pyriproxyfen)	1.5-2.0 lb		1	12	Apply when ants are actively foraging.
Grasshoppers	1A	**10% Sevin Granules** (carbaryl)	20 lb		3	12	Maximum of 4 applications, not more often than once every 7 days.
	3A	***Asana XL (0.66EC)** (esfenvalerate)	2.9-9.6 fl oz	Do not apply more than 0.5 lb ai per acre per season, or 10 ap-plications at highest rate.	1	12	

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Insect	MOA Code[1]	Trade name (Active Ingredient) *Restricted	Rate (Product/acre)	Rate per Season	Days to Harvest	REI (hours)	Remarks
	3A	***Hero** (bifenthrin & zeta-cypermethrin)	4.0-10.3 oz	Do not apply more than 43.26 fl. oz./A per season.	1	12	Do not make more than 4 applications per season. Do not make applications less than 10 days apart.
	3A	**Karate with Zeon*** (lambdacyhalothrin)	0.96-1.92 fl. oz.	Do not apply more than 23.04 fl. oz. /A per season.	5	24	
	3A	***Mustang** zeta-cypermethrin)	2.4-4.3 oz	Do not apply more than 25.8 fl. oz./A per season.	1	12	Do not make applications less than 7 days apart.
	3A	**Pyganic Crop Protection EC 5.0 II** (pyrethrins)	4.5-18.0 fl oz	11.25 pints.	0	12	Pyrethrins degrade rapidly in sunlight. Thorough coverage is important. OMRI-listed. Do not apply more than 10 times per season.
	3A	***Brigade 2EC** (bifenthrin)	2.1-5.2 fl oz	Make no more than 4 applications per season.	1	12	Do not make applications less than 10 days apart.
	3A	***Proaxis Insecticide** (gamma-cyhalothrin)	1.92-3.84 fl oz	Do not apply more than 2.88 pints per acre per season.	5	24	
	3A	***Warrior II** (lambda-cyhalothrin)	0.96-1.92 fl oz	Do not apply more than 23.04 fl. oz/A per season.	5	24	
	3A & 4A	***Endigo ZC** (lambda-cyhalothrin & thiamethoxam)	4.0-4.5 fl oz	Do not exceed a total of 19.0 fl oz per acre per season.	5	24	See label for limits on each active ingredient.
	-	**Surround WP** (kaolin)	12.5-50 lbs		0	4	OMRI listed.
Lace bugs	1A	**Sevin 80S; XLR; 4F** (carbaryl)	**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.	3	12	Do not apply more than seven times.
Leafhoppers	1A	**Sevin 80S; XLR; 4F** (carbaryl)	**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.	3	12	Do not apply more than seven times.
	1B	**Dimethoate 4 EC** (dimethoate)	0.5-1.0 pt	Maximum total rate per year is 1 lb ai/A.	7	48	Minimum 6 day reapplication interval.
	3A	***Hero** (bifenthrin & zeta-cypermethrin)	4.0-10.3 oz	Do not apply more than 43.26 fl. oz./A per season.	1	12	Do not make more than 4 applications per season. Do not make applications less than 10 days apart.
	3A	**Karate with Zeon*** (lambdacyhalothrin)	0.96-1.92 fl. oz.	Do not apply more than 23.04 fl. oz. /A per season.	5	24	
	3A	***Mustang** (zeta-cypermethrin)	2.4-4.3 oz	Do not apply more than 25.8 fl. oz./A per season.	1	12	Do not make applications less than 7 days apart.
	3A	**Pyganic Crop Protection EC 5.0 II** (pyrethrins)	4.5-18.0 fl oz	11.25 pints.	0	12	Pyrethrins degrade rapidly in sunlight. Thorough coverage is important. OMRI-listed. Do not apply more than 10 times per season.
	3A & 6	***Gladiator** avermectin B1 & zeta-cypermethrin)	10-19 fl. oz.	Do not apply more than 57 fl. oz./A per 12 month cropping year.	7	12	
	3A & 28	***Voliam Xpress** (lambda-cyhalothrin & chlorantraniliprole)	5.0-9.0 fl oz	Do not apply more than 31.0 fl oz /A per season.	5	24	
	3A	***Proaxis Insecticide** (gamma-cyhalothrin)	1.92-3.84 fl oz	Do not apply more than 2.88 pints per acre per season.	5	24	
	3A	***Warrior II** (lambda-cyhalothrin)	0.96-1.92 fl oz	Do not apply more than 23.04 fl. oz/A per season.	5	24	
	3A & 4A	***Endigo ZC** (lambda-cyhalothrin & thiamethoxam)	4.0-4.5 fl oz	Do not exceed a total of 19.0 fl oz per acre per season.	5	24	See label for limits on each active ingredient.
	4A	**Actara** (thiamethoxam)	2.0-5.5 oz	Do not exceed a total of 11.0 oz/Acre per acre per growing season.	0	12	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. Minimum interval between applications is 5 days.
	4A	**Admire Pro** (imidacloprid)	7-10.5 fl oz	Maximum allowed on tomato is 10.5 fl. oz/A.	21	12	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.
	4A	**Belay 50 WDG** (clothianidin)	**foliar:** 1.6-2.1 oz	Do not apply more than 6.4 oz per acre per season.	7	12	Do not use an adjuvant. Toxic to bees. Do not release irrigation water from the treated area.

