VANCE

The Florida TOMATO PROCEEDINGS

UNIVERSITY OF FLORIDA IFAS EXTENSION

VANCE INNOVATIVE SOLUTIONS THAT GROW BUSINESSES

CITRUS+ VEGETABLE

EDITORS | **Monica Ozores-Hampton** | UF/IFAS, Southwest Florida Research and Education Center, Immokale
Crystal Snodgrass | UF/IFAS, Manatee County Extension Service, Palmetto

2013 FLORIDA TOMATO INSTITUTE PROGRAM

The Ritz-Carlton Golf Resort, Naples, Florida | Sept. 4, 2013

Moderator: Crystal Snodgrass, Manatee County Extension Service, Palmetto

Moderator: Camille Esmel McAvoy, Sumter County Extension Service, Bushnell

PRODUCTION GUIDES

Developing Machine Harvestable Tomatoes; and other Highlights from the UF Breeding Program

S.F. Hutton, J.W. Scott and B.M. Santos
Gulf Coast Research and Education Center
University of Florida, Wimauma, FL. sfhutton@ufl.edu

In times past, the vast majority of tomato variety development and germplasm improvement efforts were carried out by public breeding programs. In those days, all tomato varieties were sold as OP's (open pollinated). Around the early-1980's, OP varieties were phased out, and hybrid cultivars took over. With this transition came the private seed companies, the main goal of each being the development of finished cultivars. The majority of private breeding programs focus most of their efforts on the development and testing of inbreds and hybrids, with very little resources spent on projects that cannot be completed quickly and with a high probability of success. In contrast, the University of Florida (UF) tomato breeding program has the opportunity to focus efforts on variety development as well as on long-term and/or high-risk projects. Examples of the latter include breeding for jointless-pedicel, compact growth habit tomatoes; breeding for bacterial leaf spot resistance; and advancing TYLCV (tomato yellow leaf curl virus) resistance.

COMPACT GROWTH HABIT, JOINTLESS PEDICEL

The concept of a machine-harvestable, fresh market tomato is not new. 'Florida MH-1,' which was released in 1971, combined a high level of fruit firmness with jointless pedicels, making it amenable to machine harvest (Crill, 1971). The variety was never a huge success, but the concept wasn't entirely abandoned. The UF breeding program currently has a strong emphasis on developing compact growth habit (CGH) tomatoes, with the hopes that such a variety would lead to stake-less culture and a once-over machine harvest.

Table 1. Once-over harvest yield of compact growth habit (CGH) tomato inbreds at University of Florida, Gulf Coast Research and Education Center, Wimauma, FL spring 2012[z].

	Yield (boxes/acre)	
Genotype	Extra-large	Total marketable
Fla. 8916	1,076 a	2,514 a
Fla. 8607	750 b	2,296 ab
Fla. 8834	274 c	2,139 bc
Fla. 8107	658 b	2,008 bc
Fla. 8914	362 c	1,965 c

[z]Split-plot design with varying nitrogen rates as the main plot; 10 plants per plot at 1-ft. spacing; mean separation by LSD.

Plant architecture plays an important role in the development of tomatoes for mechanical harvest. Among a number of genes that affect growth habit in tomato, Dr. Edward (Ed) Tigchelaar, former tomato breeder at Purdue University, was among the first to describe and begin using the brachytic gene (*br*) for development of CGH tomatoes (Tigchelaar, 1986). This gene essentially removes the apical dominance of a plant, resulting in vines that have a 50-60% reduction in internode length and more branching than normal growth habit cultivars (Kemble, 1993). Dr. Tigchelaar supplied some of his material to Dr. Randolf (Randy) Gardner in the 1980's, who sought to combine *br* with prostrate growth habit tomatoes. In the late 1990's, Dr. Gardner supplied some of his br material to Dr. Jay Scott at the University of Florida. The program here has since sought to combine *br* with jointless pedicels in both upright and prostrate types.

Our CGH breeding project has a strong emphasis on developing materials with concentrated fruit set, good firmness and larger fruit. Graywall resistance is also being actively selected for, as much of the earlier materials were sensitive to this disorder. In contrast to breeding jointless-pedicel plum tomatoes for the processing industry, breeding for jointless pedicels in large-fruited fresh market tomatoes is inherently difficult; common characteristics associated with jointlessness include small fruit, rough blossom scars and asymmetrical fruit shapes. Additionally, there is great difficulty in combining heat-tolerant fruit setting ability in jointless backgrounds (Scott, 2001).

Despite these difficulties, considerable progress has been made in this area. The first line that showed some promise was Fla. 8834 in 2010. This line proved inconsistent for yield and fruit size with further testing, but in 2012 more promising lines emerged, including Fla. 8916 and sister lines 8916a and b. In an once-over harvest of a trial in spring 2012, Fla. 8916 yielded best among five CGH lines tested, with over 2,500 boxes/acre marketable yield—more than 1,000 of which were extra-large (**Table 1**). Again in a grower trial last winter, Fla. 8916 and its sister lines each yielded more than 1,300 boxes/acre marketable yield in an once-over harvest (**Table 2**). It is to be noted in the latter trial that the lower yields of 'Florida 47' do not reflect its true potential, but rather illustrate the importance of having concentrated fruit set for a once-over harvest.

Work is continuing in this area, and future breeding goals include selection for consistent marketable yields, even under adverse conditions; continued monitoring of fruit firmness; and incorporation of TYLCV and fusarium crown rot (FCR) resistances. Other goals include experiments to better understand the impact of different cultural practices to this type of tomato.

BACTERIAL LEAF SPOT RESISTANCE

Bacterial leaf spot resistance has long been a goal of the UF tomato breeding program. In the 1980's, breeding efforts focused on resistance derived from H7998 to *Xanthomonas euvesicatoria* race T1. Upon the emergence of X. *perforans* race T3 in 1991 (Jones et al., 1995) and its subsequent displacement of race T1 (Jones et al., 1998b), breeding efforts shifted to H7981-based resistance to race T3 because race T1-based resistance was not effective against the new pathogen. In 1998, X. perforans race T4 emerged (Minsavage et al. 2003) and overcame the race T3-based resistance in the program. Since then, breeding efforts have shifted to identification and utilization of QTL (genes) that confer partial resistance across bacterial leaf spot races. We have identified several QTL (Hutton et al., 2010)

Table 2. Once-over harvest yield of compact growth habit (CGH) tomato inbreds compared to 'Florida 47' on a grower farm, winter 2013[z].

Genotype	25 lb box/acre	25 lb box/bin
Florida 47	490	33.26
Fla. 8916	1,359	32.36
Fla. 8916a	1,476	30.76
Fla. 8916b	1,482	31.87
Fla. 8915	900	25.72
Fla. 8914	490	24.50
Fla. 8834	660	33.00

[z] 8916, 8916a, 8916b grown on 0.31 A, other CGH lines grown on 0.1 A, 'Florida 47' grown on 11.25 A.

already in our breeding materials, and current research aims to identify novel QTL from the resistant accession, PI 114490. Additional breeding efforts aim in incorporate a "non-blighting" resistance into advanced materials, which contributes to the ability of plants to maintain healthy foliage even under moderate infection by bacterial leaf spot and some other foliar pathogens.

TYLCV RESISTANCE

Breeding for resistance to TYLCV and other begomoviruses has been a major goal of the program since 1990. The majority of our breeding efforts have focused on resistance derived from several *Solanum chilense* accessions. Two genes, *Ty3* and *Ty-4*, were previously identified from these accessions by our program (Ji et al., 2007; Ji et al., 2009), and a third, "*Ty-6*," was discovered last year. We recently fine-mapped and cloned *Ty-1* and *Ty-3*, and demonstrated that they are in fact the same gene (Verlaan et al., 2013).

Resistance in commercial varieties is mainly based on either *Ty-1* or *Ty-3*. It is generally accepted among breeders that the S. *chilense* introgressions containing this gene are associated with considerable linkage drag, negatively affecting performance of the hybrid. Our work has resulted in *Ty-3* material containing a very small introgression with no apparent linkage drag. Fla. 8923 is a recently developed inbred with high yields of large fruit, and which contains this reduced *Ty-3* introgression. Yield data of this inbred were not available for including in this manuscript but will be presented orally.

LITERATURE CITED

Crill, P., J.W. Strobel, D.S. Burgis, H.H. Bryan, C.A. John, P.H. Everett, J.A. Bartz, N.C. Hayslip, and W.W. Dean. 1971. Florida MH-1, Florida's first machine harvest fresh market tomato. Florida Agric. Exp. Sta. Circ. S-212. Univ. of Florida, Gainesville.

Hutton, S.F., J.W. Scott, w. Yang, S.C. Sim, D.M. Francis, and J.B. Jones. 2010. Identification of QTL associated with resistance to bacterial spot race T4 in tomato. Theor Appl Genet. 121:1275-1287.

Ji, Y, Schuster DJ,Scott JW (2007) Ty-3, a begomovirus resistance locus near the tomato yellow leaf curl virus resistance locus Ty-1 on chromosome 6 of tomato. Molecular Breeding 20:271-284.

Ji Y, Scott JW, Schuster DJ, Maxwell DP (2009) Molecular mapping of Ty-4, a new tomato yellow leaf curl virus resistance locus on chromosome 3 of tomato. J. Amer. Soc. Hort. Sci., 134:281-288.

Jones, J.B., R.E. Stall, J.W. Scott, G.C. Somodi, H. Bouzar, and N.C. Hodge. 1995. A third tomato race of *Xanthomonas* campestris pv. vesicatoria. Plant Dis. 79:395-398.

Jones, J.B., R.E. Stall, and H. Bouzar. (1998) Diversity among *Xanthomonads pathogenic* on pepper and tomato. Annu Rev Phytopathol. 36:41-58.

Kemble, J.M. 1993. Cultural and genetic manipulation of compact growth habit fresh-market tomatoes (*Lycopersicon esculentum* Mill.). North Carolina State Univ., Fletcher, MS Thesis.

Minsavage, G.V., B. Balogh, R.E. Stall, and J.B. Jones. 2003. New tomato races of *Xanthomonas campestris pv. vesicatoria* associated with mutagenesis of tomato race 3 strains. Phytopathology 93:S62.

Scott, J.W. 2000. Fla. 7771, a medium-large, heat-tolerant, jointless-pedicel tomato. HortScience 35:968-969.

Tigchelaar, E.C. 1986. Tomato Breeding. In Breeding Vegetable Crops. M.J. Bassett (Editor), pp. 135-171. AVI Publishing Co., Westport, CT.

Verlaan, M.G., S.F. Hutton, R.M. Ibrahem, R. Kormelink, R.G.F. Visser, J.W. Scott, J.D. Edwards, and Y. Bai. 2013. The Tomato Yellow Leaf Curl Virus Resistance Genes *Ty-1* and *Ty-3* are Allelic and Code for DFDGD-class RNA-dependent RNA Polymerases. PLoS Genet 9(3): e1003399. doi:10.1371/journal.pgen.1003399.

Variety Evaluation of Compact Growth Habit Tomatoes with Jointless Pedicels in a Modified Bed Configuration

Monica Ozores-Hampton[1], Aline Coelho Frasca[1], and Eugene McAvoy[2].
[1]University of Florida/IFAS, SWFREC, Immokalee, FL.
[2]University of Florida/IFAS Hendry County Extension Service, LaBelle, FL. Ozores@ufl.edu

INTRODUCTION

Florida ranks first nationally in fresh-market tomato production with a value of $267 million in 2012 [U.S. Department of Agriculture (USDA), 2013]. In the 2012 season, Florida had the second largest fresh-market tomato acreage in the United States with 29,000 acres harvested and an average yield of 33,000 lb/acre resulting in almost 1 billion pounds of tomato fruit [U.S. Department of Agriculture (USDA), 2013].

The most common tomato types produced in Florida are round, roma, cherry, and grape, of which the majority are determinate plants with upright growth habit for the fresh market (Ozores-Hampton et al., 2011). Determinant round and roma tomato plants will cease their growth at fruit set on the apical meristems and are commonly harvested at the mature-green stage. Lodging of determinate upright tomatoes can reduce tomato fruit yield and quality, thus commercial hybrids require staking (Adelana, 1980). Labor costs related to practices such as transplanting, staking, pruning, tying, and harvesting may be as high as 55% of the total tomato production cost (Davis and Estes, 1993), which was estimated at $16,259/acre in 2008 for Southwest Florida (VanSickle et al., 2009). Besides the labor costs, availability of farm labor and immigration issues are a major concern to the Florida tomato industry (McAvoy and Ozores-Hampton, 2011; Scott et al., 2010). Mexican tomatoes may be produced at a reduced cost, due to the lower labor and land cost, as compared to the Florida tomato industry (McAvoy and Ozores-Hampton, 2011).

Compact growth habit tomatoes (CGH), which are determinate varieties with a unique architecture, may provide a viable alternative production system for Florida. These tomatoes have low growth and spreading characteristics forming a compact plant that holds fruit above the ground due to its short branches (Kemble, 1993). Therefore, CGH plants do not require staking, tying, or pruning (Kemble, 1993). Plants of CGH tomatoes have shortened internodes due to the brachytic gene (*br*) (Burton et al., 1955), strong side branching, and can be prostrate or upright in growth due to undefined gene(s) (Ozminkowski et al., 1990). These traits result in a plant approximately 24 inches in diameter and a 50% to 60% reduction in internode length compared to staked upright varieties (Kemble, 1993). Each short branch, including the terminal bud, terminates in a flower cluster resulting in plants with concentrated fruit set early in maturity. These tomato plants will cover the polyethylene mulch bed but will not grow into the row middles holding most of the fruit above the ground (Kemble, 1993; Scott et al., 2010).

Furthermore, CGH varieties with the jointless characteristic may be harvested mechanically, eliminating the need for expensive hand-harvest labor (Scott et al., 2010). In jointless varieties, when the fruit is harvested, the calyx and stem remain attached to the plant; however, in jointed varieties part of the stem and the calyx remain attached to the fruit (Zahara and Scheuerman, 1988). When jointed tomatoes are mechanically or hand harvested stems and calyx that remain attached to the fruit may puncture or bruise other fruit during transportation and packing. Thus, hand-harvesting of jointed cultivars requires additional time for workers to remove the stem and calyx in order to avoid fruit damage (Zahara and Scheuerman, 1988).

The unique plant growth of CGH tomatoes may be used by the Florida mature-green fresh-market tomato growers to reduce labor costs associated with staking, tying, and pruning. However, the use of new varieties may require changes to the current tomato production system. Compact growth habit tomatoes do not grow into the row middles but lay their branches and leaves on the bed surface (Scott et al., 2010). Therefore, an increase on the bed slope to allow for improved drainage is critical to avoid water accumulation on the bed, which creates a favorable environment for several plant pathogens.

The objective of this study was to evaluate six CGH tomato breeding lines with jointless pedicels in a modified bed configuration on yield and postharvest quality.

MATERIALS AND METHODS

Plant material. The study was located in a commercial farm in Immokalee, FL during spring 2013. Beds were 8 inches high in the middle, 7 inches high on the edges and 32 inches wide, and covered with black VIF (virtually impermeable film) polyethylene mulch. Beds were formed and fumigated with Telone and chloropicrin (40:60) at a rate of 110 lb/acre. The total nutrient applied (dry fertilizer and fertigation) in terms of N-P2O5-K2O was 280-100-600 lb/acre, respectively. The polyethylene mulched beds slope was modified from 70.35o to 63.43o or 10% steeper slope. This procedure was performed manually by rolling a polyvinyl chloride (PVC) pipe on the shoulders of the polyethylene mulched beds. Six CGH tomato breeding lines (8914, 8915, 8916, 8916a, 8916b, and 8834) from the UF-TBP were planted in a single row on beds placed 6-ft center to center with 24 inches in-row spacing for a plant population of 3,630 plants/acre. The plots were 20 ft long and the experimental design was a randomized complete block with four replications. Tomato breeding lines were planted as 6-week old transplants, produced by Redi Plants Corp (Naples, FL). Transplants were grown in 128-cell Styrofoam trays. The crop was irrigated by a hybrid system of drip and seepage irrigation. The drip irrigation was used to supplement the seepage irrigation and to allow for fertigation. Pesticide applications were performed as needed according to regular scouting reports and UF/IFAS recommendations (Olson et al., 2012).

Data collection. Tomato plants were manually harvested two times at the mature-green stage. Fruit were then graded into marketable yield size categories and weighed. Size categories followed the USDA specifications for extra-large (5x6), large (6x6), and medium (6x7) fruits [U.S. Department of Agriculture (USDA), 1997]. Unmarketable fruit weight was recorded and categorized according to the presence of sunscald, off-shape, and other defects (scratch and gray wall) (Ozores-Hampton et al., 2010). After the first harvest, a sub-sample of 20 mature-green tomato fruits per plot was collected, placed in labeled paper bags, and transported to the University of Florida/Southwest Florida Research and Education Center (UF/SWFREC) Vegetable Laboratory (VegLab) in Immokalee, FL. Fruit were washed in chlorinated water (100 ppm solution) for one minute and then allowed to dry at room temperature (71^{o}F). Then, tomatoes were placed into clean paper bags, transported to Gargiulo, Inc. packing-house, and subjected to ethylene treatment at 68°F and 85% to 90% relative humidity until breaker stage of ripeness (Sargent et al., 2005). After tomatoes achieved the breaker stage, they were transported to the VegLab and ripened at room temperature until red stage for postharvest evaluations. Four fruit from each plot were measured for fruit firmness as fruit deformation using an 11 mm probe and 1 kg force applied to the fruit equator area for five seconds utilizing a portable digital firmness tester (Model C125EB; Mitutoyo, Corp.; Aurora, ILL.). Color was measured using a 1 to 6 scale where 1= green and 6= red [U.S. Department of Agriculture (USDA), 1997]. Marketable and unmarketable fruit yield, firmness, and color were analyzed by analysis of variance (ANOVA) and means were separated by Duncan's multiple range test at 95% confidence level using SAS (SAS 9.3 SAS Institute Inc., Cary, NC, 2011).

RESULTS AND DISCUSSION

Weather conditions. Weather conditions were recorded by the Florida Automated Weather Network (FAWN) for Immokalee, FL. Average air temperature was 65.8oF ranging from a minimum of 52.6oF to a maximum of 81.5oF from 18 Dec. 2012 to 4 Apr. 2013. The lowest average temperature was in Dec. (47.8oF) and the warmest average temperature occurred in Feb. (76.6oF). Two minimal freeze events occurred on 23 Dec. 2012 (30.25oF) and on 4 Mar. 2013 (31.56oF); however, freeze damage was not observed in the study. Total rainfall accumulation was 5.7 inches. Weather conditions were average for Southwest Florida during the spring season based on 14 years data recorded by FAWN.

Fruit yields. The modified bed shoulder provided adequate drainage, since there were no plant or fruit diseases detected during the season. First harvest accounted for 64% to 38% of the total yield and ranged from 463 to 1,025 boxes/acre. The highest extra-large fruit yield at first harvest was from breeding line 8916 and the lowest from 8914 and 8834 (**Table 1**). However, breeding line 8915 had the highest large and medium fruit yields. The highest total marketable yield at first harvest was from breeding lines 8915 and 8916 and the lowest from 8914 and 8834. There were no differences in unmarketable fruit yields at first harvest.

Total marketable yield at second harvest ranged from 392 to 873 boxes/acre. Extra-large fruit yields decreased in the second harvest in all breeding lines. Breeding line 8916a had the highest extra-large and large

Table 1. First, second, and total marketable and unmarketable (culls) fruit yield by size categories for compact growth habit tomatoes grown in Immokalee, FL during spring 2013.