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Insect	MOA Code[1]	Trade name (Active Ingredient) *Restricted	Rate (Product/acre)	Rate per Season	Days to Harvest	REI (hours)	Remarks
	4A	**Belay 50 WDG** (clothianidin)	**soil:** 4.8-6.4 oz	Do not apply more than 6.4 oz per acre per season.	Apply at planting	12	See label for application instructions. Do not release irrigation water from the treated area.
	4A	**Platinum** (thiamethoxam)	5-11 fl oz	Do not exceed a total of 11 fl. oz. Platinum/A per growing season.	30	12	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
	4A	**Platinum 75 SG** (thiamethoxam)	1.66-3.67 oz	Do not exceed a total of 3.67 Platinum 75 SG/A per growing season.			
	4A	**Provado 1.6F** (imidacloprid)	3.8-6.2 fl oz	Maximum per crop per season 19.2 fl oz/A.	0	12	Do not apply to crop that has been already treated with imidacloprid or thiamethoxam at planting.
	4A	**Scorpion** (dinotefuran)	**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.	1	12	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.
	4A	**Venom 20 SG** (dinotefuran)	**foliar:**0.44-0.895 lb	Do not apply more than 1.34 lb./A per season.	1	12	Use only one application method (soil or foliar). Limited to three applications per season. Toxic to honeybees.
	4A	**Venom 20 SG** dinotefuran)	**soil:** 1.13-1.34 lb	Do not apply more than 2.68 lb/A per season.	21	12	Use only one application method (soil or foliar). Must have supplemental label for rates over 6.0 oz/acre.
	4A & 28	**Durivo** (thiamethoxam & chlorantraniliprole)	10-13 fl oz	Do not exceed a total of 13.0 fl oz per acre per growing season.	30	12	Several methods of soil application – see label.
	4A & 28	**Voliam Flexi** (thiamethoxam & chlorantraniliprole)	4.0-7.0 oz	Do not exceed 14 oz/A per season.	1	12	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.
	4D	**Sivanto Prime** (flupyradifurone)	**soil:** 21.0 - 28.0 fl oz; **foliar:** 7.0-10.5 fl oz	Do not apply more than 28.0 fl oz per acre per year.	soil application: 45 days; foliar: 1 day	4	Minimum interval between applications: 7 days.
	6	***Proclaim** (emamectin benzoate)	2.4-4.8 oz	No more than 28.8 oz/A per season.	7	12	Do not use in greenhouses, nurseries, plant propagation houses, or on any plants grown for use as transplants.
	16	**Courier 40SC** (buprofezin)	9.0-13.6 fl oz	Do not apply more than 27.2 fl. oz./A per crop cycle.	1	12	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.
	-	**Aza-Direct** (azadirachtin)	1-2 pts, up to 3.5 pts, if needed		0	4	Antifeedant, repellant, insect growth regulator. OMRI-listed.
	-	**Azatin XL** (azadirachtin)	5-21 fl oz		0	4	Antifeedant, repellant, insect growth regulator.
	-	**SuffOil-X** (unsulfonated residue of petroleum oil)	1-2 gallons per 100 gallons of water.		0	4	OMRI listed.
	-	**Surround WP** (kaolin)	12.5-50 lbs		0	4	OMRI listed.
	-	**M-Pede 49% EC** (Soap, insecticidal)	1-2% V/V		0	12	OMRI-listed
	-	**Ultra Fine Oil, Saf-T-Side, others**	1.0-2.0 gal/100 gal		0	4	Do not exceed four applications per season.
	-	**JMS Stylet-Oil** (oil, insecticidal)	3.0-6.0 qt/100 gal water		0	4	
***Liriomyza* leafminers**	1A	***Vydate L** (oxamyl)	**foliar:** 2.0-4.0 pt	Do not apply more than 32 pts/A per season.	3	48	

INSECTICIDES LABELED FOR MANAGEMENT OF ARTHROPOD PESTS ON TOMATO. (continued)