	Yield (boxesz/acre)														
	First harvest					Second harvest					Total harvest				
Breeding Line	XLy	L	M	C	T	XL	L	M	C	T	XL	L	M	C	T
8914	152dx	237b	146bc	153	535c	41bc	197b	635a	212b	873a	193d	434b	781a	366b	1,409cd
8915	375c	360a	290a	284	1,025a	35bc	183bc	602a	384a	821a	410c	543a	892a	668a	1,846a
8916	599a	270b	153bc	200	1,022a	59b	137cd	443b	319ab	639b	658a	407b	596b	519ab	1,661ab
8916a	419bc	232b	152bc	292	803b	99a	254a	439b	402a	792a	518b	486ab	591b	694a	1,595bc
8916b	483b	206bc	191b	179	879b	45bc	92de	358b	272ab	494bc	526b	298c	549bc	439b	1,373d
8834	186d	162c	115c	172	463c	16c	48e	328b	224b	392c	202d	210c	443c	396b	855e
P-value	0.0001	0.0003	0.0002	0.12	0.0001	0.0009	0.0001	0.0001	0.002	0.0001	0.0001	0.0001	0.0001	0.009	0.0001
Sig.	***	***	***	NS	***	***	***	***	**	***	***	***	***	**	***

z 25-lb tomatoes/box.
y XL= Extra-large (5x6 industry grade); L=Large (6x6); M=Medium (6x7); C=culls; and T=total.
x Within columns means followed by different letters are significantly different according to Duncan's multiple range test at 5%.
NS *, **, *** Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Table 2. Total culls and culls distribution in the categories of sunscald, off-shape, and other defects for compact growth habit tomatoes grown in Immokalee, FL during spring 2013.

	First harvest				Second harvest				Total harvest			
	Total culls	Sunscald	Off-shape	Other	Total culls	Sunscald	Off-shape	Other	Total culls	Sunscald	Off-shape	Other
Breeding line	(boxes[z]/acre)		(%)		(boxesz/acre)		(%)		(boxesz/acre)		(%)	
8914	153	4.7by	64.8	30.5a	212b	34.9c	32.6a	32.5	366b	23.4d	46.0a	30.7
8915	284	30.6a	35.4	34.0a	384a	54.8ab	11.7b	33.5	668a	45.4abc	20.9b	33.7
8916	200	33.6a	51.7	14.7ab	319ab	57.3ab	17.5b	25.2	519ab	49.1ab	29.5b	21.4
8916a	292	18.4ab	72.9	8.7b	402a	44.9bc	34.6a	20.5	694a	35.3bcd	49.0a	15.8
8916b	179	42.1a	49	8.9b	272ab	68.4a	11.4b	20.2	439b	58.0a	26.8b	15.2
8834	172	21.3ab	51.3	27.4ab	224b	43.6bc	38.7a	17.7	396b	33.8cd	44.7a	21.5
P-value	0.12	0.05	0.06	0.03	0.002	0.007	0.0001	0.29	0.009	0.001	0.0001	0.07
Sig.	NS	*	NS	*	**	**	***	NS	**	***	***	NS

z 25-lb tomatoes/box.
y Within columns means followed by different letters are significantly different according to Duncan's multiple range test at 5%.
NS *, **, *** Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

fruit yields, and the lowest were from 8834 at second harvest. The highest medium fruit yields were obtained by 8914 and 8915. The highest total marketable yield at second harvest was from breeding lines 8914, 8915, and 8916a. Unmarketable fruit yields were highest for 8915 and 8916a, but not different from 8916 and 8916b.

Total season harvest marketable yields ranged from 855 to 1,846 boxes/acre. Breeding line 8916 had the highest extra-large fruit yield, whereas 8914 and 8834 had the lowest. The highest large fruit yields were from breeding line 8915 and 8916a; however the highest medium fruit yields were from 8914 and 8915. The highest total season marketable yields (all sizes and harvests combined) were obtained by breeding lines 8915 and 8916 and the lowest was from 8834. Total unmarketable fruit yields were highest with 8915, 8916, and 8916a.

In the total unmarketable category the most common fruit defects were sunscald and off-shape. In the first harvest fruit with sunscald ranged from 4.7% to 42% of the total unmarketable fruit (**Table 2**) or 0.4% to 3.8% of the average total season (marketable and unmarketable) fruit harvested (data not shown). The lowest percentage of sunscalded fruit was from breeding line 8914, which was not different from 8916a and 8834. There were no significant differences in percentage of off-shape at first harvest. In the second harvest sunscalded fruit was higher than first harvest for all breeding lines and ranged from 34% to 68% of the total second harvest unmarketable fruit or 3.7% to 9.4% of the average total season fruit harvested. Breeding lines 8915, 8916, and 8916b had the highest sunscald percentages at second harvest. In the total season harvest fruit with sunscald were higher for breeding lines 8915, 8916, and 8916b than 8914. Off-shaped fruit was highest for breeding lines 8914, 8916a and 8834 in the total season unmarketable fruit.

Postharvest evaluation. Fruit firmness and skin color were not different among the six breeding lines with a mean of 2.5 mm (ranging from medium to very soft) and 5.9 ripening stage, respectively (**Table 3**).

Conclusion. In conclusion, CGH tomatoes may be a viable option for the Florida mature-green fresh market based on yield and quality. The total production cost of CGH tomatoes can potentially be lower than staked upright varieties, since production practices such as staking, tying, and pruning are not required. In addition, CGH tomatoes may be planted in a higher plant density, recovering the loss of vertical space, and with lower fertilizer inputs than staked upright varieties.

LITERATURE CITED

Adelana, B.O. 1980. Relationship between lodging, morphological characters and yield of tomato cultivars. Scientia Hort. 13:143-148.

Burton, D.W., L. Butler, J.A. Jenkins, C.M. Rick, and P.A. Young. 1955. Rules for nomenclature in tomato genetics. J. Hered. 46:22-76.

Davis, J.M. and E.A. Estes. 1993. Spacing and pruning affect growth, yield and economic returns of staked, fresh-market tomatoes. J. Amer. Soc. Hort. Sci. 118:719-725.

Kemble, J.M. 1993. Cultural and genetic manipulation of compact growth habit fresh-market tomatoes (*Lycopersicon esculentum* Mill.). North Carolina State Univ., Fletcher, MS Thesis. Abstr. 304053740. http://search.proquest.com/docview/304053740?accountid=10920

McAvoy, E. and M. Ozores-Hampton. 2011. Unique challenges for Florida growers in tomato and pepper production. Univ. Florida, IFAS, EDIS Circ. IPM-201. 31 Dec. 2012. http://edis.ifas.ufl.edu/in733

Olson, S.M., W.M. Stall, G.E. Vallad, S.E. Webb, S.A. Smith, E.H. Simonne, E. McAvoy, and B.M. Santos. 2012. Tomato production in Florida, p. 295-316. In: S.M. Olson and B. Santos (eds.). 2012-2013 Vegetable production handbook for Florida. Vance Publishing, Lenexa, KS.

Ozminkowski, Jr., R.H., R.G. Gardner, W.P. Henderson, and R.H. Moll. 1990. Prostrate growth habit enhances fresh-market tomato fruit yield and quality. HortScience 25:914-915.

Ozores-Hampton, M., E. McAvoy, S.M. Olson, K. Cushman, and N. Roe. 2011. Tomato varieties for Florida – Florida "red rounds", plum, cherries, and grapes. Univ. Florida, IFAS, EDIS Circ. HS1189. 31 Dec. 2012. http://edis.ifas.ufl.edu/hs1189

Ozores-Hampton, M., E. McAvoy, S. Sargent, and P. Roberts. 2010. Evaluation of tomato yellow leaf curl virus (tylcv) resistant and Fusarium crown rot (fcr) resistant tomato variety under commercial conditions in southwest Florida. Florida Tomato Inst. Proc., 53:11-15.

Sargent, S.A., J. K. Brecht, and T. Olczyk. 2005. Handling Florida vegetables series - round and roma tomato types. Univ. Florida, IFAS, EDIS Circ. SS-VEC-928. 31 Dec. 2012. http://edis.ifas.ufl.edu/pdffiles/VH/VH07900.pdf

SAS. 2011. SAS/STAT user's guide, Ver. 9.3, SAS Institute, Cary, NC.

Scott, J.W., S.F. Hutton, and J. Strobel. 2010. Some highlights from the University of Florida tomato breeding program. Florida Tomato Inst. Proc., 53:9-10.

U.S. Department of Agriculture. 1997. United States standards for grades of fresh tomatoes. Agr. Mktg. Serv. 21 Feb. 2013. http://www.ams.usda.gov/getfile?dDocName=STELPRDC5050331

U.S. Department of Agriculture. 2013. Vegetable 2012 summary. 21 Feb. 2013. http://usda01.library.cornell.edu/usda/current/VegeSumm/VegeSumm-01-29-2013.pdf

VanSickle, J., S. Smith, and E. McAvoy. 2009. Production budget for tomatoes in southwest Florida. Univ. Florida, IFAS, EDIS Circ. FE818. 31 Dec. 2012. http://edis.ifas.ufl.edu/fe818

Zahara, M.B. and R.W. Scheuerman. 1988. Hand-harvesting jointless vs. jointed-stem tomatoes: Jointless-stem fresh-market varieties take much less time to pick than jointed types. Univ. of California, Veg. Res. and Info. Ctr. 31 Dec. 2012. http://ucanr.org/repository/view.cfm?i=i&search=harvesting%20&article=68779&groupid=1&mailer=yes

Table 3. Postharvest evaluation of tomato fruit firmness (as fruit deformation) and skin color at red stage of ripeness from the first harvest for compact growth habit tomatoes grown in Immokalee, FL during spring 2013.

Breeding line	Deformation (mm)z	Color (1-6 scale)y
8914	2.11	5.94
8915	2.19	6.00
8916	2.35	5.88
8916a	2.61	5.81
8916b	2.74	6.00
8834	2.95	5.94
P-value	0.31	0.29
Sig.	NS	NS

z Very firm ≤ 0.7 mm; firm ≤ 1.4mm; medium ≤ 2.1 mm; Soft ≤ 2.8 mm; very soft > 2.8 mm.
y 1 = green and 6 = red (USDA, 1997).
NS, *, **, *** Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

New Insecticides for Management of Silverleaf Whitefly (*Bemisia tabaci*) and Tomato Yellow Leaf Curl Virus

Hugh A. Smith,
University of Florida,
Gulf Coast Research and Education Center, Wimauma FL 33598. hughasmith@ufl.edu

INTRODUCTION

Tomato yellow leaf curl virus (TYLCV) is persistently vectored by the silverleaf whitefly (*Bemisia tabaci biotype B*) and is one of the primary production constraints facing Florida tomato growers, causing complete crop loss in some instances (Mosler et al. 2009, Moriones and Navas-Castillo 2010). Management of TYLCV involves destruction of crop residues and other virus reservoirs, and the use of reflective mulches and TYLCV-resistant tomato varieties when appropriate (Schuster et al. 2008). Insecticides are a key component of whitefly and virus management. Several modes of action are available to manage adult and immature whitefly and to reduce the spread of virus. With the loss of endosulfan in 2014 and increasing tolerance of whitefly to registered insecticides, including imidacloprid and other neonicotinoids, there is a need for new insecticides to manage the virus vector. Four new insecticides that will receive their registration in 2013 or 2014 were evaluated in greenhouse and/or field trials. The purpose of these trials was to gather preliminary information on the most appropriate placement of these products in insecticide rotations and contribute to the development of insecticide use guidelines for Florida tomato growers.

The new insecticides evaluated were cyazypyr™ (also known as cyantraniliprole) (DuPont Corp.; www.dupont.com), flupyradifurone™ (Bayer Crop Science; www.cropscience.bayer.com), pyrifluquinazon™ (Nichino; www.nichino.net) and sulfoxaflor™ (Dow AgroScience; www.dowagro.com). Cyazypyr is a diamide insecticide that interferes with the functioning of ryanodine receptors and has an expected EPA registration date of 2013. Flupyradifurone and sulfoxaflor are both in the neonicotinoid group of insecticides. The mode of action of pyrifluquinazon is unknown. Sulfoxaflor (Closer™) received EPA registration in 2013. Flupyradifurone and pyrifluquinazon are expected to be registered in 2014. Cyazypyr, flupyradifurone and sulfoxaflor are systemic materials that can be applied at-plant, through drip irrigation or foliarly. Pyrifluquinazon functions primarily through contact and is applied foliarly.

These materials were compared in greenhouse studies to registered insecticides including pymetrozine (Fulfill®; Syngenta Crop Protection; www.syngentacropprotection.com), and zeta-cypermethrin/bifenthrin (Hero®; FMC Corporation; www.fmc.com), and in the field to dinotefuran (Venom®; Valent Corporation; www.valent.com). Sulfoxaflor was not included in field studies.

MATERIALS AND METHODS

Greenhouse studies

Greenhouse studies were carried out to evaluate the effect of cyazypyr, flupyradifurone, pyrifluquinazon, sulfoxaflor, pymetrozine and zeta-cypermthrin/bifenthrin on egg-laying and transmission of TYLCV by B. tabaci on tomato seedlings (var. Florida 47) confined in cages (32 seedlings/cage). The concentrations of the active ingredients were: 0.320 g/L cyazypyr (DuPont DPX-HGW86 10 SE); 0.437 g/L flupyradifurone (Bayer Sivanto 200SL); 0.206 g/L pymetrozine (Syngenta Fulfill Insecticide); 0.108 g/L pyrifluquinazon (Nichino NNI-0101 20SC); 0.210 g/L sulfoxaflor (Dow AgroSciences GF-2032 240SC); 0.059 g/L zeta-cypermethrin + 0.178 g/L bifenthrin (FMC Hero Insecticide). Applications were made with a hand-held CO2-powered sprayer, pressurized to 60 psi and outfitted with a single nozzle with a D-5 disk and #45 core (Spraying Systems Co., Glendale Heights, IL). One hundred whitefly adults were introduced into each of the seedling cages at either 3, 7 or 14 days after treatment with the insecticides.

Egg densities. Tomato seedling samples were collected from each cage 7, 14 and 21 d after whitefly adults were introduced. On each sample date, four seedlings were removed randomly from each cage. The underside of each leaf was examined beneath a stereo microscope for the presence of whitefly eggs. In total, twelve plants from each cage were sampled. The average of the egg densities from these twelve plants was used for analysis. Egg data were log-transformed in order to obtain residuals that were approximately normally distributed. Confidence intervals for the treatment medians were constructed using Tukey's multiple pairwise comparisons test. Non-transformed means are reported in tables.

Percent virus. Six weeks after exposure to whiteflies, ten plants from each cage were examined and the number of plants with unambiguous symptoms of TYLCV – stunted, curled upper leaves with bright yellow edges and interveinal areas – were

Table 1. Whole plant egg densities on tomato seedlings exposed to whiteflies 3, 7, or 14 days after application of insecticide.

Days After Treatment (DAT)	Treatment	Egg	± SEM
3	Untreated	127.04	± 39.76 A†
	Pymetrozine	3.56	± 1.26 B
	Cyazypyr	0.71	± 0.35 C
	Flupyradifurone	0.46	± 0.19 C
	Sulfoxaflor	0.23	± 0.06 C
	Zeta-cyper/bifen	0.15	± 0.08 C
	Pyrifluquinazon	0.10	± 0.05 C
	F6,84.46 = 97.76		
	P < 0.0001		
7	Untreated	184.15	± 36.57 A†
	Pymetrozine	6.70	± 1.56 B
	Cyazypyr	1.67	± 0.80 C
	Zeta-cyper/bifen	1.08	± 0.69 C
	Pyrifluquinazon	0.52	± 0.18 C
	Sulfoxaflor	0.38	± 0.21 C
	Flupyradifurone	0.33	± 0.17 C
	F6,84.99 = 87.88		
	P < 0.0001		
14	Untreated	149.77	± 46.74 A†
	Pymetrozine	14.98	± 3.65 B
	Zeta-cyper/bifen	6.31	± 1.34 B
	Sulfoxaflor	1.56	± 1.10 C
	Cyazypyr	1.29	± 0.62 C
	Flupyradifurone	0.06 CD	± 0.03
	Pyrifluquinazon	0.02	± 0.02 D
	F6,84.46 = 100.65		
	P < 0.0001		

†Means within the same DAT (3, 7, 14) not followed by the same upper case letter are different using Tukey's multiple comparisons test (P=0.05).

SEM = Standard error mean.

Table 2. Percentage of plants with TYLCV symptoms when exposed to viruliferous whiteflies 3, 7 or 14 days after application of insecticide.

Days After Treatment (DAT)	Insecticide treatment	% TYLCV ± SEM	
3	Untreated	100 ± --	A†
	Pymetrozine	30 ± 0.07	B
	Cyazypyr	13 ± 0.05	B
	Sulfoxaflor	10 ± 0.04	B
	Pyrifluquinazon	8 ± 0.04	B
	Flupyradifurone	0 ± --	C
	Zeta-cypermethrin /bifenthrin	0 ± --	C
	$F_{6,819}$ = 3678		
	$P < 0.0001$		
7	Untreated	100 ± --	A
	Pymetrozine	63 ± 0.07	B
	Sulfoxaflor	13 ± 0.05	C
	Cyazypyr	10 ± 0.04	C
	Pyrifluquinazon	10 ± 0.04	C
	Zeta-cypermethrin /bifenthrin	5 ± 0.03	C
	Flupyradifurone	0 ± --	D
	$F_{6,819}$ =2753		
	$P < 0.0001$		
14	Untreated	149.77	
	Pymetrozine	14.98	
	Cyazypyr	6.31	
	Sulfoxaflor	1.56	
	Zeta-cypermethrin /bifenthrin	1.29	
	Pyrifluquinazon	0.06	
	Flupyradifurone	0.02	
	$F_{6,819}$ =742		
	$P < 0.0001$		

†Means within the same DAT (3, 7, 14) not followed by the same upper case letter are different using Tukey's multiple comparisons test (P=0.05).

SEM = Standard error mean.

recorded as infected. A Generalized Linear Model (GLM) was fit for the binary outcome TYLCV and classification variables insecticide treatment and waiting period before inoculation with whiteflies from the TYLCV colony. Tukey-Kramer multiple pairwise comparisons were carried out and the corresponding letter groupings assigned in order to group the proportions in homogeneous groups of significantly greater proportions.

The data analysis was performed using SAS/STAT and SAS/IML software, Version 9.3 of the SAS System for Windows (SAS 2011). The linear models were fit in PROC GLIMMIX and the goodness of fit analysis was performed in PROC UNIVARIATE.

FIELD TRIAL FALL 2012

Experimental plots were established on raised beds covered with white plastic mulch, spaced on 5-ft. centers, with a single row of tomato plants (var. Florida 47) spaced 18 inches apart. Plots consisted of single beds of 28 plants each. Treatments consisted of cyazypyr at-plant followed by foliar applications of flupyradifurone, pyrifluquinazon or nothing; flupyradifurone at-plant followed by foliar applications of cyazypyr, pyrifluquinazon or nothing, and dinotefuran at-plant followed by foliar applications of cyazypyr, pyrifluquinazon or nothing. There were nine insecticide treatments and one untreated control, each replicated four times. Drench applications were hand ladled on the day of transplant at the rate of 4 fl. oz. of preparation per plant (181.5 gal. per acre). Foliar treatments were applied with a hand-held sprayer with a spray wand outfitted with a single nozzle containing a 45° core and a D-5 disk. The sprayer was pressurized by CO2 to 60 psi and calibrated to deliver 60 gal. per acre. All plants within each sub-plot were inspected weekly in the field and those which possessed symptoms of TYLCV were recorded. Cumulative weekly percent of plants showing TYLCV symptoms were calculated and transformed arcsine [$\sqrt{(\%TYLCV/100)}$] prior to ANOVA. Means were separated by Fisher's Protected LSD (P=0.05). All means were reported in the original scale.

RESULTS

Representative results are presented in data tables here. Please contact the author for complete results. In greenhouse studies, cyazypyr, flupyradifurone, pyrifluquinazon, and sulfoxaflor demonstrated a similar ability to suppress densities of whitefly eggs (Smith and Giurcanu 2013). They were consistently more effective than pymetrozine in reducing egg numbers **(Table 1)**. The percentage of tomato seedlings expressing virus symptoms was

Table 3. Cumulative % of tomato plants with tomato yellow curl leaf virus (TYLCV) symptoms (N = 28; 77 days after transplanting). Field trial fall 2012 GCREC Balm, Florida.