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Insect	MOA Code[1]	Trade name (Active Ingredient) *Restricted	Rate (Product/acre)	Rate per Season	Days to Harvest	REI (hours)	Remarks
	3A & 6	***Gladiator** (avermectin B1 & zeta-cypermethrin)	10-19 fl. oz.	Do not apply more than 57 fl. oz./A per 12 month cropping year.	7	12	
	4A	**Venom 20 SG** (dinotefuran)	**foli-ar:**0.44-0.895 lb	Do not apply more than 1.34 lb./A per season.	1	12	Use only one application method (soil or foliar). Limited to three applications per season. Toxic to honeybees.
	4A	**Venom 20 SG** (dinotefuran)	**soil:** 1.13-1.34 lb	Do not apply more than 2.68 lb/A per season.	21	12	Use only one application method (soil or foliar). Must have supplemental label for rates over 6.0 oz/acre.
	5	**Entrust** (spinosad)	0.5-2.5 oz	Do not apply more than 9 oz per acre per crop.	1	4	OMRI-listed. For thrips, rotate to other class of effective insecticide after 2 applications of a Group 5 insecticide for at least 2 applications.
	5	**Radiant SC** (spinetoram)	5-10 fl oz.	Do not apply more than 34 fl. oz./A per calendar year.	1	4	
	6	***Agri-Mek SC** (abamectin)	1.75-3.5 fl oz	Do not apply more than 10.25 fl. oz./A in a growing season.	7	12	Do not make more than 2 sequential applications of Agri-Mek SC or any other foliar applied abamectin-containing product in a growing season.
	6	***Agri-Mek 0.15 EC** (abamectin)	8.0-16.0 fl. oz	Do not apply more than 48 fl oz per acre per season.	7	12	Do not make more than 2 sequential applications per season.
	28	**Exirel** (cyantraniliprole)	7-20.5 fl. oz.	Do not apply a total of more than 0.4 lb ai/A per crop.	1	12	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.
	28	**Verimark** (cyantraniliprole)	5-13.5 fl. oz.	Do not apply more than 0.4 lb ai/A per crop.	1	4	
	-	**Requiem 25EC** (extract of Chenopodium ambrosioides)	2-4 qt	Limited to 10 applications per crop cycle.	0	4	Begin applications before pests reach damaging levels.
Mites (including broad mites, twospotted spider mites, tomato russett mites, carmine spider mites)	1B	**Malathion 5** (malathion)	1.0-2.5 pt	10 pints	1	12	8F can be used in greenhouse.
	1B	**Malathion 8 F**	1.5 pt				
	3A	***Danitol 2.4 EC** (fenpropathrin)	7-10.67 fl oz	Do not exceed 42.67 fl. oz. total application /A per season.	3	24	
	3A	***Hero** (bifenthrin & zeta-cypermethrin)	4.0-10.3 oz	Do not apply more than 43.26 fl. oz./A per season.	1	12	Do not make more than 4 applications per season. Do not make applications less than 10 days apart.
	3A	***Karate with Zeon** (lambdacyhalothrin)	0.96-1.92 fl. oz.	Do not apply more than 23.04 fl. oz. /A per season.	5	24	
	3A	**Pyganic Crop Protection EC 5.0 II** (pyrethrins)	4.5-18.0 fl oz	11.25 pints.	0	12	Pyrethrins degrade rapidly in sunlight. Thorough coverage is important. OMRI-listed. Do not apply more than 10 times per season.
	3A	***Brigade 2EC** (bifenthrin)	2.1-5.2 fl oz	Make no more than 4 applications per season.	1	12	Do not make applications less than 10 days apart.
	3A	***Proaxis Insecticide** (gamma-cyhalothrin)	1.92-3.84 fl oz	Do not apply more than 2.88 pints per acre per season.	5	24	
	3A & 6	***Gladiator** (avermectin B1 & zeta-cypermethrin)	10-19 fl. oz.	Do not apply more than 57 fl. oz./A per 12 month cropping year.	7	12	
	6	***Agri-Mek SC** (abamectin)	1.75-3.5 fl oz	Do not apply more than 10.25 fl. oz./A in a growing season.	7	12	Do not make more than 2 sequential applications of Agri-Mek SC or any other foliar applied abamectin-containing product in a growing season.
	6	***Agri-Mek 0.15 EC**	8.0-16.0 fl. oz	Do not apply more than 48 fl oz per acre per season.	7	12	Do not make more than 2 sequential applications per season.
	20B	**Kanemite 15 SC** (acequinocyl)	31 fl oz	Do not apply more than 62 fl. oz/A per season.	1	12	Do not use less than 100 gal per acre. Make no more than 2 applications at least 21 days apart.
	21A	**Portal** (fenpyroximate)	2.0 pt	Do not apply more than 4.0 pints/A per crop cycle.	1	12	Do not make more than two applications per growing season. Allow 14 days between applications.
	23	**Movento** (spirotetramat)	4.0-5.0 fl oz	Maximum of 10 fl oz/acre per season.	1	24	

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Insect	MOA Code[1]	Trade name (Active Ingredient) *Restricted	Rate (Product/acre)	Rate per Season	Days to Harvest	REI (hours)	Remarks
	23	**Oberon 2SC** (spiromesifen)	7.0-8.5 fl oz	Maximum amount per crop: 25.5 fl oz/A.	1	12	No more than 3 applications.
	-	**Acramite-50WS** (bifenazate)	0.75-1.0 lb	One application allowed per season.	3	12	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.
	-	**Aza-Direct** (azadirachtin)	1-2 pts, up to 3.5 pts, if needed		0	4	Antifeedant, repellant, insect growth regulator. OMRI-listed.
	-	**Grandevo** (*Chromobacterium subtsugae*)	1.0-3.0 lb		0	4	Thorough coverage is necessary for effective control.
	-	**M-Pede 49% EC** (Soap, insecticidal)	1-2% V/V		0	12	OMRI-listed
	-	**MET52 EC** (*Metarhizium anisopliae* strain F52)	**drench:** 40-80 fl. oz.; **foliar:** 0.5 pint - 2qt		0	0	
	-	**PFR-97** (*Isaria fumosorosea* Apopka strain 97)	1.0-2.0 lbs		0	4	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.
	-	**SuffOil-X** (unsulfonated residue of petroleum oil)	1-2 gallons per 100 gallons of water.			4	OMRI listed.
	-	**Sulfur** (many brands)				24	May burn fruit and foliage when temperature is high. Do not apply within 2 weeks of an oil spray or EC formulation.
	-	**Ultra Fine Oil, Saf-T-Side, others**	1.0-2.0 gal/100 gal		0	4	Do not exceed four applications per season.
	-	**JMS Stylet-Oil** (oil, insecticidal)	3.0-6.0 qt/100 gal water				
Mole crickets	1B	***Diazinon AG500; *50 W** (diazinon)	**AG500:** 1-4 qt **50W:** 2-8 lb	Do not make more than one soil applicationper year regrardless of target pest.	preplant	48	Incorporate into soil - see label.
Plant bugs + tarnished plant bugs	1A	**Sevin 80S; XLR; 4F** (carbaryl)	**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.	3	12	Do not apply more than seven times.
	3A	***Brigade 2EC** (bifenthrin)	2.1-5.2 fl oz	Make no more than 4 applications per season.	1	12	Do not make applications less than 10 days apart.
	3A	***Mustang** (zeta-cypermethrin)	2.4-4.3 oz	Do not apply more than 25.8 fl. oz./A per season.	1	12	Do not make applications less than 7 days apart.
	3A	**Pyganic Crop Protection EC 5.0 II** (pyrethrins)	4.5-18.0 fl oz	11.25 pints.	0	12	Pyrethrins degrade rapidly in sunlight. Thorough coverage is important. OMRI-listed. Do not apply more than 10 times per season.
	3A	***Proaxis Insecticide** (gamma-cyhalothrin)	1.92-3.84 fl oz	Do not apply more than 2.88 pints per acre per season.	5	24	
	3A	***Warrior II** (lambda-cyhalothrin)	0.96-1.92 fl oz	Do not apply more than 23.04 fl. oz/A per season.	5	24	
	3A & 4A	***Endigo ZC** (lambda-cyhalothrin & thiamethoxam)	4.0-4.5 fl oz	Do not exceed a total of 19.0 fl oz per acre per season.	5	24	See label for limits on each active ingredient.
	4A	**Belay 50 WDG** (clothianidin)	**foliar:** 1.6-2.1 oz	Do not apply more than 6.4 oz per acre per season.	7	12	Do not use an adjuvant. Toxic to bees. Do not release irrigation water from the treated area.
	4A	**Belay 50 WDG** (clothianidin)	**soil:** 4.8-6.4 oz	Do not apply more than 6.4 oz per acre per season.	Apply at planting	12	See label for application instructions. Do not release irrigation water from the treated area.
	4C	**Closer SC** (sulfoxaflor)	2.75-4.5 fl oz	Do not apply more than 17 fl oz per acre per year.	1	12	DO NOT APPLY THIS PRODUCT UNTIL AFTER PETAL FALL.
	15	**Rimon 0.83EC** (novaluron)	9.0-12.0 fl oz	Do not apply more than 36 fl oz per acre per season.	1	12	Minimum of 7 days between applications.
	29	**Beleaf 50 SG** (flonicamid)	2.0-2.8 oz	Do not apply more than 8.4 oz per acre per season.	0	12	Begin applications before pests reach damaging levels. Do not apply more than 2 applications per season. Allow a minimum of 7 days between applications.
	--	**M-Pede 49% EC** Soap, insecticidal)	1-2% V/V		0	12	OMRI-listed

INSECTICIDES LABELED FOR MANAGEMENT OF ARTHROPOD PESTS ON TOMATO. (continued)

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Insect	MOA Code[1]	Trade name (Active Ingredient) *Restricted	Rate (Product/acre)	Rate per Season	Days to Harvest	REI (hours)	Remarks
Planthoppers	16	**Courier 40SC** (buprofezin)	9.0-13.6 fl oz	Do not apply more than 27.2 fl. oz./A per crop cycle.	1	12	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.
Psyllids	4D	**Sivanto Prime** (flupyradifurone)	7.0-14.0 fl. oz.	Do not apply more than 28.0 fl. oz./A per year.	1	4	Minimum interval between applications: 7 days.
	23	**Movento** (spirotetramat)	4.0-5.0 fl oz	Maximum of 10 fl oz/acre per season.	1	24	
	-	**Neemix 4.5** (azadirachtin)	4.0-16.0 fl oz		0	12	IGR, feeding repellent. OMRI-listed.
Soil insects (including centipedes, crickets, earwigs, millipedes, sow bugs, springtails)	1A	**10% Sevin Granules** (carbaryl)	20 lb		3	12	Maximum of 4 applications, not more often than once every 7 days.
Stinkbugs (including brown stink bug and green stink bug)	1A	**Sevin 80S; XLR; 4F** (carbaryl)	**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.	3	12	Do not apply more than seven times.
	3A	***Baythroid XL** (beta-cyfluthrin)	1.6-2.8 fl oz	Do not apply more than 16.8 fl oz per acre per season.	0	12	
	3A	***Brigade 2EC** (bifenthrin)	2.1-5.2 fl oz	Make no more than 4 applications per season.	1	12	Do not make applications less than 10 days apart.
	3A	***Danitol 2.4 EC** (fenpropathrin)	7-10.67 fl oz	Do not exceed 42.67 fl. oz. total application /A per season.	3	24	
	3A	***Hero** (bifenthrin & zeta-cypermethrin)	4.0-10.3 oz	Do not apply more than 43.26 fl. oz./A per season.	1	12	Do not make more than 4 applications per season. Do not make applications less than 10 days apart.
	3A	**Karate with Zeon*** (lambdacyhalothrin)	0.96-1.92 fl. oz.	Do not apply more than 23.04 fl. oz. /A per season.	5	24	
	3A	***Mustang** (zeta-cypermethrin)	2.4-4.3 oz	Do not apply more than 25.8 fl. oz./A per season.	1	12	Not recommended for vegetable leafminer in Florida. Do not make applications less than 7 days apart.
	3A	***Proaxis Insecticide** (gamma-cyhalothrin)	1.92-3.84 fl oz	Do not apply more than 2.88 pints per acre per season.	5	24	
	3A	***Warrior II** (lambda-cyhalothrin)	0.96-1.92 fl oz	Do not apply more than 23.04 fl. oz/A per season.	5	24	
	3A & 4A	***Leverage** 360 (beta-cyfluthrin & imidacloprid)	3.8-4.1		0	12	
	3A & 6	***Gladiator** (avermectin B1 & zeta-cypermethrin)	10-19 fl. oz.	Do not apply more than 57 fl. oz./A per 12 month cropping year.	7	12	
	3A & 28	***Voliam Xpress** (lambda-cyhalothrin & chlorantraniliprole)	5.0-9.0 fl oz	Do not apply more than 31.0 fl oz /A per season.	5	24	
	3A & 4A	***Endigo ZC** (lambda-cyhalothrin & thiamethoxam)	4.0-4.5 fl oz	Do not exceed a total of 19.0 fl oz per acre per season.	5	24	See label for limits on each active ingredient.
	4A	**Actara** (thiamethoxam)	2.0-5.5 oz	Do not exceed a total of 11.0 oz/Acre per acre per growing season.	0	12	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. Minimum interval between applications is 5 days.
	4A	**Belay 50 WDG** (clothianidin)	1.6-2.1 oz (foliar application)	Do not apply more than 6.4 oz per acre per season.	7	12	Do not use an adjuvant. Toxic to bees. Do not release irrigation water from the treated area.
	4A	**Scorpion** (dinotefuran)	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.	1	12	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.
	4A & 28	**Voliam Flexi** (thiamethoxam & chlorantraniliprole)	4.0-7.0 oz	Do not exceed 14 oz/A per season.	1	12	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.