Treatment/Formulation	Rate Amount/acre	Application method	Virus (%)
1. Non-treated	--	--	65.2 a*
2. Flupyradifurone	28.0 fl. oz.	drench	30.4 b-d
3. Flupyradifurone	28.0 fl. oz.	drench	
fb† Cyazypyr	20.5 fl. oz.	foliar	36.6 b-d
4. Flupyradifurone	28.0 fl. oz.	drench	
fb Pyrifluquinazon	3.2 fl. oz.		
+ Induce	0.25% v/v	foliar	23.2 d
5. Cyazypyr	14.0 fl. oz.	drench	42.0 bc
6. Cyazypyr	14.0 fl. oz.	drench	
fb Flupyradifurone	20.5 fl. oz.	foliar	37.5 b-d
7. Cyazypyr	14.0 fl. oz.	drench	
fb Pyrifluquinazon	3.2 fl. oz.		
+ Induce	0.25% v/v	foliar	25.9 cd
8. Venom 70 WP	6.0 oz.	drench	50.9 ab
9. Venom 70 WP	6.0 oz.	drench	
fb Cyazypyr	20.5 fl. oz.	foliar	49.1 ab
10. Venom 70 WP	6.0 oz.	drench	
fb Pyrifluquinazon	3.2 fl. oz.		
+ Induce	0.25% v/v	foliar	32.1 b-d
$F_{9,27}$			3.16
P-value			0.0097

*Means within columns of a section not followed by the same letter are significantly different using Fisher's Protected LSD (P=0.05.).

†fb = followed by.

Table 4. Some modes of action available for management of whitefly, caterpillars and leafminers on Florida tomato.

MOA #	Grouping or action site	Active ingredient examples	Silverleaf whitefly	Caterpillars	Leafminers
1A	Carbamate	Oxamyl*	x	x	
1B	Organophosphate	Dimethoate, methamidophos	x		x
3	Pyrethroid	Esfenvalerate, betacyfluthrin*, bifenthrin	x	x	
4A	Neonicotinoid	imidacloprid, thiamethoxam, dinotefuran, thiamethoxam	x		
4C		Sulfoxaflor	x		
5	Spinosyns	Spinosad, spinetoram		x	x
6	Avermectins	Abamectin		x	x
7C	Juvenile hormone mimics	Pyriproxifen	x		
9B	Selective homopteran feeding blocker	Pymetrozine*	x		
11	Microbial disruptor of insect midgut membrane	Bacillus thuringiensis subspecies aizawai; subspecies kurstaki		x	
15	Inhibitors of chitin biosynthesis	Novaluron	(nymphs)	x	x
16		Buprofezin	(nymphs)		
17	Dipteran molting disruptor	Cyromazine			x
18	Ecdysone receptor agonist	Tebufenozide, methoxyfenozide		x	
21A	METI insecticides	Fenpyroximate	x		
22	Sodium channel blocker	indoxacarb		x	
23	Lipid biosynthesis inhibitor	Spiromesifen, spirotetramat	x		
28	Ryanodine receptor modulators	Chlorantraniliprole, cyantraniliprole†, flubendiamide	Cyantran iliprole†	x	x
---	unknown	Azadirachtin	x	x	
---	unknown	Beauvaria bassiana	x		
---	unknown	Cryolite	x		
---	unknown	Insecticidal soap	x		
---	unknown	Extract of Chenopodium ambrosioides	x		x
---	unknown	Stylet oils	x		x

*Suppression (uneven or limited control) of whitefly. †Registration anticipated 2013.

lowest in plants treated with flupyradifurone in greenhouse studies, although zeta-cypermethrin/bifenthrin demonstrated comparable efficacy in plants exposed to viruliferous whiteflies 3 and 7 days after treatment (**Table 2**).

In a field trial in the fall of 2012, sixty-five percent of plants in the untreated control had virus symptoms (Table 3). Numerically lowest percentages of plants with virus were in tomatoes treated at-plant with flupyradifurone followed by foliar applications of pyrifluquinazon (23 %) and tomatoes treated at-plant with cyazypyr followed by foliar applications of pyrifluquinazon (26 %).

CONCLUSIONS

Cyazypyr, flupyradifurone, pyrifluquinazon and sulfoxaflor are new insecticides representing three different modes of action that can contribute to management of silverleaf whitefly and TYLCV. Insecticide programs should emphasize the rotation of multiple modes of action using "treatment windows" so that successive generations of whitefly are not exposed to the same mode of action. Given the importance of protecting the tomato crop from TYLCV during the first 5-6 weeks after transplanting, applications at-plant and during the first five weeks after transplanting can be considered priority windows for the use of neonicotinoid (Group 4A) insecticides and the diamide cyazypyr (Group 28) (Smith 2013). Cyazypyr is the only Group 28 insecticide with significant activity against whitefly adults. Like rynaxypyr (Coragen®), cyazypyr has efficacy against leafminers and caterpillars. Flubendiamide (Belt™) is another Group 28 insecticide useful for suppressing caterpillars on tomato. Overuse of Group 28 insecticides to manage leafminers and caterpillars on tomato can be avoided by including insecticides with alternate modes of action in rotations to control these pests (**Table 4**).

REFERENCES CITED

Moriones E., Navas-Castillo J. 2010. Tomato yellow leaf curl disease epidemics. Ch. 8 in *Bemisia*: *Bionomics and Management of a Global Pest*. Springer Science+Business Media B. V. pp. 259-282.

Mosler M., Aerts M. J., and Nesheim O. N. 2009. Florida Crop/Pest Management Profiles: Tomatoes. University of Florida, IFAS Cooperative Extension. Circular 1238.

Schuster D.J., Stansly P. A., Gilreath P. R. , Polston J. E. 2008. Management of *Bemisia*, TYLCV and insecticide resistance in Florida vegetables. Journal of Insect Science 8: 43-44.

Smith, H. A. 2013. Managing diamide resistance in Florida tomato. ENY-867, Entomology and Nematology Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL.

Smith, H. A. and M. C. Giurcanu. 2013. Residual effects of new insecticides on egg and nymph densities of *Bemisia tabaci*. Florida Entomologist 96: 504-511.

Further Insights into the Epidemiology and Monitoring Practices of Tomato Viruses

William Turechek[1], Jongsung Kim[1], Craig Webster[1], Joseph Russo[2], H. Charles Mellinger[3], Galen Frantz[3], Leon Lucas[3], Eugene McAvoy[4], and Scott Adkins[1]

[1]USDA-ARS-USHRL, Subtropical Plant Pathology, Fort Pierce FL, william.turechek@ars.usda.gov
[2]ZedX, Inc., Bellefonte, PA
[3]Glades Crop Care, Inc., Jupiter, FL
[4]Hendry County Extension, University of Florida, LaBelle, FL

INTRODUCTION

There are a number of serious virus threats to tomato production in Florida. These include the whitefly-transmitted *Tomato yellow leaf curl virus* (TYLCV) which was first detected in 1997 in south Florida (Polston, et al., 1999) and has since appeared to varying degrees in all seasons resulting in millions of dollars of lost production. More recently, *Groundnut ringspot virus* (GRSV) and *Tomato chlorotic spot virus* (TCSV) have been detected in Florida production and are thought to pose a significant threat to the crop (Webster et al., 2010; Londoño et al., 2012). Both GRSV and TCSV are vectored by thrips and are closely related to Tomato spotted wilt virus (TSWV), perhaps the most significant virus of solanaceous crops in the southeastern U.S. (Bauske, 1998). The economic damage caused by GRSV and TCSV is not well documented in Florida, but significant losses are known to occur in regions where these viruses are endemic.

For the past several years, our team has been working on several different projects in an effort to better understand and to improve management of these important insect-vectored viruses of tomato. Ongoing studies on the epidemiology of TYLCV have largely focused on the analysis of virus incidence and whitefly densities obtained from scouting reports received from cooperating growers. For GRSV and TCSV, studies investigating virus host and geographic ranges and the diversity of insect vectors have been initiated. In working to improve overall disease and insect management, we have developed and are working to implement the AgScouter system. This talk, will provide updates on the progress in these initiatives.

MATERIALS AND METHODS

Epidemiological studies (TYLCV and GRSV). Scouting reports were submitted by cooperating growers located across southwest Florida from 2006 through the 2013 growing seasons. The reports cover approximately 24,000 acres of mainly tomato production. The data are being used to track and identify regional hot spots of whitefly, thrips and virus and to identify geographical and/or management practices that may be linked to viral (e.g., TYLCV and GRSV) epidemics. Identifying hot spots will enable us to focus in on areas to scout more intensively to search for alternate hosts that may exist in neighboring fallow fields, hedge rows, or unmanaged fields and forests.

In addition to characterizing the impact of geographical features, climatic conditions play an equally important role in the development of epidemics. Previous studies of TYLCV epidemics showed correlations between several weather variables and whitefly density (Turechek, 2010). However, it is critical to know the specific climatic conditions that lead to viral epidemics in order to make informed and timely pest-management decisions. Weather variables including minimum, maximum, and average temperature, dew point, relative humidity, wet bulb temperature, precipitation, and wind (direction and speed) were obtained daily from four weather stations operated by National Climate Data Center and one weather station operated by Florida Automated Weather Network. Polynomial distributed lag (PDL) regression was used to determine the relationship between weather conditions and whitefly densities. Paul et al. (2007) showed successful application of a PDL regression to identify the relationship between weather variables and *Gibberella zeae* inoculum density on wheat spikes.

Host, geographic and vector range studies (GRSV and TCSV). Ten plants of representative plant species from solanaceous, fabaceous, asteraceous and other plant families were mechanically inoculated with Florida isolates of GRSV and TCSV. Plants were monitored weekly for symptoms and tested for GRSV or TCSV by enzyme-linked immunosorbent assay (ELISA) and/or reverse transcription-polymerase chain reaction (RT-PCR)(Webster et al., 2010; 2011b; 2013). In addition, field surveys targeting crops and weeds with symptoms indicative of tospovirus infection were made to gain additional insight on the host range and geographical distribution of GRSV and TCSV in Florida. Furthermore, locally important thrips species were used for virus acquisition and transmission experiments as previously described (Webster et al., 2011a).

AgScouter. AgScouter is a system for collecting and viewing scouting data using GPS capable smartphones and/or tablet computers. Users utilize a mobile device (e.g., smartphone) to collect and upload GPS-labeled scouting data to a central server. Data can be processed and then delivered as real-time reports to growers and/or their scouts. To make it widely adaptable, AgScouter was developed to record both crop production and pest information for a wide variety of crops, and is currently being upgraded to serve as a tool for delivering and storing management recommendations. AgScouter's mobile-device and desktop interfaces were designed and developed by ZedX Inc., (www.zedxinc.com).

RESULTS AND DISCUSSION

Epidemiological studies (TYLCV and GRSV). Our analyses continue to show that the severity of TYLCV follows closely the increase in mean whitefly density and the average age of the fields in production. The data showed a strong correlation between both disease and insect pressure in neighboring fields, and extending out to 2nd and 3rd order neighbors. In terms of distance, the correlations between an affected field and the surrounding fields extended to a 1.5 mile radius for whiteflies and a 3 mile radius for TYLCV. In examining the climatic variables, whitefly density was negatively correlated with temperature, dew point, and wet bulb temperature and positively correlated with average wind speed. We are currently identifying the optimal window size (i.e., an interval of time, usually in days) over which to measure various climatic variables for prediction of whitefly density and/or TYLCV incidence; and later thrips density and GRSV/TCSV. For example, we may discover that the average temperature over the previous two weeks is a good predictor of insect density. Identifying key weather variables and knowing when they have the most impact on a pest or disease cycle could be useful for forecasting epidemic development.

Host, geographic and vector range studies (GRSV and TCSV). To date, most experimental and field hosts of GRSV and TCSV have been solanaceous crops or weeds. In field surveys, GRSV and TCSV have only been detected in commercial tomato and/

or pepper fields in the Florida peninsula, including Charlotte, Collier, Hendry, Lee, Manatee, Martin, Miami-Dade, Palm Beach and St. Lucie Counties. TSWV is widespread throughout the Florida panhandle and southeastern U.S. Western flower thrips (*Frankliniella occidentalis*), a known vector for TSWV, has been confirmed to transmit GRSV (Webster et al., 2011a). Other locally important thrips species, such as Florida flower thrips (*F. bispinosa*), tobacco thrips (*F. fusca*) and common blossom thrips (*F. schultzei*), are currently being tested to determine their ability to acquire and transmit GRSV and TCSV.

AgScouter. The initial impetus for AgScouter was the realization that both insect vectors and the viruses they transmit respond to stimuli (climatic, geographical, etc.) that occur at scales significantly larger than what a typical farm operation has control over. Hence, management of these pests requires a coordinated, regional effort from the grower community. AgScouter could facilitate such an effort. The development of AgScouter as an all-inclusive crop, disease and insect management tool was spurred by the suggestion/request of the potential users. The development and testing of AgScouter continues at a seemingly slow but productive pace. This rate of progress is, unfortunately, the nature of the beast. The continuous development, testing, and revamping of AgScouter is complicated by emerging technology, third party vendors, and the sheer magnitude of what AgScouter hopes to become. Recently, we were awarded an USDA-NIFA-AFRI grant to promote AgScouter on a large-scale in Florida and to begin developing the network in a limited region of California vegetable and grape production which we hope will quicken the pace of development.

ACKNOWLEDGEMENTS

We thank Lisa Rouse, Joshua O'Brien, Mark Verbeck, Carrie Vanderspool, Aleena Moreno, Spencer Marshall and Bridget Burns for their excellent assistance. Financial support was provided in part by USDA-NIFA Specialty Crop Initiative Grant 2008-04890, USDA-NIFA Critical Issues Grant 2011-37610-31178, and Florida Specialty Crop Block Grant 018014.

LITERATURE CITED

Bauske, E.M. 1998. Southeastern tomato growers adopt integrated pest management. HortTechnology 8, 40-44.

Londoño, A., Capobianco, H., Zhang, S. and Polston, J.E. 2012. First record of *Tomato chlorotic spot virus* in the USA. Tropical Plant Pathology 37:333-338.

Paul, P.A., Lipps, P.E., De Wolf, E., Shaner, G., Buechley, G., Adhikari, T., Ali, S., Stein, J., Osborne, L., and Madden, L.V. 2007. A distributed lag analysis of the relationship between *Gibberella zeae* inoculums density on wheat spikes and weather variables. Phytopathology 97:1608-1624.

Polston, J.E., McGovern, R.J., and Brown, L.G. 1999. Introduction of *Tomato yellow leaf curl virus* in Florida and implications for the spread of this and other geminiviruses of tomato. Plant Disease 83:984-988.

Turechek, W.W. 2010. Environmental and geographical variables associated with TYLCV epidemics in southwest Florida. In M. Ozores-Hampton and C. Snodgrass [eds.], 2010 Florida Tomato Institute Proceedings. University of Florida, Naples, Florida.

Webster, C.G., Perry, K.L., Lu, X., Horsman, L., Frantz, G., Mellinger, C. and Adkins, S. 2010. First report of *Groundnut ringspot virus* infecting tomato in south Florida. Plant Health Progress doi: 10.1094/PHP-2010-0707-01-BR.

Webster, C.G., Estévez de Jensen, C., Rivera-Vargas, L.I., Rodrigues, J.C.V., Mercado, W., Frantz, G., Mellinger, H.C. and Adkins, S. 2013. First report of *Tomato chlorotic spot virus* (TCSV) in tomato, pepper and jimsonweed in Puerto Rico. Plant Health Progress. In Press.

Webster, C.G., Reitz, S.R., Perry, K.L. and Adkins, S. 2011a. A natural M RNA reassortant arising from two species of plant- and insect-infecting bunyaviruses and comparison of its sequence and biological properties to parental species. Virology 413:216-225.

Webster, C.G., Turechek, W.W., Mellinger, H.C., Frantz, G., Roe, N., Yonce, H., Vallad, G. and Adkins, S. 2011b. Expansion of *Groundnut ringspot virus* host and geographic ranges in solanaceous vegetables in peninsular Florida. Plant Health Progress doi: 10.1094/PHP-2011-0725-01-BR.

Results of Field Studies on Lowering pH of Alkaline and Calcareous Soils with Sulfur

Kelly T. Morgan
University of Florida, IFAS, Soil and Water Science Department, Southwest Florida Research and Education Center, 2685 State Road 29 North, Immokalee, FL 34142-9515, conserve@ufl.edu

Abstract. Phosphorus (P) precipitates out of soil solution and becomes unavailable for plant uptake as soil pH and Ca content increases. The reduced P plant availability in soils with pH greater than 7.0 and Ca concentrations >1000 ppm renders soils tests using Mehlich 1 extractant ineffective because the acids that make up this extractant can dissolve precipitated P and reflect soil P concentrations not available to plants. The effect of lowering soil pH with sulfur (S) to increase plant availability of fertilizer P is of interest to growers, environmentalists, regulators and the general public because of improved P availability to crop plants and possible impact of increased S concentrations on the environment. The objective of this field study was to determine the length of time soil pH was reduced by application of S in polyethylene mulched beds and the subsequent affect on growth and productivity of tomato (*Solanum lycopersicum L*). Sulfur was applied to two selected fields at two rates in combination with four P rates. It was determined that the soil pH reduction from the initial S applications rates equivalent to 233 and 467 pounds of S per acre applied only in the planted row lasted less than 60 days and had minimum effect on P availability during the entire crop growing season.

Sandy mineral soils in South Florida are predominantly Spodosols, which have low organic matter, low nutrient retention capacity above the *Bh* or spodic horizon which are typically less than 3 feet below the soil surface (Graetz and Nair, 1995; Nair and Harris, 2004; Zhang et al., 2002). After many years of vegetable production the sandy horizons above the spodic of many soils in south Florida have increased soil pH (>7.3) and high in Ca. Under these soil conditions, fertilizer P goes into solution and was initially available for the crops. However, P in solution quickly forms water insoluble precipitates in soil with high soil pH and high calcium (Ca) concentrations (Bieleski, 1973; Nair and Harris, 2004). These P-Ca precipitates did not form in soils with lower soil pH (< 7.0) even in the presence of high Ca concentrations (Gartley and Sims, 1994). Phosphorus from P-Ca precipitates were not readily available to crop plants and reduced P leaching potential because P from these precipitates was dissolved very slowly in water, and only in water with low soluble P concentrations (Graetz and Nair, 1995). Thus, once formed P from P-Ca precipitates may take many years to dissolve into the soil solution (Rhue and Everett, 1987).

The objective of this project was to determine the effectiveness of lowering soil pH as a best management practices to increase P availability and reduce fertilizer P applications. Specifically, the projects assessed plant uptake from existing soil P on marketable yield and quality of the crops by lowering soil pH. In this project, plant biomass, tissue P concentration, soil pH, soil P concentration and yield for vegetable crops grown under commercial conditions were determined. Crop growth and productivity in plots of selected P application rates and pH levels were compared with plots receiving selected rates of S in the planted row.

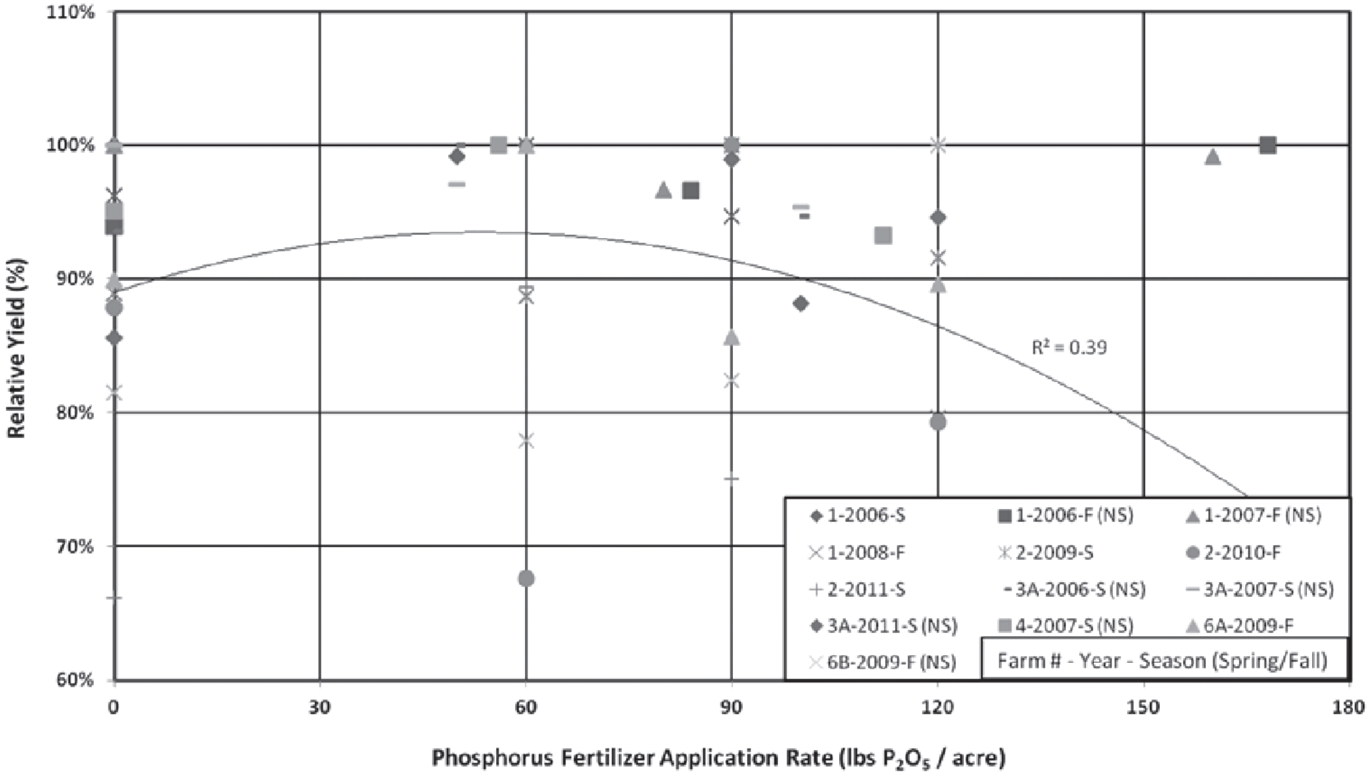


Figure 1. Tomato increase yield response to added fertilizer phosphorus in soils with pH greater than 7.0.