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Insect	MOA Code[1]	Trade name (Active Ingredient) *Restricted	Rate (Product/acre)	Rate per Season	Days to Harvest	REI (hours)	Remarks
	15	**Rimon 0.83EC** (novaluron)	9.0-12.0 fl oz	Do not apply more than 36 fl oz per acre per season.	1	12	Minimum of 7 days between applications.
	-	**Aza-Direct** (azadirachtin)	1-2 pts, up to 3.5 pts, if needed		0	4	Antifeedant, repellant, insect growth regulator. OMRI-listed.
Thrips: check label for species controlled (includes melon thrip, western flower thrips, Florida flower thrips, eastern flower thrips, foliar feeding thrips, chilli thrips)	1A	**Sevin 80S; XLR; 4F** (carbaryl)	**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.	3	12	Do not apply more than seven times.
	3A	***Baythroid XL** beta-cyfluthrin)	1.6-2.8 fl oz	Do not apply more than 16.8 fl oz per acre per season.	0	12	
	3A	***Brigade 2EC** (bifenthrin)	2.1-5.2 fl oz	Make no more than 4 applications per season.	1	12	Do not make applications less than 10 days apart.
	3A	***Hero** (bifenthrin & zeta-cypermethrin)	4.0-10.3 oz	Do not apply more than 43.26 fl. oz./A per season.	1	12	Do not make more than 4 applications per season. Do not make applications less than 10 days apart.
	3A	**Karate with Zeon*** (lambdacyhalothrin)	0.96-1.92 fl. oz.	Do not apply more than 23.04 fl. oz. /A per season.	5	24	
	3A	***Mustang** (zeta-cypermethrin)	2.4-4.3 oz	Do not apply more than 25.8 fl. oz./A per season.	1	12	Not recommended for vegetable leafminer in Florida. Do not make applications less than 7 days apart.
	3A	***Proaxis Insecticide** (gamma-cyhalothrin)	1.92-3.84 fl oz	Do not apply more than 2.88 pints per acre per season.	5	24	
	3A	***Warrior II** (lambda-cyhalothrin)	0.96-1.92 fl oz	Do not apply more than 23.04 fl. oz/A per season.	5	24	
	3A	**Pyganic Crop Protection EC 5.0 II** (pyrethrins)	4.5-18.0 fl oz	11.25 pints.	0	12	Pyrethrins degrade rapidly in sunlight. Thorough coverage is important. OMRI-listed. Do not apply more than 10 times per season.
	3A & 4A	***Leverage** 360 (beta-cyfluthrin & imidacloprid)	3.8-4.1		0	12	
	3A & 6	***Gladiator** (avermectin B1 & zeta-cypermethrin)	10-19 fl. oz.	Do not apply more than 57 fl. oz./A per 12 month cropping year.	7	12	
	3A & 28	***Voliam Xpress** (lambda-cyhalothrin & chlorantraniliprole)	5.0-9.0 fl oz	Do not apply more than 31.0 fl oz /A per season.	5	24	
	4A	**Admire Pro** (imidacloprid)	7-10.5 fl oz	Maximum allowed on tomato is 10.5 fl. oz/A.	21	12	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.
	4A	**Assail 70WP** (acetamiprid)	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.	7	12	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.
	4A	**Platinum** (thiamethoxam)	5-11 fl oz	Do not exceed a total of 11 fl. oz. Platinum/A per growing season.	30	12	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
	4A	**Platinum 75 SG** (thiamethoxam)	1.66-3.67 oz	Do not exceed a total of 3.67 Platinum 75 SG/A per growing season.			
	4A	**Scorpion** (dinotefuran)	**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.	1	12	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.
	4A	**Venom 20 SG** (dinotefuran)	**foliar:**0.44-0.895 lb	Do not apply more than 1.34 lb./A per season.	1	12	Use only one application method (soil or foliar). Limited to three applications per season. Toxic to honeybees.
	4A	**Venom 20 SG** (dinotefuran)	**soil:** 1.13-1.34 lb	Do not apply more than 2.68 lb/A per season.	21	12	Use only one application method (soil or foliar). Must have supplemental label for rates over 6.0 oz/acre.