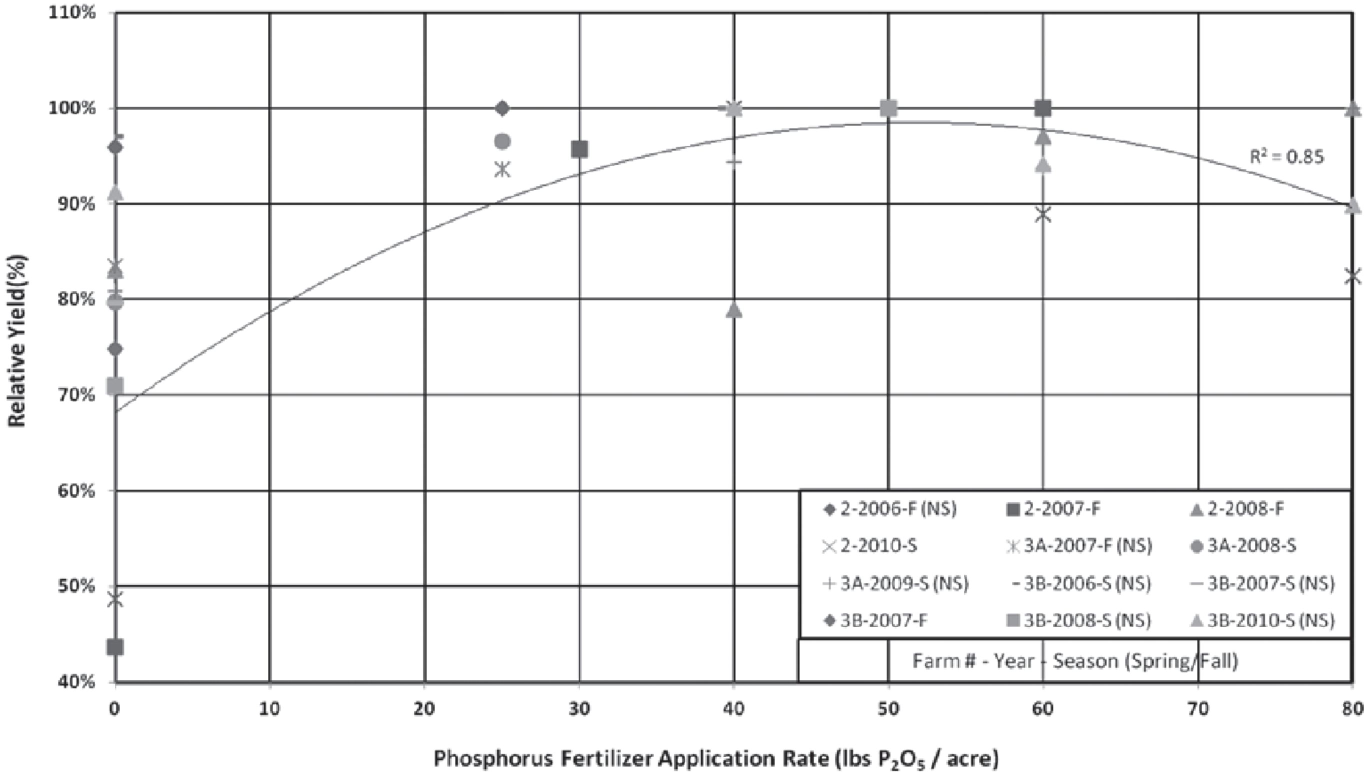


Figure 2. Green bean yield increase with added fertilizer phosphorus in soils with pH greater than 7.0.

METHODS AND MATERIALS

Preliminary studies. Six tomato and green bean (*Phaseolus vulgaris L.)* crops were grown in both spring and fall seasons over a three year period (2006 to 2008) in Hendry county, FL. Spring planting dates were in Jan. or Feb. for all crops and fall planting dates were in Sept. or Oct. Soil types at all locations were Immokalee fine sand (Sandy, siliceous, hyperthermic Arenic Alaquods). Three fertilizer P rates were applied to four randomly replicated plots forming a randomized compete block design. The P application rates were based on 0%, 50%, and 100% of the rate applied to the bulk of the grower's field by adjusting the amount of P in the fertilizer bottom mix blend with the amount of N and

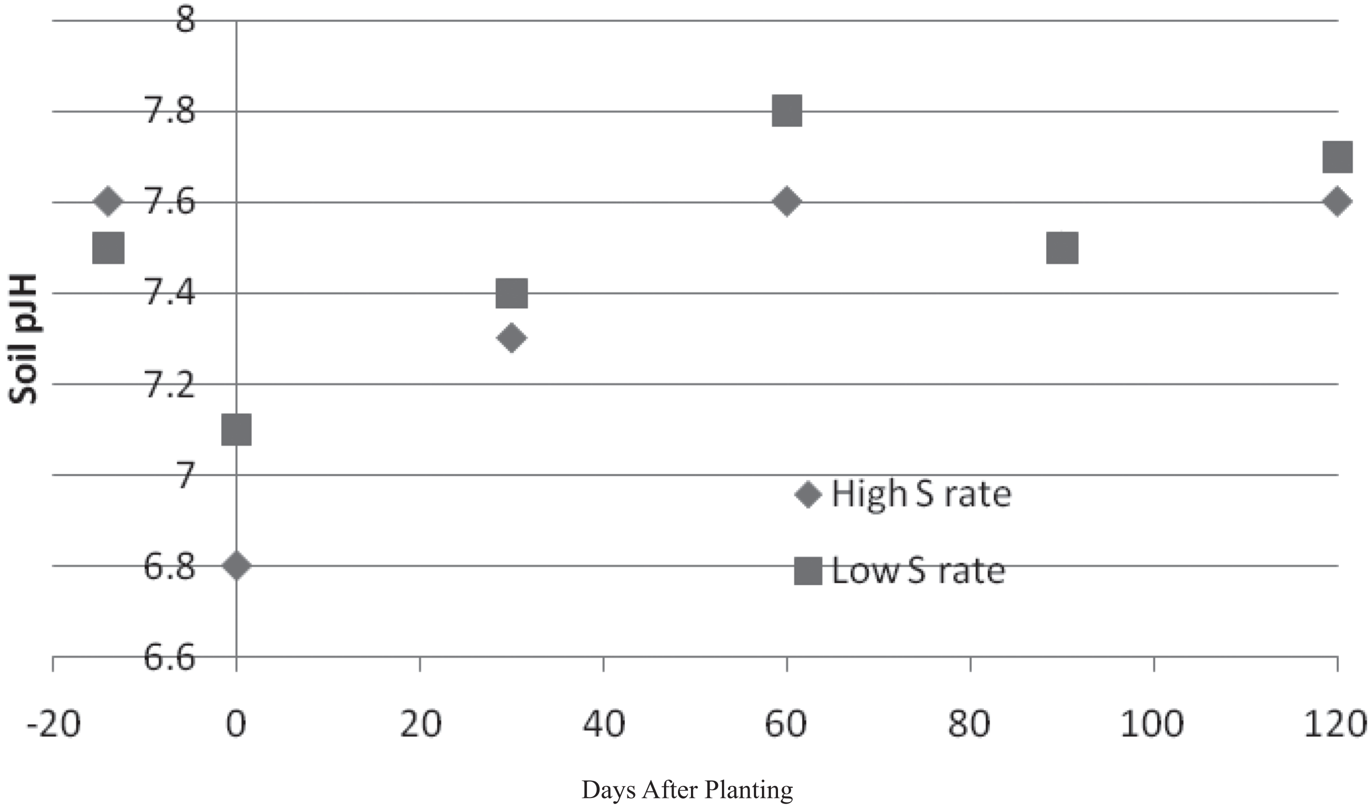


Figure 3. Soil pH responce to sulfur (S) application and two rates. The high and low rates were 467 and 233 pounds of S per acre, respectively, in the planted bed. Notice that soil pH reduced by about one and one-half pH unit after application of the high and low rate, but then returned to the beginning soil pH between 30 and 60 days after planting.

K held constant over the entire planting. Approximately 20% of the total N and K were applied in the bottom mix and the remaining 80% in the top mix. The top mix was applied in grooves on the right and left shoulders of plant beds as they were formed. The top mix did not contain any fertilizer P. Plot size was 6 rows wide and 120 to 270 feet long.

Soil samples were taken from each plot prior to bed preparation. The soil pH of each sample was determined using water extraction at a ratio of 1 part soil to 10 parts water. Soil P concentration was determined using Mehlich 1 soil extraction. Plant dry biomass was determined by collecting the above ground tissue from plants on 3 m of row and drying at 221^{O} F prior to weighing. The number of plants in 10 feet of row were counted and a dry weight per plant was determined. Yields were determined from two 10 foot lengths of row and weighed in the field.

Soil pH moderation studies. Three studies were conducted at two grower fields. Tomato crops were planted on 29 Oct. 2008 (winter), 4 Mar. 2009 (spring) and 24 Nov. 2009 (winter). Phosphorus and elemental S was applied in the bottom mix before bedding and was incorporated in the soil during the pre-bedding and bedding operation. Treatments were applied by adjusting the P content of the bottom mix to provide 49, 37, 24 and 0 pounds of P per acre. Elemental S was applied to plots at 467, 233 and 0 pounds of S per acre, for soil pH moderation in the bottom mix, restricting the volume of soil receiving S to the soil in the bed and protected from runoff by the polyethylene mulch. All treatments received 216 pounds of N per acre and 267 pounds of K per acre. The experimental design at each location was a split plot design with four replications. The P rate was the main plot consisting of 6 rows by 120 to 270 feet and S treatment as the sub plots spaced evenly over the length of each set of six rows.

Soil samples were collected prior bed preparation. Soil pH and Mehlich 1-P were determined using the same procedures used in the previous studies. Dry above ground biomass and fresh fruit weights were determined by harvesting plants and fruit on 10 feet of row in each plot at 30 day increments stating 30 days after planting. Statistical analysis of all data from both sets of experiments were determined using General Linear Model in SAS (SAS Institute, Cary NC).

RESULTS AND DISCUSSION

Biomass and yield data from four fall and two spring tomato crops grown in 2006, 2007 and 2008 were combined to determine the effect of soil pH at time of planting on crop growth and productivity. The data were separated into initial soil pH values less than 7.2, 7.2 to 7.6 and greater than 7.6. No Soil in fields where tomatoes were grown were found to have initial soil pH greater than 7.6 (data not shown). End of season dry above ground tomato biomass weight ranged from 7.05 to 15.87 ounces per plant but were not significantly different (P<0.05) among fertilizer P rates for either initial soil pH level. Total fresh fruit yield for three harvests from the same six crops ranged from 10,583 to 38,083 lb/acre 423 to 1,523 boxes/acre (**Figure 1**). Yields were not significantly affected by fertilizer P rates at either of the lower two pH levels (<7.2 and 7.2-7.6). The lack of significant difference in fruit yield as affected by fertilizer P rates indicates no measureable benefit of added fertilizer P for either growth or productivity of tomato.

However, when green bean dry biomass as affected by no fertilizer P was compared with added fertilizer P, significant increases were found when initial soil pH was less than 7.2. A similar response was found with increased yield with increased fertilizer P applied at initial soil pH of less than 7.2 and greater than 7.6. The range of Mehlich 1 soil P concentrations ranged from 31 to 482 ppm for tomato and 34 to 570 ppm for green bean. The current high soil P index using Mehlich 1 extractant of 31 indicates that no P should have been needed in any plots for adequate P crop nutrition (Olsen and Santos, 2012).

A relationship of increased growth and productivity with increased fertilizer P rate existed for green beans at soil pH levels

Table 1. Tomato biomass, fruit weight and leaf phosphorus (P) at 30 day increments after planting for two crops in Fall 2008 and Spring 2009 as affected by fertilizer P rate and elemental sulfur (S) application at planting.

Fertilizer P (lb/acre)	Biomass dry weight (oz/plant)			Fruit Fresh weight (lb/plant)			Leaf P (%)		
	Elemental S Applied (lb/acre)								
	0	233	467	0	233	467	0	233	467
30 Days after planting									
0	0.47	0.41	0.38	-[Z]	-	-	0.340	0.348	0.333
24	0.43	0.44	0.48	-	-	-	0.339	0.293	0.348
37	0.49	0.55	0.52	-	-	-	0.347	0.349	0.342
49	0.51	0.53	0.51	-	-	-	0.351	0.359	0.345
Significance *(P)*	0.321	0.056	0.012	-	-	-	0.491	0.564	0.605
60 Days after planting									
0	7.63	8.03	7.24	2.67	4.49	5.67	0.350	0.346	0.345
24	8.21	8.15	7.36	2.73	4.13	6.48	0.355	0.357	0.338
37	7.20	8.13	7.97	2.93	8.91	7.49	0.297	0.399	0.345
49	6.78	8.31	8.13	2.45	7.90	7.29	0.353	0.355	0.350
Significance *(P)*	0.309	0.563	0.509	0.522	0.753	0.178	0.436	0.543	0.268
90 Days after planting									
0	10.49	10.56	10.94	25.3	28.1	21.9	0.333	0.384	0.374
24	9.62	12.00	9.56	19.0	28.5	29.3	0.332	0.369	0.345
37	9.17	11.47	10.89	21.3	30.2	23.3	0.392	0.346	0.340
49	10.25	10.78	13.81	22.5	25.7	22.7	0.333	0.402	0.342
Significance *(P)*	0.306	0.534	0.386	0.276	0.564	0.961	0.249	0.564	0.391
120 Days after planting									
0	11.06	10.15	11.62	17.6	18.4	21.0	0.309	0.435	0.300
24	10.97	11.55	12.85	17.4	20.8	23.5	0.300	0.360	0.293
37	11.33	11.70	12.97	19.3	22.5	25.9	0.383	0.231	0.334
49	12.47	11.41	13.36	24.7	16.4	27.7	0.294	0.332	0.300
Significance *(P)*	0.333	0.653	0.534	0.563	0.834	0.754	0.561	0.758	0.790

[Z]Fruit not sampled

greater than 7.0 (**Figure 2**). The same relationship did not appear to exist for tomato at soil pH greater than 7.0 when current soil P index indicated that none should occur. Thus, contradictory to current soil P index values, green bean production benefited from P applications at high soil pH. The question was would tomato production in high pH soil on soil with a high soil P index benefit from reduction of pH to levels just above the current pH recommendation for vegetables of 5.5 to 6.5 (Olsen and Santos, 2012).

Application of S at 233 and 467 pounds per acre in the planted row reduced soil pH to 7.1 and 6.8 at planting, respectively (**Figure 3**). However, soil pH returned to 7.4 to 7.6 by 60 days after planting. Dry plant biomass significantly increased with fertilizer P rate for both S application rates at 30 days after planting but was not for the no S control (**Table 1**). The higher level of significance at the higher S rate (467 pounds per acre, $P<0.05$) compared with the lower S rate (233 pounds per acre, $P<0.1$) indicated a greater affect of the higher S rate on improving plant biomass at 30 days after planting. Neither biomass nor yield was significantly different with P application rate at 60 days after planting and beyond. Leaf P concentrations were not significantly different with P and S levels for any sampling data indicating that P uptake was responsible for lower biomass weight and not lower plant P nutrition per unit leaf mass. The increase in biomass with P rate at 30 days after planting indicated an increase in availability at soil pH below 7.0 but not at pH levels above 7.0. The affect of added soil S lasted only as long as the soil pH was reduced below 7.0. Thus, these results confirm the lack of increased growth and productivity with P rate response of the previous cropping studies.

LITERATURE CITED

Agyin-Birikorang, S., G.A. O'Connor, and S.R. Brinton. 2008. Evaluating phosphorus loss from a Florida Spodosol as affected by phosphorus-source application methods. J. Environ. Qual. 37:1180–1189.

Bieleski, R.L. 1973. Phosphate pools, phosphate transport, and phosphate availability. Ann. Rev. Plant Physiol. 24:225-252.

Cushman, K.E. 2005. Basin vegetable production best management practices. Citrus and Vegetable Magazine. 69(12):20.

Daroub, S. H., Ellis, B. G., and Robertson, G. P. 2001. Effect of cropping and low-chemical input systems on soil phosphorus fractions. Soil Science. 166:281-291.

Gartley, K.L. and J.T. Sims. 1994. Phosphorus soil testing: environmental uses and implications. Commun. Soil Sci. Plant Anal. 25:1565–1582.

Graetz, D.A. and V.D. Nair. 1995. Fate of phosphorus in Florida Spodosols contaminated with cattle manure. Ecol. Eng. 5:163–181.

Mehlich, A. 1953. Determination of P, Ca, Mg, K, Na, and NH_4 by North Carolina soil testing laboratories. North Carolina Soil Test Div., Mimeo, North Carolina Dept. of Agr., Raleigh, NC.

Morgan, K.T., S. Sato and E. McAvoy. 2009. Preliminary Data on Phosphorus Soil Test Index Validation in Southwest Florida. Proc. Fla. State. Hort. Soc. 122:233-239.

Morris, D. R., Glaz, B. and Daroub, S. H. 2004. Organic matter oxidation potential determination in a periodically flooded Histosol under sugarcane. Soil Science Soc. Am .J. 68:994-1001.

Nair, V.D. and W.G. Harris. 2004. A capacity factor as an alternative to soil test phosphorus in phosphorus risk assessment. New Zealand Journal of Agricultural Research 47: 491-497.

Olsen, S.M., and Santos, B. 2012 Vegetable Production Handbook for Florida. University of Florida, Gainesville, Fla.

Rhue, R.D. and P.H. Everett. 1987. Response of tomatoes to lime and phosphorus on a sandy soil. Agron. J. 79:71–77.

SFWMD. 2006. 2007 Draft South Florida Environmental Report. West Palm Beach, Fla.

SFWMD. 2009. 2010 Draft South Florida Environmental Report. West Palm Beach, Fla.

Sharpley, A.N. 1995. Dependence of runoff phosphorus on extractable soil phosphorus. Journal of Environmental Quality 29:920-926.

Zhang, M.K., Z.L. He, D.V. Calvert, P.J. Stoffella, Y.C. Li, and E.M. Lamb. 2002. Release potential of phosphorus in Florida sandy soils in relation to phosphorus fractions and adsorption capacity. J. Environ. Sci. Health (Part A) 37:793–809.

Fumigation Practices and Challenges among Florida Tomato Growers: Survey Results

Crystal Snodgrass[1], Monica Ozores–Hampton[2], Andrew MacRae[3] and Joe Noling[4],
[1]Manatee County Extension Service, Palmetto.
[2]University of Florida, Institute of Food and Agricultural Sciences, South West Florida Research and Education Center, Immokalee, FL.
[3]University of Florida, Institute of Food and Agricultural Sciences, Gulf Coast Research and Education Center, Wimauma, FL.
[4]University of Florida, Institute of Food and Agricultural Sciences, Citrus Research and Education Center, Lake Alfred, FL., crys21@ufl.edu

INTRODUCTION

Approximately 32,400 acres of tomatoes were harvested in Florida during the 2010-2011 season representing a total value of over $564 million [Florida Department of Agriculture and Consumer Services (FDACS), 2012]. Historically, tomato growers have relied on methyl bromide (MBr) as a broad spectrum fumigant to kill soil born pests (Gilreath et al.,1994). With the Montreal Protocol and Clean Air Act, the Environmental Protection Agency (EPA) mandated a phase out of MBr by 2011. States have been allowed to apply for critical use exemptions (CUE) of MBr, however, the approved allocations have nearly diminished. In 2013, only 2.2% of the 1991 baseline was approved nationwide. The Florida nomination is only enough to cover 138 acres [U.S. Environmental Protection Agency (EPA), 2011]. In 2014 there will be no CUE exemption for Florida [Florida Fruit and Vegetable Association (FFVA), personal communication]. Several fumigant alternatives have been developed and trialed with successful outcomes. However, the use of alternatives is a delicate process and relies more on field preparation, application, and crop production practices than on fumigant selection (Snodgrass and MacRae, 2009). Currently, vegetable growers have learned to adapt to producing their crops using fumigant alternatives. However, many growers are experiencing pest problems and plant injury with their continued use. Growers are no longer able to correct the mistakes of previous seasons and must focus on sustainability as they move forward (Vallad et al., 2010).

MATERIALS AND METHODS

In 2011, a survey was conducted to: 1) determine what fumigants are being used and at what rate among Florida tomato growers; 2) determine what pest problems and crop injury issues growers may be experiencing. The survey team interviewed growers in person, by telephone, or via e-mail. Growers' responses were recorded representing 32,853 acres of the total estimated 38,200 acres in Florida (86%). Nematode, disease and weed ratings were analyzed by analysis of variance (ANOVA) and means were separated by Duncan's multiple range test at 95% confidence level using SAS (SAS 9.3 SAS Institute Inc., Cary, NC, 2011).

Table 1. Fumigant name, rate per acre, and number of acres treated for tomatoes grown in Florida during 2010-2011 season.

Fumigant	Rate/acre	Acres treated
Methyl bromide 98:2	NU[z]	-
Methyl bromide 67:33	NU	-
Methyl bromide 50:50	200 lb	15,336
Vapam	50 gal	50
K-Pam	42 gal	664
Telone C35	NU	-
Inline	NU	-
Telone II	NU	-
Telone EC	NU	-
Midas 50/50	180 lb	500
Midas 98/2	NU	-
PicClor 60[y]	202 lb	14,380
PicClor 60EC[x]	195 lb	1,232
Metapicrin	130 lb	166
Total	-	32,328

z NU= not in use.
y PicClor 60= 1,3 Dichloropropene 39% and Chloropicrin 59.6%.
x PicClor 60 EC= 56.7% Chloropicrin and 1,3 Dichloropropene 37.1%.

Table 2. Fumigant effectiveness on nematodes, diseases, and weeds in tomatoes grown in Florida during 2010-2011 season.

Fumigant	Nematodes	Diseases	Weeds
	(1 – 10 scale)[z]		
Methyl bromide 98:2	9.4a[y]	9.4a	9.4a
Methyl bromide 67:33	8.8a	8.8ab	8.7ab
Methyl bromide 50:50	7.3ab	7.3abc	6.8abc
Vapam	3.7bcd	5.3abc	5.3abc
K-Pam	2.5d	5.5abc	6.3abc
Telone C35	7.5ab	6.0abc	4.0c
Inline	7.0ab	7.0abc	7.0abc
Telone II	8.0a	5.0bc	5.0bc
Midas 50/50	7.4ab	6.6abc	6.0abc
Midas 98/2	5.5abcd	4.5c	4.8bc
PicClor 60[x]	6.8abc	6.4abc	5.4abc
PicClor 60EC[w]	6.5abc	6.5abc	8.5ab
Metapicrin	3.0cd	7.0abc	0.0d
P-value	0.0009	0.02	0.002
Significance	***	*	**

z Scale: 0=no control and 10=complete control.
y Within columns means followed by different letters are significantly different according to Duncan's multiple range test at 5%.
x PicClor 60= 1,3 Dichloropropene (39%) and Chloropicrin (59.6%).
w PicClor 60 EC= 1,3 Dichloropropene (37.1%) and Chloropicrin (56.7%).
NS *, **, *** Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

RESULTS AND DISCUSSION

FUMIGANT USAGE

Of the 32,853 acres surveyed 4,198 acres were double cropped with melons. The use of alternatives did not affect growers' ability to double crop. When asked what type of plastic mulch was used, 31% used standard, 51% used virtually impermeable film (VIF), and 18% used metalized. When asked whether or not they have experienced crop injury with alternatives only 24% of growers had when using PicClor 60 (1,3 Dichloropropene 39% and Chloropicrin 59.6%). Injury has occurred in all seasons, and conditions were typically low temperatures and high soil moisture. Injury was also due to herbicide toxicity when using PicClor 60 EC (56.7% Chloropicrin and 1,3 Dichloropropene 37.1%). Growers were asked to identify which fumigants and rates they used in the 2010/2011 season. MBr 50:50 and PicClor 60 comprise the majority of the acreage surveyed with 47.5 and 4.5%, respectively (**Table 1**).

PEST CONTROL

Growers were asked to identify alternative fumigants used in the previous 10 years and rate them for nematode, disease, and weed control on a scale of 1-10 (1=no control, 10=complete control). The lowest nematode controls were from Vapam, K-pam and Metapicrin (**Table 2**). The lowest disease controls were from Telone II and Midas 98/2. The lowest weed controls were from Telone C35, Telone II, Midas 98/2 and Metapicrin. Primary pest problems identified were: Fusarium wilt, Fusarium crown rot, nutsedge, southern blight, and root knot nematode (**Table 3**). Growers indicated that pest problems were increasing. Growers were asked to indicate average production losses due to pests associated with alternatives and indicated average losses of 8%. Growers were asked if they thought a periodic cleanup with MBr would effectively resolve pest problems indicated (example MBr 67:33 at 175 lb/treated acre = 101.5 lb/planted acre). All agreed that a rescue treatment was needed. Finally, we asked if in their opinion the future of vegetable and fruit production in Florida requires the use of fumigation and if there is a true alternative for MBr. They indicated that yes, fumigation is needed for the success of production and no there is no true alternative. If an alternative fumigation must be selected PicClor 60 was the most effective.

CONCLUSIONS

Based on survey results, growers successfully used fumigant alternatives in the 2010/2011 season. The most commonly used fumigants were MBr 50:50 and PicClor 60. The majority of growers are currently using VIF mulch. Effectiveness of several alternatives is enhanced with the use of VIF mulch. The most commonly used fumigants in tomato only received average ratings. This is probably due to high cost and/or availability of more highly rated fumigants. Although growers have used alternatives successfully, pest problems are increasing and growers are experiencing production losses. Growers may need a periodic clean-up of MBr for problem pests in order to produce their crops sustainably.

REFERENCES

Environmental Protection Agency. 2011. 2013 nomination from the phaseout of methyl bromide. 25 June 2013. http://www.epa.gov/ozone/mbr/2013_nomination.html

Florida Department of Agriculture and Consumer Services. 2012. 2012 Florida agriculture by the numbers. 25 June 2013. http://www.florida-agriculture.com/brochures/P-01304.pdf

Gilreath, J.P., J.P. Jones, A.J. Overman. 1994. Soil-borne pest control in mulched tomato with alternatives to methyl bromide. Proc. Fla. State Hort. Soc. 107:156–159.

Locasio, S.J., J.P. Gilreath, D.W. Dickson, T.A. Kucharek, J.P. Jones, and J.W. Noling. 1997. Fumigant alternatives to methyl bromide for polyethylene-mulched tomato. HortScience. 32:1208-1211.

Snodgrass, C.A. and A.W. MacRae. 2009. Factors affecting a fumigant performance. Growing Produce - Florida Grower. 25 June 2013. http://www.growingproduce.com/article/8637/factors-affecting-fumigant-performance

Vallad, G., A.W. MacRae, T. Jacoby, and J.W. Noling. 2010. Sustainability of methyl bromide alternatives - tomato and pepper initial crop. Proc. Annu. Intl. Res. Conf. Methyl Bromide Alternatives Emissions Reductions. 49:1-2.

Table 3. Major pest problems, acreage affected, increase of pest problem, fumigant usage, production losses, and additional control measurements for tomatoes grown in Florida.

Pest problem	Acres affected 2010-2011	Pest problem increasing	Fumigants used in 2010-2011 in areas with pest problems	Production losses (%)	Additional control measures
Nutsedge	7,654	Y[z]	MBry 50:50/PicClor 60[x]	10.2	Dual/Sandea/Roundup /handweeding
Root knot nematode	676	Y/N	MBr 50:50	22.0	Vydate
Sting nematode	59	Y	MBr 50:50/Kpam	15.3	Dazital
Charcoal rot	55	Y/N	MBr 50:50/PicClor 60	0.0	No treatments
Phytophthora	762	Y	MBr 50:50/PicClor 60	7.5	Ridomil/Nutriphite
Fusarium wilt	2,887	Y	MBr 50:50/PicClor 60	14.1	Ridomil
Southern blight	1,680	Y	PicClor 60	9.8	No treatments
Bacterial wilt	650	Y	PicClor 60	5.0	No treatments
Fusarium crown rot	2,347	Y	PicClor 60	4.4	Resistant varieties/Ridomil
Purslane	1,985	Y	PicClor 60/MBr 50:50	1.5	Herbicides/hand weeding
Smartweeds	960	Y	PicClor 60	1.5	Clethodim
Carolina geranium	20	Y	MBr 50:50	10.0	Hand weeding
Other	1,000	Y	PicClor 60/MrBr 50:50	0.0	No treatments
Total/average	20,735	Y	-	8.0	-

ZY= yes and N= no.
yMBr= methyl bromide.
xPicClor 60= 1,3 Dichloropropene 39% and Chloropicrin 59.6%.

Improved Nutsedge Control on Bed Edges with Metam Potassium and Soil Surfactants

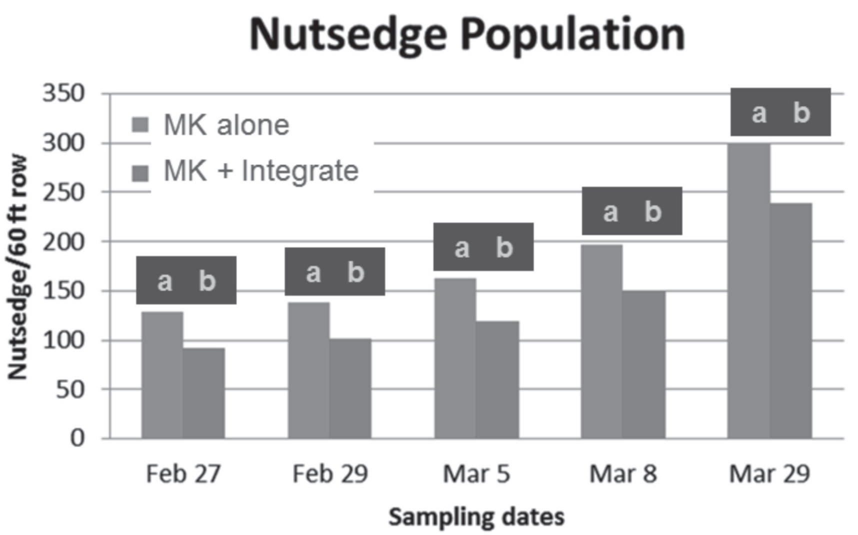
Bielinski M. Santos, Tyler P. Jacoby, and Nathan S. Boyd
University of Florida, Gulf Coast Research and Education Center, Wimauma, FL, bmsantos@ufl.edu.

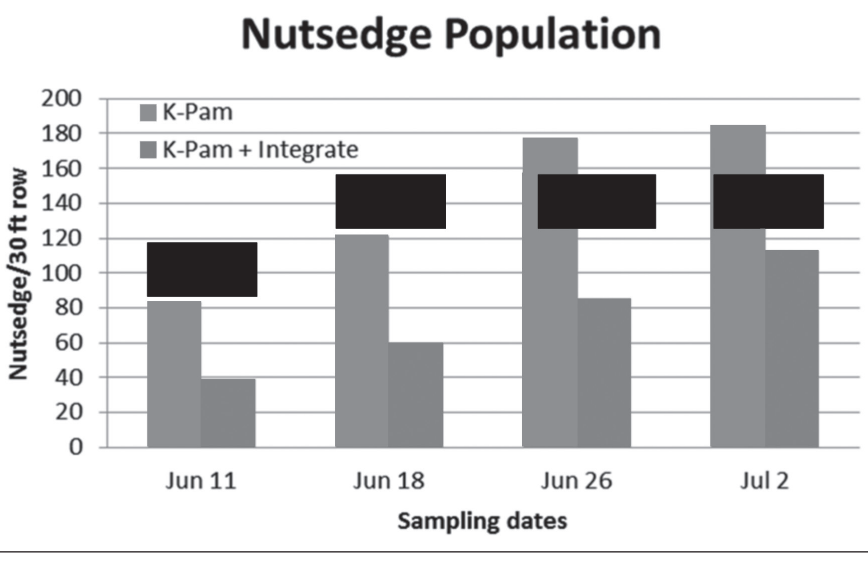
INTRODUCTION

Florida is the second largest fresh market vegetable and small fruit producing state in the country. More than 30,000 acres of tomato (*Solanum lycopersicum*) are planted each year in Florida (NASS, 2012). Soil fumigation is the cornerstone for management of soilborne pests, including weeds in production fields. Growers have historically relied on methyl bromide but with the loss of it due to environmental concerns, most growers have adapted their management programs based on 1,3-dichloropropene (1,3-D), chloropicrin (Pic), and metam potassium. These three fumigants lack the robust broad-spectrum activity that methyl bromide possessed, even when combined together in one system.

Purple and yellow nutsedge are two economically important weeds in tomato. They are the most invasive weeds of fruiting vegetable crops in the southern U.S., competing for light, water, and nutrients (Webster, 2006). Previous research demonstrated that high nutsedge populations can reduce pepper yields up to 73% (Morales-Payan et al., 1998; Motis et al., 2003) and tomato yields by 51% (Gilreath and Santos, 2004). Most small fruit and vegetable growers in Florida rely on 1,3-D, Pic, or isothiocyanate (ITC) generators as alternatives to methyl bromide and are looking for ways to improve the efficacy of these fumigants on weeds and other soilborne pests while reducing costs and regulatory burdens (Snodgrass et al, 2011)

Figures 1-2. Impact of metam potassium with or without Integrate on nutsedge density over time in the spring of 2012.

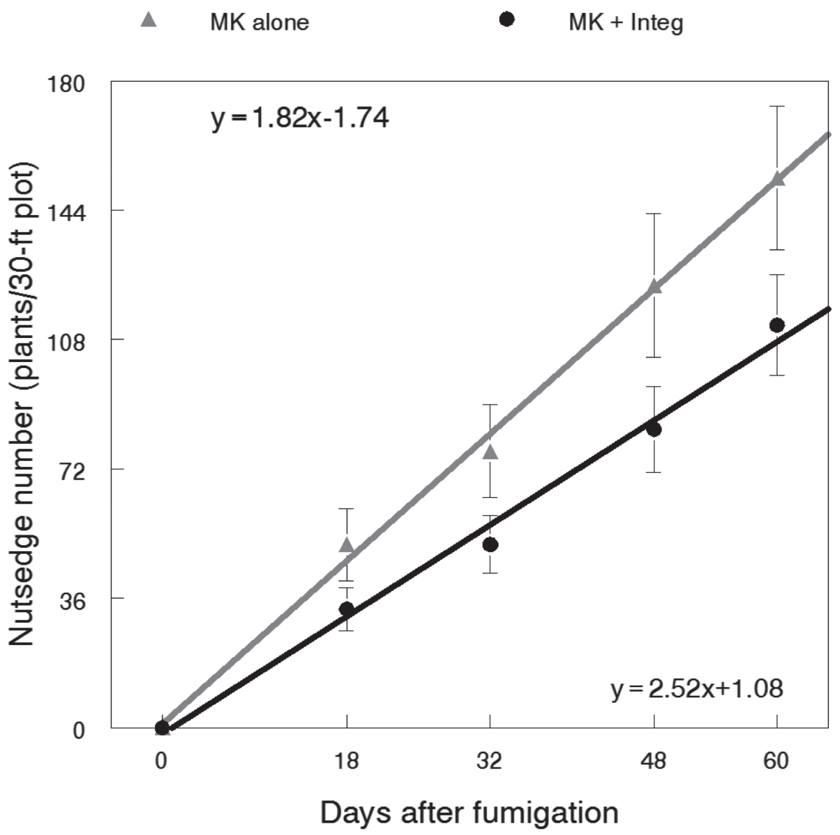




Metam potassium is an ITC-generator that provides adequate to excellent nutsedge control when the tubers are exposed at the appropriate concentration (Santos and Gilreath, 2007). Metam potassium can be sprayed or rototilled into the soil but drip application provides the most consistent level of control. Research has been done to evaluate optimal rate and placement to reduce problems associated with inconsistent pest control. Adequate bed coverage can be achieved with drip application when two or more drip tapes are utilized on the bed tops and injected with a water volume of 1 acre-inch/acre or more at a concentration of 5000-6000 ppm in water. The combination of concentration and duration ultimately determines metam potassium efficacy.

When applied through drip irrigation, metam potassium breaks down as a weak gas and moves laterally in beds as far as the water front allows which can be challenging in deep sandy soils where tomato, pepper, and strawberry are produced. As a result of poor lateral movement, metam potassium effectively controls nutsedges at the bed center but fails to do so at the bed edges. A three-year study showed a significant increase in nutsedge shoot emergence over time in tomato for four of the most used fumigant systems and was likely attributed to the thriving nutsedge tubers that originated from the under-fumigated bed edges (Jacoby, 2012). Therefore, alternative practices to increase lateral movement of metam potassium must be devised to improve nutsedge control on bed edges. Potential alternatives include the use of soil surfactants and different bed configurations, such as reduced bed widths, to help improve the lateral movement of drip-applied fumigants. It is well known that a single drip tape cannot cover the width of a 28 in. bed top (MacRae, 2010). However, with the use of a surfactant, this coverage could be achieved. Integrate® is designed to reduce water surface tension and improve lateral movement. This surfactant is made of alkoxylated polyols and glucoethers and can be applied through drip irrigation or a conventional sprayer.

Figure 3. Nutsedge shoot emergence from 0 to 60 days following fumigation with metam potoassium with and without Integrate.



The objective of this study was to evaluate the performance of metam potassium against nutsedge when Integrate® was applied to the soil.

MATERIALS AND METHODS

Three trials were initiated in the spring of 2012 at the Gulf Coast Research and Education Center of the University of Florida, in Wimauma, Florida to evaluate the performance of metam potassium against nutsedge when Integrate® was applied to the soil. The treatments included a) metam potassium (60 gal/acre and 5.5% v/v), b) Integrate® (1 gal/acre and 5.5% v/v) followed by metam potassium, and c) a non-fumigated control (water only). Both treatments were applied to plastic covered raised beds through a hydraulic injector (Dosatron®, Dosatron International, Inc., Clearwater, FL) using single drip tape (0.45 gal/100 ft/acre) containing 1 ft between emitters, with Integrate® being injected one to two days before metam potassium. Plots were 30 and 60 ft long, and arranged in a randomized complete block design with six replications per treatment. The majority of the nutsedge population was purple nutsedge.