INSECTICIDES LABELED FOR MANAGEMENT OF ARTHROPOD PESTS ON TOMATO. (continued)

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Insect	MOA Code[1]	Trade name (Active Ingredient) *Restricted	Rate (Product/acre)	Rate per Season	Days to Harvest	REI (hours)	Remarks
	4A & 28	**Durivo** (thiamethoxam & chlorantraniliprole)	10-13 fl oz	Do not exceed a total of 13.0 fl. oz./A per growing season.	30	12	Several methods of soil application – see label.
	5	**Entrust** (spinosad)	0.5-2.5 oz	Do not apply more than 9 oz per acre per crop.	1	4	OMRI-listed2. For thrips, rotate to other class of effective insecticide after 2 applications of a Group 5 insecticide for at least 2 applications.
	5	**Radiant SC** (spinetoram)	5-10 fl oz.	Do not apply more than 34 fl. oz./A per calendar year.	1	4	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.
	6	***Agri-Mek SC** (abamectin)	1.75-3.5 fl oz	Do not apply more than 10.25 fl. oz./A in a growing season.	7	12	Do not make more than 2 sequential applications of Agri-Mek SC or any other foliar applied abamectin-containing product in a growing season.
	6	***Agri-Mek 0.15 EC** (abamectin)	8.0-16.0 fl. oz	Do not apply more than 48 fl oz per acre per season.	7	12	Do not make more than 2 sequential applications per season.
	15	**Rimon 0.83EC** (novaluron)	9.0-12.0 fl oz	Do not apply more than 36 fl oz per acre per season.	1	12	Minimum of 7 days between applications.
	23	**Movento** (spirotetramat)	4.0-5.0 fl oz	Maximum of 10 fl oz/acre per season.	1	24	
	28	**Exirel** (cyantraniliprole)	7-20.5 fl. oz.	Do not apply a total of more than 0.4 lb ai/A per crop.	1	12	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 treatments is 5 days.
	28	**Verimark** (cyantraniliprole)	5-13.5 fl. oz.	Do not apply more than 0.4 lb ai/A per crop.	1	4	
	29	**Beleaf 50 SG** (flonicamid)	4.2 oz.	Do not apply more than 8.4 oz per acre per season.	0		Begin applications before pests reach damaging levels. Do not apply more than 2 applications per season. Allow a minimum of 7 days between applications.
	-	**Aza-Direct** (azadirachtin)	1-2 pts, up to 3.5 pts, if needed		0	4	Antifeedant, repellant, insect growth regulator. OMRI-listed.
	-	**Azatin XL** (azadirachtin)	5-21 fl oz		0	4	Antifeedant, repellant, insect growth regulator.
	-	**Botanigard ES** (*Beauvaria bassiana* strain GHA)	0.25 - 1 quart per acre. Apply in sufficient water to cover foliage, typically 5 - 100 gallons per acre.		0	4	Thorough coverage is necessary for effective control.
	-	**Grandevo** (*Chromobacterium subtsugae*)	1.0-3.0 lb		0	4	
	-	**MET52 EC** (*Metarhizium anisopliae* strain F52)	drench: 40-80 fl. oz.; foliar: 0.5 pint - 2qt		0	0	OMRI Listed
	-	**Mycotrol ESO** (*Beauvaria bassiana* strain GHA)	0.25 quart -1 quart/100 gallons		0	4	Repeat applications at 3-10 days asneeded to maintain control. Can be used in greenhouse for food crop transplants raised to be planted into the field. OMRI listed.
	-	**PFR-97** (*Isaria fumosorosea* Apopka strain 97)	1.0-2.0 lbs		0	4	Begin applications before pests reach damaging levels.
	-	**Requiem 25EC** (extract of Chenopodium ambrosioides)	2-4 qt	Limited to 10 applications per crop cycle.	0	4	OMRI listed.
	-	**Surround WP** (kaolin)	12.5-50 lbs		0	4	OMRI-listed
	--	**M-Pede 49% EC** (Soap, insecticidal)	1-2% V/V		0	12	Do not exceed four applications per season.
	--	**Ultra Fine Oil, Saf-T-Side, others**	1.0-2.0 gal/100 gal		0	4	
		JMS Stylet-Oil (oil, insecticidal)	3.0-6.0 qt/100 gal water				

INSECTICIDES LABELED FOR MANAGEMENT OF ARTHROPOD PESTS ON TOMATO. (continued)