RESULTS AND DISCUSSION

After one hour of irrigation through a single drip tape, the control provided 31% coverage of the soil moisture field compared to the Integrate® treatment which increased coverage to 52% of the soil moisture field. Six weeks after treatment in the spring of 2012, the nutsedge population in the untreated was >350 nutsedge shoots per 60 feet of row. The metam potassium and metam potassium plus Integrate® treatments had 300 and 240 nutsedge shoots per 60 ft of row (**Figure 1**). The nutsedge population in the Summer of 2012 showed the same trend over all sampling dates as the spring of 2012 with the addition of Integrate® significantly reducing nutsedge density (**Figure 2**). At five weeks after treatment in the Summer 2012, soil moisture was significantly higher on the middles and sides of the beds in the metam potassium plus Integrate® plots, compared to the metam potassium alone plots. In the Fall of 2012, at 60 days after fumigation there was a 30% difference in nutsedge population between the metam potassium alone and metam potassium plus Integrate® treatments, showing the positive effect of the soil surfactant.

Nutsedge control was improved by 25-30% when Integrate® was combined with metam potassium due to increased lateral movement of the metam potassium carried in water (**Figure 3**). Improved fumigant efficacy should enable reduced reliance on post emergence weed management with products such as Sandea.

CONCLUSION

Metam potassium is recommended to control purple and yellow nutsedges (*Cyperus rotundus* and *C. esculentus*) in fumigated beds. When metam potassium is injected through the drip lines, untreated strips on the sides of beds occur. Integrate® (triblock co polymer 61% and glucoethers 19%) is a liquid polymer used to improve soil wetting. The objective of this study was to evaluate the performance of metam potassium against nutsedge when Integrate® was applied to the soil. Treatments consisted of: a) metam potassium (60 gal/acre and 5.5% v/v), b) Integrate® (1 gal/acre and 5.5% v/v) followed by metam potassium, and c) a non-fumigated control. Integrate was applied 1 day before the fumigant. Addition of Integrate to the soil prior to the fumigation improved nutsedge control and soil moisture at 5 inches deep in the both trials. Plots treated with the soil surfactant and metam potassium had 50, 52 and 39% less nutsedge than plots treated with metam potassium only.

REFERENCES

Gilreath, J.P. and B.M. Santos. 2004. Efficacy of methyl bromide alternatives on purple nutsedge control (*Cyperus rotundus*) in tomato and pepper. Weed Technol. 18:141-145

Santos, B.M. and J.P. Gilreath. 2007. Effects of water delivery volume, rates and concentrations of metam potassium on purple nutsedge emergence in mulched beds. Hort. Technol. 17, 191-194

Jacoby, T.P. 2012. Evaluation of the long term sustainability of methyl bromide alternatives in tomato (*Solanum lycopersicum* Mill.) and pepper (*Capsicum annuum* L.). M.S. Thesis, University of Florida, Gainesville, Florida.

Morales-Payan, J.P., Santos, B.M., Stall, W.M., and Bewick, T.A. 1998. Influence of purple nutsedge (*Cyperus rotundus*) population densities on bell pepper (*capsicum annuum*) yield as influenced by nitrogen. Weed Technol. 12:230-234.

Motis, T.M., S.J. Locascio, J.P. Gilreath, and W.M. Stall, 2003. Season-long interference of yellow nutsedge (*Cyperus esculentus*) with polyethylene-mulched bell pepper (*Capsicum annuum*). Weed Technol. 17:543-549.

Snodgrass, C., Ozores-Hampton, M., MacRae, A., Noling, J., Whidden, A., and McAvoy, G. 2011. Current fumigation practices among tomato, strawberry and pepper growers: Survey results. Presentation at the 2011 Florida AgExpo, UF/IFAS Gulf Coast REC, Wimauma, FL.

http://flagexpo.ifas.ufl.edu/2011/AgExpo2011presentations/Fumigation%20survey%20presentation.pdf

Webster, T.M. 2006. Weed survey – southern states: vegetable, fruit, and nut crops subsection. In: Proc. South. Weed Sci. Soc., San Antonio, TX 260-277.

Weed Control Strategies in Tomato

Peter J. Dittmar[1]. [1]University of Florida Horticultural Sciences Department, Gainesville, FL. pdittmar@ufl.edu.

INTRODUCTION

Yellow and purple nutsedge are the most problematic weeds in tomato production. The phase-out of methyl bromide has required the use of Eptam (EPTC), Sandea (halosulfuron), and Dual Magnum/Brawl (S-metolachlor) by tomato growers for control of these problematic weeds. Recently, Reflex (fomesafen) and League (imazosulfuron) have been registered in tomato and pepper.

League provides control of broadleaf weeds and nutsedge. In tomato, League can be applied pre-transplant or post-transplant, however, only one application per year is allowed. A pre-transplant application can be made under the plastic mulch and tomato can be planted 1 day after application. If applying post-transplant make the application "over the top" of the crop between 3 to 5 days after transplanting and early bloom. In pepper, League is registered post-transplant only. Apply after the pepper plants are 10 inches tall directing the spray solution to the bottom 2 inches of the plant avoiding contact with the pepper fruit. Tomato and pepper have a 21 day pre-harvest interval. Crop rotation is 5 months for cantaloupe and cucumber and 9 months for cabbage and squash. Consult the label for other crop rotation restrictions.

Reflex controls broadleaf weeds, grasses, and nutsedge. Reflex herbicide is an indemnified label for tomato and pepper in Florida. To use in tomato and pepper, growers must sign the appropriate paper work through the Syngenta website. Consult a Syngenta representative for the exact process. Reflex is also registered in dry beans, snap beans, and potato. In tomato and pepper, apply Reflex to a finished bed before laying the plastic mulch. Reflex may also be applied pre-plant over the top of the mulch, but the mulch must be washed or 0.5 inches of rain must occur. Do not apply Reflex in Miami-Dade County. Apply Reflex 70 days before harvest. Reflex has an 18 month rotation restriction for cucurbit crops and sorghum and 10 month restriction for corn.

MATERIALS & METHODS AND RESULTS

The first trial was conducted at Plant Science Research and Education Center, Citra, FL to investigate the inclusion of Reflex in a Florida production system. Reflex at 1 pt./acre and Dual Magnum at 1 pt./acre were applied under the plastic on March 28, 2011. Tomato 'BHN602' was transplanted on April 4, 2011. Post-transplant application of Sandea at 0.75 oz/acre was directed to the base of the tomato plants. Nutsedge control and crop injury were evaluated on April 11, 15, 22, and 29; May 27; Jun 10 and 17. Tomatoes were harvested on June 21 and 27. Dual Magnum and Reflex have similar control of nutsedge at 11 to 25 days after the PRE treatment. Late in the season an application of Sandea increased the control of nutsedge. In the PRE only treatments, nutsedge control was 0%, however, the application of Sandea increased control to 86 to 98%. No differences in yield (46,451 to 62,783 lb/acre) were observed among all the treatments (**Table 1**).

In a second trial, Dual Magnum, Reflex, and Sandea were applied PRE under the plastic. The rates and timing were similar to the first trial. Including Sandea PRE along with Dual Magnum or Relfex did not increase the length of control compared to the first study. Again, a POST application increased nutsedge control later in the season. No differences in yield (51,953 to 62,952 lb./acre) were observed among the herbicides (**Table 2**).

DISCUSSIONS

Reflex has similar levels of control and a similar weed species control spectrum compared to Dual Magnum. However, Reflex provides an important tool for rotation of herbicide mode of action. The inclusion of a POST herbicide such as Envoke, League, Matrix, or Sandea is important for season long control. The reduction in nutsedge will reduce competition with the tomato leading to better yields. Control of nutsedge in the crop is important for reducing the number of tubers that will be present in the field for the next crop.

Table 2. Effect of Dual Magnum, Reflex, and Sandea PRE under the plastic on percent nutsedge control.

	Days after PRE/Days after POST					
Treatment	11/-	18/-	25/-	60/10	74/24	81/31
	(%)					
Weed free	100az	100a	100a	100a	100a	100a
Weedy	0c	0e	0e	0c	0c	0c
Dual Magnum	93a	79c	65c	0c	0c	0c
Reflex	94a	85bc	73bc	0c	0c	0c
Dual Magnum + Reflex	96a	91b	81b	0c	0c	0c
Sandea	53b	45d	31d	0c	0c	0c
Dual Magnum + Sandea	94a	83bc	79b	0c	0c	0c
Reflex + Sandea	93a	89bc	76bc	0c	0c	0c
Dual Magnum + Reflex + Sandea	96a	88bc	75bc	0c	0c	0c
Sandea fb. Sandea	58b	51d	34d	88b	93b	85b

z Within columns, means followed by different letters are significantly different.

Table 1. Effect of Dual Magnum and Reflex PRE under the plastic followed by Sandea POST-directed on percent nutsedge control.

	Days after PRE/Days after POST					
Treatment	11/-	18/-	25/-	60/10	74/24	81/31
	(%)					
Weed free	100az	100a	100a	100a	100a	100a
Weedy	0c	0d	0e	0c	0c	0d
Dual Magnum	94a	80b	60c	0c	0c	0d
Reflex	89a	81b	66bc	0c	0c	0d
Dual Magnum+ Reflex	90a	80b	71b	0c	0c	0d
Sandea POST	0c	0d	0e	86b	96ab	90c
Dual Magnum fb. Sandea	93a	80b	73b	88b	96ab	93bc
Reflex fb. Sandea	88a	90b	75b	85b	93b	93bc
Dual Magnum +	94a	81b	71b	84b	98ab	98ab
Sandea fb. Sandea	63b	54c	46d	91b	95ab	95bc

z Within columns, means followed by different letters are significantly different.

A Recent Survey of *Xanthomonads* Causing Bacterial Spot of Tomato In Florida Provides Insights Into Management Strategies.

G.E. Vallad[1], S. Timilsina[1,2], H. Adkison[1], N. Potnis[2], G. Minsavage[2], J. Jones[2], and E. Goss[2]
[1]Gulf Coast Research and Extension Center, University of Florida, Wimauma, FL
[2]Department of Plant Pathology, University of Florida, Gainesville, FL, gvallad@ufl.edu

INTRODUCTION

Few diseases cause Florida tomato growers consistent seasonal losses like bacterial leaf spot (BLS). A previous study estimated that monetary losses attributed to BLS at nearly $3,000 per an acre (VanSickle et al. 2009). Such losses are unsustainable, in the face of narrowing profit margins and increased competition from tomato imports. Management options are limited, and mostly center around frequent applications of copper mixed with the dithiocarbamate fungicide, mancozeb. Unfortunately, this reliance on copper has led to the spread and establishment of copper tolerant *Xanthomonas* strains throughout Florida (Stall et al. 1986). Efforts over past decades to improve copper efficacy through formulation improvements have done little to resolve the problem.

Some non-copper alternatives have shown promise, but commonly give inconsistent levels of control with little or no economic return. The most promising of the non-copper alternatives tested to date has been the compound acibenzolar-S-methyl (ASM). ASM works indirectly against the pathogen by systemically activating plant defenses against the pathogen through a process called systemic acquired resistance (SAR). Although, the effectiveness of ASM against *Xanthomonas* spp. is well documented, growers have been reluctant to adopt this product due to associated yield reductions and the additional expense of using ASM compared to copper-based bactericides (Louws et al. 2001). However, recent studies found that weekly applications of ASM at lower rates addressed these concerns (Huang et al. 2012). Regardless, control with ASM alone is not adequate, especially when weather conditions are conducive for rapid disease development (high rain, relative humidity and temperatures).

Several bactericidal compounds have demonstrated efficacy in field trials, including streptomycin sulfate, kasugamycin and quinoxyfen. Streptomycin sulfate is a well known aminoglycoside antibiotic that was widely used for bacterial spot in the 1950's, but was restricted to transplant production due to the rapid development of resistant *Xanthomonas euvesicatoria* strains in Florida (Thayer and Stall, 1962). A recent 2006 survey of 377 *Xanthomonas* strains from 20 tomato fields throughout Florida found that the BLS population consisted of only X. *perforans*, of which only 20 strains were resistant to streptomycin sulfate; whereas all strains were copper tolerant (Horvath et al. 2012). This survey along with results from recent field trials, indicate that streptomycin sulfate could be used as a viable control option once more, as long as effective measures could be deployed to prevent the buildup of resistant strains. The commercial bactericide Kasumin 2L, containing the aminoglycoside antibiotic kasugamycin (2.3%), has also shown promise against bacterial spot (Vallad et al., 2010), but resistant strains were recovered during the trials and the extent of this resistance throughout Florida is unknown. Kasumin 2L registration is expected, but restrictive labeling and lack of effective partners for resistance management may restrict its utility for bacterial spot control. Quintec, which contains the fungicide quinoxyfen, is a third promising product that was recently labeled for bacterial spot of pepper (Sanders and Langston, 2009), with efforts to expand labeling on tomato. In tomato field trials, Quintec alone was 15 – 20% more effective at controlling bacterial spot than the grower standard copper treatment (G. Vallad, unpublished data). While the exact mode of activity for quinoxyfen is unknown, it is assumed to be antibacterial due to its structural similarity to quinolone antibiotics.

Efforts are underway to register products like Kasumin 2L and Quintec for field production. However, due to the antibacterial activity of these products, resistance management will be a big concern. Because of the wide-spread prevalence of copper tolerance among *Xanthomonas* on tomato, simply rotating or mixing these products with copper will not prevent the buildup of insensitive strains. Our current research efforts are focused on using an integrated approach of combining bactericidal products with plant defense activators, and other biological control agents to manage bactericide resistance and to improve overall control of bacterial spot. Although similar strategies are commonly employed to manage pesticide resistance among many fungal and insect pathogens, the lack of effective compounds has made this approach infeasible for managing bacterial pathogens.

The long-term goal of the work described herein is to provide growers effective integrated strategies for managing BLS that incorporate non-copper bactericides with plant defense elicitors, and improved application strategies that limit disease development and minimize bactericide resistance in the pathogen population. In order to develop rotational strategies, a state-wide survey of BLS causing xanthomonads was conducted to ascertain sensitivity to copper, streptomycin, kasugamycin, and quinoxyfen. This survey also presented an additional opportunity to assess the diversity of BLS causing xanthomonads in Florida, information useful for tomato breeding programs and for identifying any novel strains.

MATERIALS & METHODS

With the aid of growers, consultants, and county extension agents, nearly 225 tomato samples were collected throughout the state from field and transplant production facilities from 2011 to 2012. Disease lesions from leaves and fruit were surface sterilized, excised, homogenized, and plated onto a semi-selective medium to isolate xanthomonads or other bacteria. After processing and storing, 176 *xanthomonas* strains were collected of which 175 were confirmed to be pathogenic. Strains were tested for sensitivity to copper, streptomycin, kasugamycin (Kasumin 2L), and quinoxyfen.

Strains were assayed for copper resistance using a standard procedure in which streaked bacterial suspensions that grew on a nutrient agar amended with 200 ppm of $CuSO_4$ were considered copper tolerant. Strains that grew on nutrient agar amended with 200 ppm streptomycin

Table 1. Summary of Xanthomonas strains collected from tomato plants and seedlings during the 2011-2012 survey of Florida tomato production areas.

			Field	Isolations	All
Production Area	Represented Counties	Transplant	Leaf	Fruit	Strains
North	Gadsden		24		24
West Central	Hillsborough, Manatee, Hardee	13	62	7	82
South	Collier, Hendry, Lee	30	40		70
	Total	43	126	7	176

sulfate or 100 ppm kasugamycin (based on Kasumin 2L) were also considered resistant. A subset of 16 strains was evaluated further on media amended with technical grade kasugamycin at 25, 50, and 100 ppm rates. As no protocol exists for evaluating strain sensitivity to quinoxyfen, the same subset of 16 strains were evaluated on amended media as described above at 200 and 400 ppm rates of technical grade quinoxyfen or Quintec (22.6% quinoxyfen) alone or when mixed with CuSO4 (200 ppm). Race determination was based on the reaction observed following infiltration of strains into leaves of tomato genotypes H7998, 216 (near isogenic line to Fl 7060 containing Xv3), 716 (near isogenic line to Fl 7060 containing Xv4) and Bonnie Best (susceptible to all known tomato races) to each strain (Stall et al., 2009).

Initial genotypic characterization of 16 representative strains for species and strain variation was also performed using multi-locus sequence analysis (MLSA) based on sequences of the fusA, gapA, gltA, gyrB, lacF, and lepA genes as described by Almeida et al. (2010). In addition, effector loci important for strain pathogenicity and virulence were also sequenced. Strain sequence information, in addition to sequence information from reference *Xanthomonas* strains were utilized to ascertain phylogenetic relationships.

RESULTS AND DISCUSSION

Of the 175 pathogenic *Xanthomonas* strains in the survey, 14%, 46% and 40% were collected from North, West Central, and South Florida production areas, respectively. Three-fourths of the strains were isolated from the field samples including seven from fruit, while the other quarter originated from transplant facilities. A county by source breakdown is provided in **Table 1**. All strains were determined to be *Xanthomonas perforans* race 4, based on the response of individual strains on tomato differentials and confirmed with MSLA of the 16 representative strains (data not shown). This is a significant change from a previous survey of 377 strains in 2006-07 (Horvath et al. 2012) that documented a 2:1 ratio of race 4 to 3 strains throughout Florida and South Georgia. This strongly suggests that race 4 strains are more fit than race 3 strains of X. *perforans* within the production environment to account for such a rapid change in 6 years. However, such changes in BLS populations are not new to Florida, especially considering that prior to the early 1990s, when X. *perforans* was first detected; X. *euvesicatoria* race 1 was the cause of BLS on tomato (Jones et al. 1998; Hert et al. 2005).

Consistent with the 2006 survey (Horvath et al. 2012), copper tolerance was predominant. The addition of 200 ppm CuSO4 to media reduced strain growth by only 10% on average. However, a single strain collected from the UF Tomato Breeding plots at the Gulf Coast REC, was determined to be copper sensitive since it failed to grow on the CuSO4 amended media. Overall, the frequency of strains resistant to 200 ppm streptomycin increased from 5% in 2006 to 32% in 2011. Two-thirds (37 out of 56 strains) of the streptomycin resistant strains were collected from transplant facilities that had a higher frequency of 86% streptomycin resistant strains compared to only 14% in production fields; more in line with the 2006 field survey. These results demonstrate the need for effective materials for transplant production to limit the buildup of streptomycin resistance. The discrepancy in the frequency of resistant strains between transplant and field populations also suggest a fitness cost associated with streptomycin resistance at the field level. Averaged across all field strains, streptomycin sulfate reduced *Xanthomonas* growth on amended media by 88%.

Initial strain screening followed the protocol of Vallad et al. (2010) using media amended with Kasumin 2L (2.3% kasugamycin) to give a final kasugamycin concentrations of 25, 50 and 100 ppm. With increasing kasugamycin levels, an increased reduction in strain growth and decreasing frequency of insensitive strains was observed. Kasumin 2L applied to media at 25 and 50 ppm kasugamycin equivalent rate reduced strain growth on average by 59 and 99%, respectively. None of the strains grew on media amended at a 100 ppm kasugamycin equivalent rate of Kasumin 2L. Interestingly, a recent study used a technical grade kasugamycin in a semi-selective media for assessing populations of X. citri on citrus (Behlau et al. 2012), since X. citri exhibited a high level of resistance to kasugamycin. A set of 16 strains were tested for sensitivity to technical grade kasugamycin using media amended with 25, 50, and 100 ppm rates. Unlike media amended with Kasumin 2L at a 100 ppm kasugamycin equivalent rate that inhibited growth of all strains, media amended with an equivalent rate of technical grade kasugamycin still supported significant

Table 2. Effect of quinoxyfen (technical grade or commercially formulated) and kasugamycin (technical grade) on the growth of Xanthomonas perforans strains (n = 16).

Media[z]	Log-normal CFU[y]	Media[x]	Log-normal CFU
Non-amended	5.52a[w]	non-amended	5.72a
Quin., 200 ppm	5.50ab	Kasug., 25 ppm	5.62b
Quin., 400ppm	5.48b	Kasug., 50 ppm	5.57b
Quin., 200 ppm + CuSO4, 200 ppm	3.84c	Kasug., 100 ppm	4.70c
Quin., 400 ppm + CuSO4, 200 ppm	3.32d		
	Pmedia < 0.0001		Pmedia < 0.0001
	Pstrain < 0.0001		Pstrain < 0.0001
	Pmedia x strain < 0.0001		Pmedia x strain < 0.0001

z Quinoxyfen (Quin.) amended nutrient agar media prepared by adding either technical grade quinoxyfen dissolved in acetone or commercial Quintec (22.6% quinoxyfen). Rates based on quinoxyfen.

y Colony forming units (CFU) per petri-dish.

x Kasugamycin (Kasug.) amended nutrient agar prepared by adding technical grade kasugamycin to the specific rate.

w Column values followed by the same letter do not differ at the 95% level of confidence.

growth; although it was statistically reduced relative to non-amended media (**Table 2**). Among the 16 strains tested on technical grade kasugamycin, there was significant strain by media interaction (**Table 2**). Several strains were resistant to technical grade kasugamycin, even at the 100 ppm level. Furthermore, strain resistance to technical grade kasugamycin at 100 ppm did not correspond to tolerance to Kasumin 2L at the 50 ppm kasugamycin equivalent rate; raising the question of whether another mode of action is involved with the Kasumin 2L formulation.