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Insect	MOA Code[1]	Trade name (Active Ingredient) *Restricted	Rate (Product/acre)	Rate per Season	Days to Harvest	REI (hours)	Remarks
Weevils (vegetable weevil)	3A	***Proaxis Insecticide** (gamma-cyhalothrin)	1.92-3.84 fl oz	Do not apply more than 2.88 pints per acre per season.	5	24	
	3A	***Warrior II** (lambda-cyhalothrin)	0.96-1.92 fl oz	Do not apply more than 23.04 fl. oz/A per season.	5	24	See label for limits on each active ingredient.
	3A, 4A	***Endigo ZC** lambda-cyhalothrin & thiamethoxam)	4.0-4.5 fl oz	Do not exceed a total of 19.0 fl oz per acre per season.	5	24	Antifeedant, repellant, insect growth regulator. OMRI-listed.
	-	**Aza-Direct** (azadirachtin)	1-2 pts, up to 3.5 pts, if needed		0	4	Antifeedant, repellant, insect growth regulator.
	-	**Azatin XL** (azadirachtin)	5-21 fl oz		0	4	
Whiteflies	1A	***Vydate L** oxamyl)	**foliar:** 2.0-4.0 pt	Do not apply more than 32 pts/A per season.	3	48	Not recommended for control of vegetable leafminer in Florida.
	3A	***Asana XL (0.66EC)** (esfenvalerate)	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.	1	12	
	3A	***Baythroid XL** (beta-cyfluthrin)	1.6-2.8 fl oz	Do not apply more than 16.8 fl oz per acre per season.	0	12	
	3A	***Danitol 2.4 EC** (fenpropathrin)	7-10.67 fl oz	Do not exceed 42.67 fl. oz. total application /A per season.	3	24	Do not make more than 4 applications per season. Do not make applications less than 10 days apart.
	3A	***Hero** (bifenthrin & zeta-cypermethrin)	4.0-10.3 oz	Do not apply more than 43.26 fl. oz./A per season.	1	12	
	3A	**Karate with Zeon*** (lambdacyhalothrin)	0.96-1.92 fl. oz.	Do not apply more than 23.04 fl. oz. /A per season.	5	24	Not recommended for vegetable leafminer in Florida. Do not make applications less than 7 days apart.
	3A	***Mustang** (zeta-cypermethrin)	2.4-4.3 oz	Do not apply more than 25.8 fl. oz./A per season.	1	12	Pyrethrins degrade rapidly in sunlight. Thorough coverage is important. OMRI-listed. Do not apply more than 10 times per season.
	3A	**Pyganic Crop Protection EC 5.0 II** (pyrethrins)	4.5-18.0 fl oz	11.25 pints.	0	12	
	3A & 28	***Voliam Xpress** (lambda-cyhalothrin & chlorantraniliprole)	5.0-9.0 fl oz	Do not apply more than 31.0 fl oz /A per season.	5	24	Do not make applications less than 10 days apart.
	3A	***Brigade 2EC** (bifenthrin)	2.1-5.2 fl oz	Make no more than 4 applications per season.	1	12	
	3A	***Proaxis Insecticide** (gamma-cyhalothrin)	1.92-3.84 fl oz	Do not apply more than 2.88 pints per acre per season.	5	24	
	3A	***Warrior II** (lambda-cyhalothrin)	0.96-1.92 fl oz	Do not apply more than 23.04 fl. oz/A per season.	5	24	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. Minimum interval between applications is 5 days.
	4A	**Actara** (thiamethoxam)	2.0-5.5 oz	Do not exceed a total of 11.0 oz/Acre per acre per growing season.	0	12	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.
	4A	**Admire Pro** (imidacloprid)	7-10.5 fl oz	Maximum allowed on tomato is 10.5 fl. oz/A.	21	12	Greenhouse use: 1 application to mature plants, see label for cautions.
	4A	**Admire Pro** (imidacloprid)	0.6 fl oz per 1000 plants		0 (soil)	12	Planthouse: 1 application. See label.
	4A	**Admire Pro** (imidacloprid)	0.44 fl oz per 10,000 plants		21	12	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.
	4A	**Assail 70WP** (acetamiprid)	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.	7	12	Do not use an adjuvant. Toxic to bees. Do not release irrigation water from the treated area.

INSECTICIDES LABELED FOR MANAGEMENT OF ARTHROPOD PESTS ON TOMATO. (continued)

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

Insect	MOA Code[1]	Trade name (Active Ingredient) *Restricted	Rate (Product/acre)	Rate per Season	Days to Harvest	REI (hours)	Remarks
	4A	**Belay 50 WDG** (clothianidin)	1.6-2.1 oz (foliar application)	Do not apply more than 6.4 oz per acre per season.	7	12	See label for application instructions. Do not release irrigation water from the treated area.
	4A	**Belay 50 WDG** (clothianidin)	4.8-6.4 oz (soil application)	Do not apply more than 6.4 oz per acre per season.	Apply at planting	12	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.
	4A	**Platinum** (thiamethoxam)	5-11 fl oz	Do not exceed a total of 11 fl. oz. Platinum/A per growing season.	30	12	
	4A	**Platinum 75 SG** (thiamethoxam)	1.66-3.67 oz	Do not exceed a total of 3.67 Platinum 75 SG/A per growing season.	30	12	Do not apply to crop that has been already treated with imidacloprid or thiamethoxam at planting.
	4A	**Provado 1.6F** (imidacloprid)	3.8-6.2 fl oz	Maximum per crop per season 19.2 fl oz/A.	0	12	For transplant production only. Can be applied as foliar spray or soil drench.
	4A	**Safari 20 SG** (dinotefuran)	7.0-14.0 oz		1	12	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.
	4A	**Scorpion** (dinotefuran)	**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.	1	12	Use only one application method (soil or foliar). Limited to three applications per season. Toxic to honeybees.
	4A	**Venom 20 SG** (dinotefuran)	**foliar:**0.44-0.895 lb	Do not apply more than 1.34 lb./A per season.	1	12	Use only one application method (soil or foliar). Must have supplemental label for rates over 6.0 oz/acre.
	4A	**Venom 20 SG** (dinotefuran)	**soil:** 1.13-1.34 lb	Do not apply more than 2.68 lb/A per season.	21	12	Several methods of soil application – see label.
	4A & 28	**Durivo** (thiamethoxam & chlorantraniliprole)	10-13 fl oz	Do not exceed a total of 13.0 fl. oz./A per growing season.	30	12	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.
	4C	**Closer SC** (sulfoxaflor)	4.25 - 4.5 fl oz	Do not apply more than 17 fl oz per acre per year.	1	12	DO NOT APPLY THIS PRODUCT UNTIL AFTER PETAL FALL.
	4D	**Sivanto Prime** (flupyradifurone)	**soil:** 21.0 - 28.0; **foliar:** 10.5 - 14.0	Do not apply more 28.0 fl oz per acre per year.	soil application: 45 days; foliar: 1 day		
	4A & 28	**Voliam Flexi** (thiamethoxam & chlorantraniliprole)	4.0-7.0 oz	Do not exceed 14 oz/A per season.	1	12	Immatures only. Apply when nymphs first appear. 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.
	7C	**Knack IGR** (pyriproxyfen)	8-10 fl oz	Do not exceed 20 fl. oz./A per season.	14	12	(FL-040006) 24(c) label for growing transplants also (FL-03004).
	9B	**Fulfill** (pymetrozine)	2.75 oz	Do not apply more than 5.5 oz/acre per crop.	0	12	
	15	**Rimon 0.83EC** (novaluron)	9.0-12.0 fl oz	Do not apply more than 36 fl oz per acre per season.	1	12	Immatures only. 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.
	16	**Courier 40SC** (buprofezin)	9.0-13.6 fl oz	Do not apply more than 27.2 fl. oz./A per crop cycle.	1	12	Do not make more than two applications per growing season. Allow 14 days between applications.
	21A	**Portal** fenpyroximate)	2.0 pt	Do not apply more than 4.0 pints/A per crop cycle.	1	12	
	23	**Movento** (spirotetramat)	4.0-5.0 fl oz	Maximum of 10 fl oz/acre per season.	1	24	No more than 3 applications.

INSECTICIDES LABELED FOR MANAGEMENT OF ARTHROPOD PESTS ON TOMATO. (continued)							
Labels change frequently. Be sure to read a current product label before applying any chemical.							
Insect	**MOA Code[1]**	**Trade name (Active Ingredient) *Restricted**	**Rate (Product/acre)**	**Rate per Season**	**Days to Harvest**	**REI (hours)**	**Remarks**
	23	**Oberon 2SC** (spiromesifen)	7.0-8.5 fl oz	Maximum amount per crop: 25.5 fl oz/A.	1	12	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 treatments is 5 days.
	28	**Exirel** (cyantraniliprole)	7-20.5 fl. oz.	Do not apply a total of more than 0.4 lb ai/A per crop.	1	12	
	28	**Verimark** (cyantraniliprole)	5-13.5 fl. oz.	Do not apply more than 0.4 lb ai/A per crop.	1	4	Begin applications before pests reach damaging levels. Do not apply more than 2 applications per season. Allow a minimum of 7 days between applications.
	29	**Beleaf 50 SG** (flonicamid)	4.2 oz.	Do not apply more than 8.4 oz per acre per season.	0		Antifeedant, repellant, insect growth regulator. OMRI-listed.
	-	**Aza-Direct** (azadirachtin)	1-2 pts, up to 3.5 pts, if needed		0	4	Antifeedant, repellant, insect growth regulator.
	-	**Azatin XL** (azadirachtin)	5-21 fl oz		0	4	Thorough coverage is necessary for effective control.
	-	**Botanigard ES** (*Beauvaria bassiana* strain GHA)	0.25 - 1.0 quart per acre. Apply in sufficient water to cover foliage, typically 5 - 100 gallons per acre.		0	4	
	-	**Grandevo** (*Chromobacterium subtsugae*)	1.0-3.0 lb		0	4	
	-	**MET52 EC** (*Metarhizium anisopliae* strain F52)	**drench:** 40-80 fl. oz.; **foliar:** 0.5 pint - 2qt		0	0	OMRI Listed
	-	**Mycotrol ESO** (*Beauvaria bassiana* strain GHA)	0.25 - 1 quart per acre. Apply in sufficient water to cover foliage, typically 5 - 100 gallons per acre.		0	4	OMRI Listed
	-	**Neemix 4.5** (azadirachtin)	4.0-16.0 fl oz		0	12	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.
	-	**PFR-97** (*Isaria fumosorosea* Apopka strain 97)	1.0-2.0 lbs		0	4	Begin applications before pests reach damaging levels.
	-	**Requiem 25EC** (extract of Chenopodium ambrosioides)	2-4 qt	Limited to 10 applications per crop cycle.	0	4	OMRI listed.
	-	**SuffOil-X** (unsulfonated residue of petroleum oil)	1-2 gallons per 100 gallons of water.			4	OMRI-listed
	-	**M-Pede 49% EC** (Soap, insecticidal)	1-2% V/V		0	12	Do not exceed four applications per season.
	-	**Ultra Fine Oil, Saf-T-Side, others**	1.0-2.0 gal/ 100 gal		0	4	Organic Stylet-Oil and Saf-T-Side are OMRI-listed.
	-	**JMS Stylet-Oil** (oil, insecticidal)	3.0-6.0 qt/ 100 gal water				Incorporate into soil - see label.
Wireworms	1B	***Diazinon AG500; *50 W** (diazinon)	**AG500:** 1-4 qt **50W:** 2-8 lb	Do not make more than one soil application per year regrardless of target pest.	preplant	48	

[1] Mode of Action (MOA) codes for plant pest insecticides from the Insecticide Resistance Action Committee (IRAC) Mode of Action Classification v. 8.2 March 2017. Number codes (1 through 29) 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. - = 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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Product	Broadcast (Rate)	Row Application (6' row spacing - 36" bed)[4] 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 guideline 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.

Nimitz - All applications to tomato must be incorporated either physically or via drip or overhead irrigation. Make preplant applications at a rate of 3.5 to 5 pints, (56.0 to 80.0 fl. oz.) per acre, a minimum of seven days before planting. Do not plant any unlisted crops into treated land for 365 days after application of the product. Do not apply more than one application per crop, and no more than 112 fl. oz. of product per acre, per year (365 days). Provides control only for nematodes and does not provide residual control. Product is commercially available but is still actively under assessment in field trial evaluations.These products are not as consistently effective against root-knot nematodes as the fumigants, but is registered as indicated.

1. If treated area is tarped with impermeable film, dosage may be reduced by 30-40%. 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 FloridaL. 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 May 30, 2017 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.