The same set of 16 strains tested against technical grade kasugamycin were further tested for sensitivity against technical grade quinoxyfen and the fungicide Quintec (22.6% quinoxyfen) at 200 and 400 ppm rates alone, or mixed with 200 ppm $CuSO_4$. Results using Quintec and technical grade quinoxyfen did not differ statistically ($P = 0.1935$), so data was pooled. The addition of quinoxyfen alone to media at levels of 200 and 400 ppm had little impact on strain growth. However, the addition of quinoxyfen at both rates with $CuSO_4$ increased copper efficacy from less than 10% to near 90% on amended media (**Table 2**). Again, a significant strain by media interaction (**Table 2**) was detected, and several strains exhibited tolerance to media amended with both $CuSO_4$ and quinoxyfen.

Survey results serve to demonstrate the evolving nature of X. *perforans* populations. Since the last survey of tomato production fields in 2006, X. *perforans* race 4 appears to have displaced X. *perforans* race 3 strains for unknown reasons. Copper tolerance is still highly prevalent in Florida, with all but 1 strain exhibiting a high level of tolerance. Resistance to streptomycin increased nearly 3-fold since 2006 among strains collected from the field. Whereas, 86% of the strains collected from tomato transplants were resistant to streptomycin reflecting current usage on tomato transplants but not field plants. These findings highlight the immediate need to register additional bactericidal products for managing BLS in transplant and field production.

Kasugamycin and quinoxyfen both showed merit in suppressing bacterial growth in these studies. The commercial formulation of Kasumin 2L was far superior in suppressing the growth of X. *perforans* in amended media than technical grade kasugamycin at equivalent levels. Quinoxyfen appears to exhibit little bactericidal activity against X. *perforans* alone, but appears to synergize with $CuSO_4$. Ongoing trials are testing the merit of these products alone and within integrated programs to manage bacterial spot and to manage bactericide resistance in field populations of X. *perforans*.

ACKNOWLEDGMENTS

The authors would like to extend their gratitude to personnel at Glades Crop Care, KAC Agricultural Research, and Agricultural Crop Consulting, Inc., and to local tomato growers, county extension agents, and other industry personnel throughout Florida that submitted tomato samples for the survey. This research was supported with funds provided through the USDA State Specialty Crop Block Grant Program awarded by the Florida Department of Consumer and Agricultural Services, with administrative support from the Florida Specialty Crop Foundation.

REFERENCES

Almeida, N. F., Yan, S. C., Cai, R. M., Clarke, C. R., Morris, C. E., Schaad, N. W., Schuenzel, E. L., Lacy, G. H., Sun, X. A., Jones, J. B., Castillo, J. A., Bull, C. T., Leman, S., Guttman, D. S., Setubal, J. C., and Vinatzer, B. A. 2010. PAMDB, a multilocus sequence typing and analysis database and website for plant-associated microbes. Phytopathology 100:208-215.

Behlau, F., Jones, J. B., Myers, M. E., and Graham, J. H. 2012. Monitoring for resistant populations of *Xanthomonas* citri subsp. citri and epiphytic bacteria on citrus trees treated with copper or streptomycin using a new semi-selective medium. European Journal of Plant Pathology 132:259-270.

Hert, A. P., Roberts, P. D. Momol, M. T., Minsavage, G. V., Tudor-Nelson, S. M., and Jones, J. B. 2005. Relative importance of bacteriocin-like genes in antagonism of *Xanthomonas perforans* tomato race 3 to *Xanthomonas euvesicatoria* tomato race 1 strains. Appl. Env. Microbiology. 71:3581-3588.

Horvath, D. M., Stall, R. E., Jones, J. B., Pauly, M. H., Vallad, G. E., Dahlbeck, D., Staskawicz, B. J., and Scott, J. W. (2012) Transgenic resistance confers effective field level control of bacterial spot disease in tomato. PLoS ONE 7(8): e42036. doi:10.1371/journal.pone.0042036.

Huang, C.-H., Vallad, G. E., Zhang, S., Wen, A., Balogh, B., Figueiredo, J. F. L., Behlau, F., Jones, J. B., Momol, M. T., and Olson, S. M. 2012. Effect of application frequency and reduced rates of acibenzolar-S-methyl on the field efficacy of induced resistance against bacterial spot on tomato. Plant Dis. 96:221-227.

Jones, J. B., Bouzar, H., Somodi, G. C., Stall, R. E., Pernezny, K., El-Morsy, G., and Scott, J. W. 1998. Evidence for the preemptive nature of tomato race 3 of *Xanthomonas* campestris pv. vesicatoria in Florida. Phytopathology 88:33-38.

Jones J. B., Stall R. E., Bouzar H. 1998. Diversity among xanthomonads pathogenic on pepper and tomato. Annu. Rev. Phytopathol. 36: 41-58.

Louws, F. J., Wilson, M., Campbell, H. L., Cuppels, D. A., Jones, J. B., Shoemaker, P. B., Sahin, F., and Miller, S. A. 2001. Field control of bacterial spot and bacterial speck of tomato using a plant activator. Plant Dis. 85:481-488.

Sanders, F. H., and Langston, D. B. 2009. Evaluation of quinoxyfen and acibenzolar-S-methyl for suppressing bacterial spot of bell pepper. (Abstr.) Phytopathology (Suppl.) 99:S114.

Stall, R. E., Loschke, D. C., and Jones, J. B. 1986. Linkage of copper resistance and avirulence loci on a self-transmissible plasmid in *Xanthomonas* campestris pv. vesicatoria. Phytopathology 76:240-243.

Thayer, P.L., and Stall, R.E. 1962. A survey of *Xanthomonas* vesicatoria resistance to streptomycin. Proc. Fla State Hort. Soc. 75:163-165.

Vallad, G. E., Pernezny, K. L., Balogh, B., Wen, A. M., Figueiredo, J. F. L., Jones, J. B., Momol, T., Muchovej, R. M., Havranek, N., Abdallah, N., Olson, S., and Roberts, P. D. 2010. Comparison of kasugamycin to traditional bactericides for the management of bacterial spot on tomato. Hortsci. 45:1834-1840.

Van Sickle, J., and Weldon, R. 2009. The economic impact of bacterial leaf spot on the tomato industry. 2009 Proceedings of the Florida Tomato Institute. Pg. 30-31.

An Overview of the U.S. Tomato Industry

Manhong Zhu[1], Zhengfei Guan[2], Feng Wu[2]
[1] Food and Resource Economics Department (FRED), University of Florida (UF), Gainesville, FL
[2]Gulf Coast Research and Education Center &FRED, UF, Tampa, FL, guanz@ufl.edu

INTRODUCTION

Tomatoes are a major vegetable crop worldwide. According to the data from Food and Agricultural Organization (FOA) of the United Nations, the worldwide fresh and processing tomato production exceeded 159 million metric tons in 2011. Over the last decade, the world production has been increasing consistently; it grew more than 30% from 2001 to 2011. Among the major tomato producers, the United States was the second largest producer behind China before 2011, but India surpassed the U.S. in 2011. Tomato production in China, India and the U.S. was about 49 million tons, 17 million tons, and 13 million tons, respectively. Other important producers are Turkey, Egypt, Italy, Iran, Spain, Brazil and Mexico. Mexico's production of tomatoes ranks relatively low among major producers, but its impact on the U.S. tomato industry is the most significant. This study will provide an overview of fresh tomato production and trade in North America, focusing on the U.S. and its trade relations with Mexico and Canada in the framework of the North American Free Trade Agreement (NAFTA). In particular, we will provide an in-depth analysis of the influence of Mexico tomato exports on the U.S. tomato industry.

U.S. TOMATO PRODUCTION

Over the past decade, fresh tomato production in the U.S. has exhibited a declining trend. It has slipped from 4 billion lbs in 2002 to 2.8 billion lbs in 2012, dropping 30% (**Figure 1**). Production value was at an all-time high in 2006 at $1.6 billion, and has been continually decreasing since then. The main reason for the decrease is the imports of tomatoes from Mexico. Mexico's competitive advantages in production cost and favorable government policies are among the major reasons. Over the years, fairness of Mexican trade practices has been questioned by U.S. growers since the NAFTA was implemented, which will be discussed shortly.

Fresh tomatoes are produced in every state of the whole nation. The top three fresh tomato producing states are Florida, California, and North Carolina. **Figure 2** indicates that Florida and California accounted for almost two thirds of the commercial production in the U.S. The states of North Carolina, Virginia, Ohio, Tennessee and Georgia are also large producers in the nation. Florida has been the largest supplier in the U.S. However, its production has been trending down over the past decade. In the last few years, its production dropped dramatically because of Mexico's competition. Production fell from 1.55 billion lbs in 2005 to 0.96 billion lbs in 2012, dropping nearly 40%. Its harvested acreage dropped from the historical high of 45 thousand acres in 2001 to 29 thousand acres in 2012. The change in California is relatively small, but the general trend has been decreasing as well.

Yield in Florida generally is the highest among the top three states, averaging roughly 35,000 lbs/acre and ranging from 40,000 lbs/acre in 2000 to 29,000 lbs/acre in 2010. California yield is approximately 30,000 lbs/acre on average, fluctuating between 28,000 to 35,500 lbs/acre. North Carolina yield spiked to 44,000 lbs/acre in 2011 and then returned to its average level again in 2012.

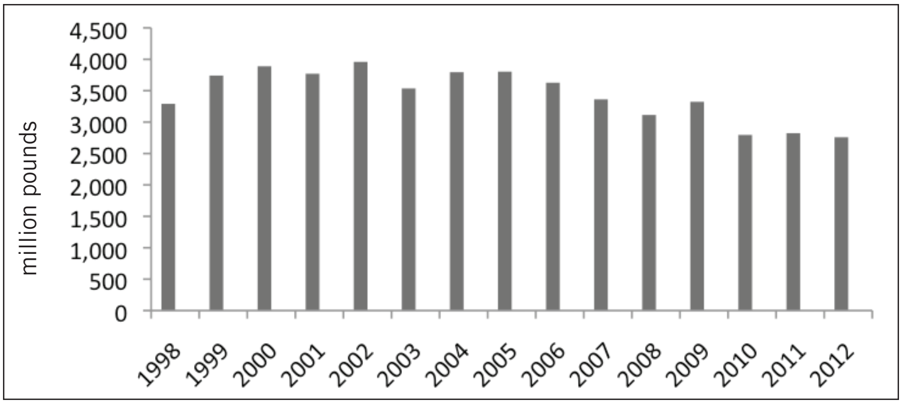


Figure 1: US Fresh Tomato Production

Source: USDA-NASS, Vegetables Summary

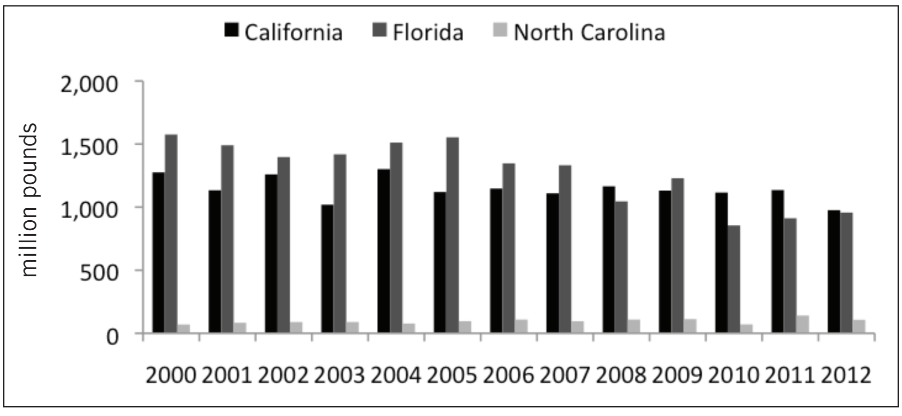


Figure 2: Fresh Tomato Production in the Top 3 States, 2000-2012

Source: USDA-NASS

MEXICO TOMATO PRODUCTION

Mexico is the major exporter of tomatoes to the U.S. In 2005, there were about 1.8 billion pounds of fresh tomatoes exported to the US, and the total amount had reached 3.04 billion pounds by 2012. The cost of tomato production is much lower in Mexico because of lower labor and transportation costs. Besides, in recent years, Mexico has been encouraging investment in agriculture which may have sped up their advancements in technology and raised its production capacity. According to the report by Flores and Ford (2010), open field yields have risen from 20,500 lbs/acre in 1990 to 34,800 lbs/acre in 2010. Though the fresh and processing tomato production in 2011 decreased relative to 2010, the total production has remained stable for the last decade (**Figure 3**).

MEXICO'S FOREIGN TRADE

Mexico is the leading country of tomato exports. Since the implementation of NAFTA in 1994, Mexico has been continually increasing its fresh tomato exports, reaching 2.4 billion lbs in 2009 and jumping up to 3.26 billion lbs in 2010

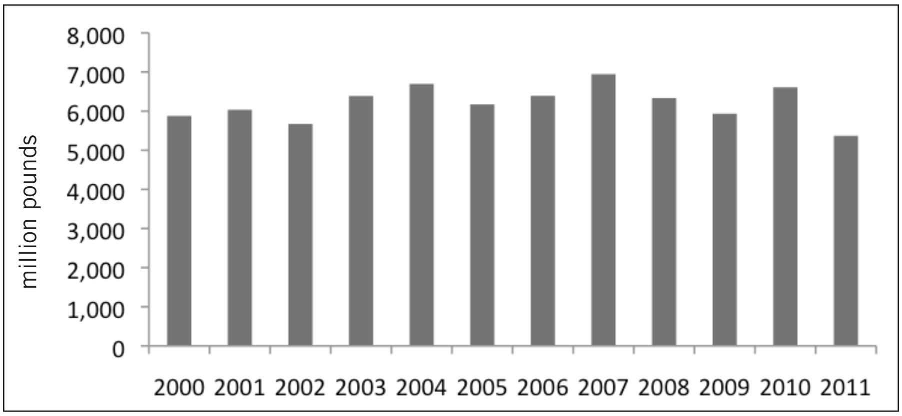


Figure 3: Mexican Total Tomato Production, 2000-2011

Source: Food and Agriculture Organization of the United Nations

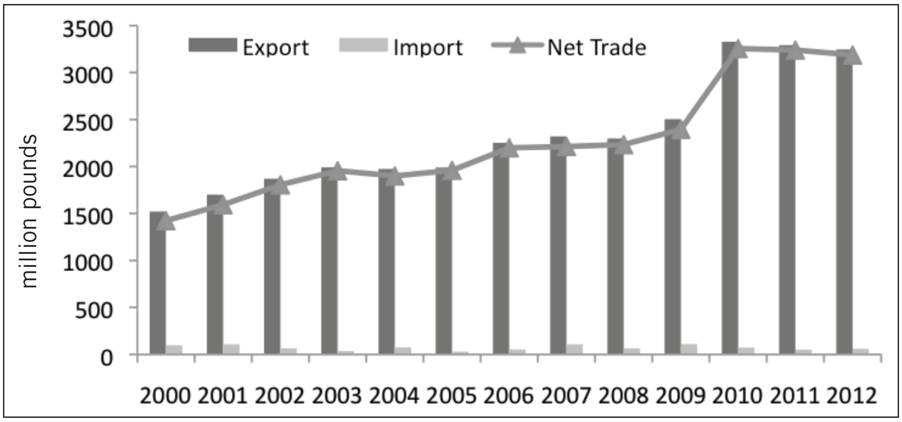


Figure 4: Mexico Fresh tomato Trade, 2000-2012

Source: U.S. Department of Commerce

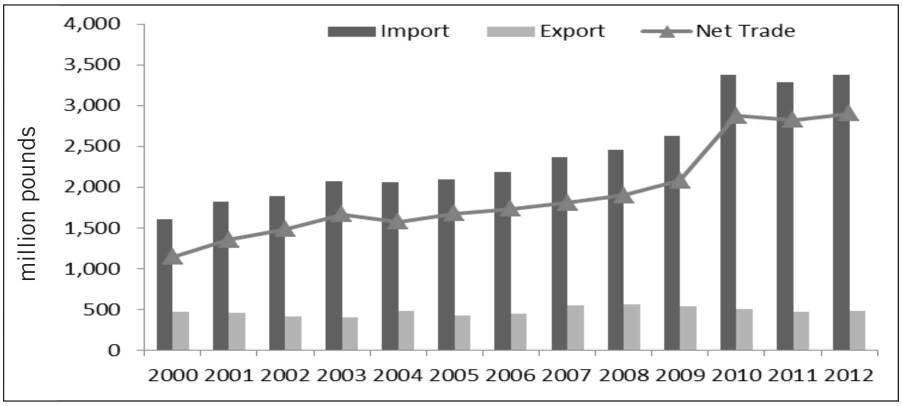


Figure 5: U.S. Trade in Fresh Tomatoes, 2000-2012

Source: U.S. Department of Commerce

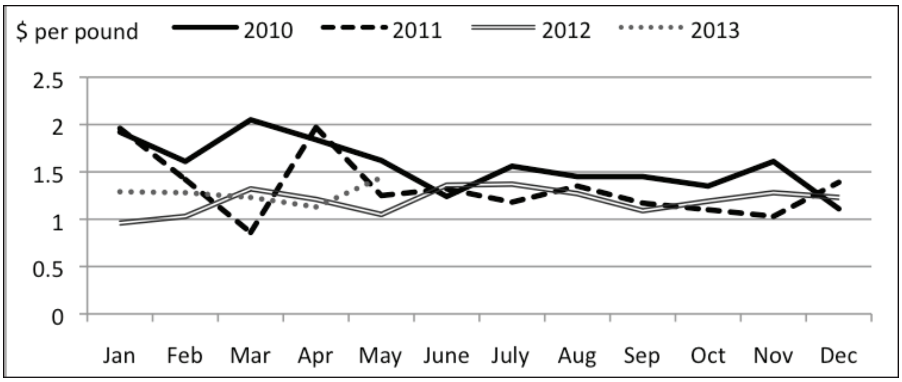


Figure 6: Retail Advised Prices for Tomatoes, 2010-2013

Source: USDA, Agricultural Marketing Service, National Fruit and Vegetable Retail Report

(Figure 4). In the past three years (2010-2012), the exports remained at more than 3 billion lbs, 93% of which were shipped to the U.S. Mexico also imports tomatoes, but the amount is negligible compared to its exports. It imported less than 60 million lbs in 2012, the majority of which was from the U.S.

U.S. FRESH TOMATOES TRADE

With the decline in the U.S. fresh tomato production in 2010, imports were up more than 36% from 2009, reaching 3.38 billion lbs, and have remained high for the past three years (Figure 5). Mexico is the leading source for fresh tomato imports (3.04 billion lbs), accounting for roughly 90 percent of total imports in 2012. Canada and Dominican Republic make up the remaining import volume with 307 and 7 million pounds, respectively.

Fresh tomato exports have seen a decrease in the past three years, which may be due to the decreasing domestic production. Following record high exports in 2008, export volume has gradually decreased to 476 million lbs in 2012, 15% lower than the peak level. Most of its tomatoes were shipped to Canada. The demand from Canada fluctuated in a relatively small range over the years. Exports to Mexico showed a strong growth in 2009, but the demand was pushed down quickly with the increase of Mexico production.

Since exports are less than 15% of imports, the movement of US fresh tomato net trade follows the pattern of imports. Net imports continue to increase, reaching a record high of 2.9 billion lbs in 2012.

U.S. fresh tomato imports remained at a high level for the first 4 months of the 2013 season, totaling 1.36 billion lbs. But compared to the same period of last year, import volume decreased 73 million lbs. U.S. fresh tomato exports remain unchanged from the previous season.

TOMATO PRICES

With the increasing imports of tomatoes from Mexico, the retail price of tomatoes in 2011 and 2012 was lower than that in 2010. And the overall trend keeps going down (Figure 6). In the first half of 2011, the retail price fluctuated dramatically because of a very cold and dry winter in 2010. The retail price for tomatoes was low throughout much of 2012, causing a crash in the crop value, particularly for Florida growers. The low price was mainly due to favorable growing conditions and consistently high imports.

Florida Fresh Tomato Production and the Trade Issue between Florida/US and Mexico

U.S. Fresh tomatoes had a total crop value of $1.4 billion in 2010. Florida is the largest supplier of fresh tomatoes, accounting for nearly half of the total crop value. However, the industry is facing serious challenges because of excessive market competition. The USDA-NASS (National Agricultural Statistical Service) data shows that U.S. tomato production decreased from 3.9 billion lbs in 2000 to 2.8 billion lbs in 2012, while the Florida production fell from 1.58 to 0.96 billion lbs. During this period, both planted and harvested acreage fell significantly. In contrast to the shrinking domestic industry, the amount of tomatoes imported from Mexico (world) jumped from 1.3 (1.6) billion pounds to 3 (3.4) billion pounds, as shown by data from the U.S. Department of Commerce. As discussed above, Mexican imports now account for 90% of the imported tomatoes. In 2000, Mexican tomatoes on the market were about 20% less than Florida's supply, but their market share is now more than 3 times higher than Florida's. The farm gate value of Florida tomato industry slumped from $620 million in 2010 to $268 million in 2012 and the national value dropped from $1.4 billion to $0.86 billion. The imports from Mexico are being considered the most serious threat to the industry. Besides foreign competition, cost escalation has also been squeezing the profit margin of the industry over the years. The main factors contributing to the rising costs are increasing labor, energy, materials, and fumigation costs, among others.

The Trade Issue between Florida/US and Mexico

The intense competition has caused tremendous tension between the U.S. and Mexico tomato industries over the years. As early as 1996, Florida tomato growers had accused Mexico growers of destroying the U.S. domestic market by dumping tomatoes at below market prices. To avoid a trade war, an agreement working under the framework of U.S. law and NAFTA was reached in November 1, 1996 between the U.S. government and the Mexican tomato growers. The agreement set a minimum price, calculated by the U.S. department of Commerce (DOC), above which the Mexican tomato growers agreed to export tomatoes to the U.S. In 2012, the U.S. industry petitioned to repeal the agreement given the scale of damage the industry sustained over the years. The Agreement was renewed by the DOC in March 2013 and the renewed agreement set higher floor prices. However, the Florida growers are currently challenging the agreement at the U.S. Court of International Trade, seeking "both free and fair" trade practices.

REFERENCES:

Flores, D. and Ford, M. "Tomato Annual: area planted down but production up." USDA Foreign Agricultural Service GAIN (Global Agricultural Information Network) Report, January 2010.

Tomato Varieties for Florida

Stephen M. Olson[1] and Eugene McAvoy[2]

[1]North Florida Research & Education Center, University of Florida, Quincy, smolson@ufl.edu

[2]Hendry County Extension, University of Florida, LaBella, gmcavoy@ufl.edu

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. In years past we have been able to give a breakdown of which varieties are used and predominantly where they were being used but this information is no longer available through the USDA Crop Reporting Service.

TOMATO VARIETIES FOR COMMERCIAL PRODUCTION

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

LARGE FRUITED VARIETIES

1. LARGE FRUITED AND BEEFSTAKE TYPES

Amelia. Vigorous determinate, main season, jointed hybrid. Fruit are firm and aromatic suitable for green or vine ripe Good crack resistance. Resistance: Verticillium wilt (race 1), Fusarium wilt (races 1, 2, and 3), root-knot nematode, gray leaf spot and Tomato spotted wilt.

Bella Rosa. Midseason maturity. Fruit are large to extra-large, deep globed shaped with firm, uniform green fruits well suited for mature green or vine-ripe production. Determinate, medium to tall vine. Resistance: Verticillium wilt (race 1), Fusarium wilt (races 1 and 2), gray leaf spot, and Tomato spotted wilt.

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

BHN 730. Intended for mature green production. Smooth fruit and a strong bush that produces well even on poor soils. Resistance: Verticillium wilt (race 1), Fusarium wilt (races 1, 2), Fusarium Crown Rot, bacterial Speck

BHN 871. Midseason maturity. Firm gold to tangerine colored globe shaped fruit with much improved taste and texture. Strong medium tall bush. Resistance: Verticillium wilt (race 1), Fusarium wilt (races 1, 2, and 3). Tolerant: Fusarium crown rot.

BHN 1064. Mainseason maturity. Strong vines with firm large to extra-large fruit that size well from bottom to top. In north Florida does well in both spring and fall seasons. Resistance: Verticillium wilt (race 1), Fusarium wilt (races 1, 2 and 3) and Tomato spotted wilt.

Biltmore. Strong determinate bush with midseason maturity. High yield potential of uniform, round, firm fruit with a small blossom end scar. Resistance: Verticillium wilt (race 1), Fusarium wilt (races 1 and 2), Alternaria stem canker and gray leaf spot.

Charger. Vigorous plant with good vine cover. Large, smooth, deep oblate fruit with excellent firmness and color. Resistance: Fusarium wilt (races 1, 2, and 3), Tomato yellow leaf curl, Verticillium wilt (race 1) and Alternaria stem canker.

Crista. Midseason maturity. Large, deep globe shaped fruit with tall robust plants. It does best with moderate pruning and high fertility. Good flavor, color and shelf-life. Resistance: Verticillium wilt (race 1), Fusarium wilt (races 1, 2, and 3), Tomato spotted wilt and root-knot nematode.

Crown Jewel. Late midseason determinate. Uniform fruit have a deep oblate shape with good firmness, quality and uniformly-colored shoulders. Determinate with medium-tall bush. Resistance: Verticillium wilt (race 1), Fusarium wilt (races 1 and 2) Fusarium crown rot, Alternaria stem canker and gray leaf spot. Tolerant to gray wall.

EX 01420200. Main season fresh market tomato intended for spring planting in south and central Florida where TYLC is a threat to growers. Bears smooth deep oblate shaped, uniform fruit on a vigorous, determinate plant with a high yield potential of high-quality fruit. Resistance: alternaria stem canker, Verticillium race 1, Fusarium races 1 and 2, Stemphylium, Tomato spotted wilt, Tomato yellow leaf curl (TYLC). and Tomato mosaic.

Finishline. Main season fall variety. Tall determinate with good cover. Good fruit quality for vine ripe or mature green production. Resistance: Verticillium wilt (race 1), Fusarium wilt (races 1, 2, and 3), Tomato spotted wilt and gray leaf spot.

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

Florida 47. A late midseason, determinate, jointed hybrid. Uniform green, globe shaped fruit. Resistance: Fusarium wilt (races 1 and 2), Verticillium wilt (race 1), Alternaria stem canker, and gray leaf spot.

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

HM 8849 CR. Early maturing variety with a strong plant and good leaf cover. Fruit extra-large, smooth and slightly flattened globe shape. Resistance: Verticillium wilt (race 1), Fusarium wilt (races 1 and 2), Fusarium crown and root rot and gray leaf spot.

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

Quincy. Full season. Large to extra-large, excellent quality, firm, deep oblate shaped fruit and uniformly colored. Very strong determinate plant. Resistance: Verticillium wilt (race 1), Fusarium wilt (races 1 and 2), Alternaria stem canker, Tomato spotted wilt and gray leaf spot.

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

Redline. Main season spring variety. Tall determinate with good cover. Good fruit quality for vine ripe or mature green production. Resistance: Verticillium wilt (race 1), Fusarium wilt (races 1, 2, and 3), Tomato spotted wilt and gray leaf spot.

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

RFT 6153. Main season. Fruit have good eating quality and fancy appearance in a large sturdy shipping tomato and are firm enough for vine-ripe. Large determinate plants. Resistance: Verticillium wilt (race 1), Fusarium wilt (races 1 and 2) and gray leaf spot.

Sanibel. Main season. Large, firm, smooth fruit with light green shoulder and a tight blossom end. Large determinate bush. Resistance: Verticillium wilt (race 1), Fusarium wilt (races 1 and 2), root-knot nematodes, Alternaria stem canker and gray leaf spot.

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

Security 28. An early season determinate variety with a medium vine and good leaf cover adapted to different growing conditions. Produces extra-large, firm, round fruit. Resistance: Alternaria stem canker, Fusarium wilt (races 1 and 2), gray leaf spot, Tomato yellow leaf curl and Verticillium wilt (race 1).

Solar Fire. An early, determinate, jointed hybrid. Has good fruit setting ability under high temperatures. Fruit are large, flat-round, smooth, and firm, with light green shoulder and blossom scars are smooth. Resistance: Verticillium wilt (race 1), Fusarium wilt (races 1, 2, and 3), gray leaf spot.

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

Talladega. Midseason. Fruit are large to extra-large, globe to deep globe shape. Determinate bush. Has some hot-set ability. Performs well with light to moderate pruning. Resistance: Verticillium wilt (race 1), Fusarium wilt (races 1 and 2), Tomato spotted wilt and gray leaf spot.

Tasti-Lee. Targeted at the premium tomato market. A midseason, 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. Resistance: Fusarium wilt (races 1, 2, and 3), Verticillium wilt (race 1), and gray leaf spot.

Tribeca. Early midseason. Strong vines with firm large to extra-large fruit. In north Florida does well in both spring and fall seasons. Resistance: Verticillium wilt (race 1), Fusarium wilt (race 1 and 2) Tomato spotted wilt and gray leaf spot.

Tribute. Main season fall variety. Vigorous plant with good cover. Medium large to large, smooth, globed shaped fruit with excellent firmness and color. Resistance: Alternaria stem canker, Fusarium wilt (races 1 and 2), Verticillium wilt (race 1), gray leaf spot, Tomato spotted wilt and Tomato yellow leaf curl.

Tygress. A main season, jointed hybrid producing large, smooth, firm fruit with good pack-outs. Resistance: Verticillium wilt (race 1), Fusarium wilt (races 1 and 2), gray leaf spot, Tomato mosaic, Tomato yellow leaf curl, and Alternaria stem canker.

PLUM TYPE VARIETIES

BHN 685. Midseason. Large to extra-large, deep blocky fruit. Determinate, vigorous bush with no pruning recommended. Resistance: Verticillium wilt (race 1), Fusarium wilt (races 1, 2, and 3) and Tomato spotted wilt.

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

Monica. Midseason. Fruit are elongated, firm, extra-large and uniform green color. Vigorous bush with good cover. Resistance: Verticillium wilt (race 1), Fusarium wilt (races 1 and 2), bacterial speck (race 0), gray leaf spot, and Alternaria stem canker.

Monticello. Uniform fruit size and a unique blocky shape with an improved disease resistance package. Large firm fruit with good interior quality and small blossom end scar. Resistance to Fusarium wilt (races 1-2, bacterial speck, grey leaf spot, tomato spotted wilt virus, verticillum and root know nematode

Picus. Main season, widely adapted determinate Roma tomato. Fruits are large, uniform and blocky, maturing to a deep-red color with great firmness at the red stage. Medium to large, vigorous plant that provides good fruit cover and sets well in hot temperatures. Resistance: Alternaria stem canker, Fusarium wilt (races 1 and 2), Tomato spotted wilt, Verticillium wilt (race 1), Alternaria stem canker and Cladosporium leaf mold.

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

Sunoma. Main season. Fruit are medium-large, elongated and cylindrical. Plant maintains fruit size through multiple harvests. Determinate plant with good fruit cover. Resistance: Verticillium wilt (race 1), Fusarium wilt (races 1 and 2), bacterial speck (race 0), root-knot nematodes, Tomato mosaic and gray leaf spot.

Tachi. Mid-season variety with classic saladette shape. Determinate mid compact plant. Uniform predominately extra-large fruit. Wide adaptability and suited for concentrated harvests for vine ripe and mature green markets. Resistance: Fusarium wilt (races 1 and 2), Verticillium wilt (race 1), tomato spotted wilt, root-knot nematodes and Alternaria stem canker.

CHERRY TYPE VARIETIES

BHN 268. Early to mid-season, determinate, medium to tall bush with high yields An extra firm cherry tomato that holds, packs and ships well. Resistance: Verticillium wilt (race 1), Fusarium wilt (race 1).

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

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

GRAPE TOMATOES

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

Brixmore. Very early. indeterminate bush. Very uniform in shape and size, deep glossy red color with very high early and total yield. High brix and excellent firm flavor. Resistance: Verticillium wilt (race 1), rootknot nematodes and Tomato mosaic.

Cupid. Early. Vigorous, indeterminate bush. Oval shaped fruit have an excellent red color and a sweet flavor. Resistance: Fusarium wilt (races 1 and 2), bacterial speck (intermediate resistance race 0), Alternaria stem canker, and gray leaf spot.

Jolly Elf. Early season. Determinate plant. Extended market life with firm, flavorful grape shaped fruits. Average 10% brix. Resistance: Verticillium wilt (race 1), Fusarium wilt (race 2) and cracking.

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

St. Nick. Mid-early season. Indeterminate bush. Oblong, grape shaped fruit with brilliant red color and good flavor. Up to 10% brix.

Smarty. 69 days. Vigorous, indeterminate bush with short internodes. Plants are 25% shorter than Santa. Good flavor, sweet and excellent flavor.

Sweethearts. Early to mid-season, indeterminate bush with intermediate internodes. Brilliant red, firm, elongated grape-shaped fruit. Matures between 70 and 75 days. Good flavor, crack-resistant and high brix. Resistance: Tobacco mosaic, Cladosporium leaf mold and Fusarium wilt (race 1).

Tami G. Early season. Indeterminate, medium tall bush. Small fruits with nice shape.

Fertilizer and Nutrient Management for Tomato

Monica Ozores-Hampton[1]
[1]University of Florida/IFAS, SWFREC, Immokalee, FL. ozores@ufl.edu

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/A N rate on 6-ft centers is the same as 240 lbs/A N rate on 5-ft centers and a 170 lbs/A 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/A (6/7 x 43,560 / 7). If the recommendation is to inject 10 lbs of N per acre (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

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

Production System	Nutrient	Recommended base fertilization[z]							Recommended supplemental fertilization[z]		
		Total (lbs/A)	Preplant[y] (lbs/A)	Injected[x] (lbs/A/day) Weeks after transplanting[w]					Leaching rain[r,s]	Measured >low=plant nutrient content[u,s]	Extended harvest season[s]
				1-2	3-4	5-11	12	13			
Drip irrigation raised beds, and polyethylene Mulch	N	200	0-50	1.5	2.0	2.5	2.0	1.5	n/a	1.5 to 2 lbs/A/day for 7 days[t]	1.5-2 lbs/A/day[p]
	K_2O	220	0-50	2.5	2.0	3.0	2.0	1.5	n/a	1.5 to 2 lbs/A/day for 7 days[t]	1.5-2 lbs/A/day[p]
Seepage irrigation, raised beds, and polyethylene Mulch	N	200	200[v]	0	0	0	0	0	30 lbs/A[q]	30 lbs/A[t]	30 lbs/A[p]
	K_2O	220	220[v]	0	0	0	0	0	20 lbs/A[q]	20 lbs/A[t]	20 lbs/A[p]

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

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 (CaCO3, MgCO3). Where calcium alone is deficient, "hi-cal" (CaCO3) 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 pounds per 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-1 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 calcium or magnesium. 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

Table 2. Deficient, adequate, and excessive nutrient concentrations 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 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	3.0	0.3	3.0	1.0	0.3	0.3	40	30	25	20	5	0.2
			range	5.0	0.6	5.0	2.0	0.5	0.8	100	100	40	40	15	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	2.8	0.2	2.5	1.0	0.3	0.3	40	30	25	20	5	0.2
			range	4.0	0.4	4.0	2.0	0.5	0.8	100	100	40	40	15	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	2.5	0.2	2.5	1.0	0.25	0.3	40	30	20	20	5	0.2
			range	4.0	0.4	4.0	2.0	0.5	0.6	100	100	40	40	10	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	2.0	0.2	2.0	1.0	0.25	0.3	40	30	20	20	5	0.2
			range	3.5	0.4	4.0	2.0	0.5	0.6	100	100	40	40	10	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	2.0	0.2	1.5	1.0	0.25	0.3	40	30	20	20	5	0.2
			range	3.0	0.4	2.5	2.0	0.5	0.6	100	100	40	40	10	0.6
			High	>3.0	0.4	2.5	2.0	0.5	0.6	100	100	40	40	10	0.6

adequate when the Mehlich-1 index is 300 to 350 ppm, or above. In these cases, added gypsum (calcium sulfate) is unlikely to reduce BER. Foliar sprays of Ca are unlikely to reduce BER because Ca does not move out of the leaves to the fruit.

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

Micronutrients. For acidic sandy soils cultivated for the first time ("new ground"), or sandy soils where a proven need exists, a general guide for fertilization is the addition of micronutrients (in elemental lbs/A) 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 (nitrogen, phosphorus, or potassium) 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 phosphorus 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 phosphorus 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 potassium 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

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

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

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

Nutrient Level	Management 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, and correctly implementing them, and monitoring crop nutritional status
5	Recommended	Soil testing, understanding IFAS recommendations, and correctly implementing them, and monitoring crop nutritional status, and practice year-round nutrient management and/or following BMP's (including of the recommended irrigation scheduling methods.)

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

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 percent to 40 percent of total nitrogen and potassium preplant in the bed. Apply the remaining N and potassium through the drip system in increments as the crop develops.

Successful crops have resulted where the total amounts of N and K_2O 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_2O to ensure young transplants are established quickly. In most situations, some preplant 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 nitrogen sources may be used to supply a portion of the nitrogen requirement. One-third of the total required nitrogen can be supplied from sulfur-coated urea (SCU), isobutylidene diurea (IBDU), or polymer-coated urea (PCU) fertilizers incorporated in the bed. Nitrogen from natural organics and most controlled-release materials is initially in the ammoniacal form, but is rapidly converted into nitrate by soil microorganisms.

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

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

SAP TESTING AND TISSUE ANALYSIS

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

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

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

SUPPLEMENTAL FERTILIZER APPLICATIONS

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

LEVELS OF NUTRIENT MANAGEMENT FOR TOMATO PRODUCTION

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

SUGGESTED LITERATURE

Cantliffe, D., P. Gilreath, D. Haman, C. Hutchinson, Y. Li, G. McAvoy, K. Migliaccio, T. Olczyk, S. Olson, D. Parmenter, B. Santos, S. Shukla, E. Simonne, C. Stanley, and A. Whidden. 2009. Review of nutrient management systems for Florida vegetable producers. EDIS HS1156, http://edis.ifas.ufl.edu/HS1156.

Florida Department of Agriculture and Consumer Services. 2005. Florida Vegetable and Agronomic Crop Water Quality and Quantity BMP Manual.

http://www.floridaagwaterpolicy.com/PDFs/BMPs/vegetable&agronomicCrops.pdf

Gazula, A., E. Simonne and B. Boman. 2007. Update and outlook for 2007 of Florida=s BMP program for vegetable crops, EDIS Doc. 367, http://edis.ifas.ufl.edu/HS367

Hochmuth, G., D. Maynard, C. Vavrina, E. Hanlon, and E. Simonne. 2004. Plant tissue analysis and interpretation for vegetable crops in Florida. EDIS http://edis.ifas.ufl.edu/EP081.

Muñoz-Carpena, R. 2004. Field devices for monitoring soil water content. EDIS. Bul 343. http://edis.ifas.ufl.edu/HS266.

Olson, S.M., W.M. Stall, G.E. Vallad, S.E. Webb, T.G. Taylor, S.A. Smith, E.H. Simonne, E. McAvoy, and B.M. Santos. 2009. Tomato production in Florida, pp. 291-312. In: S.M. Olson and E. Simonne (Eds.) 2009-2010 Vegetable Production Handbook for Florida, Vance Pub., Lenexa, KS.

Simonne, E.H. and G.J. Hochmuth. 2009. Soil and fertilizer management for vegetable production in Florida, pp. 3-15. In: S.M. Olson and E. Simonne (Eds.) 2009-2010 Vegetable Production Handbook for Florida, Vance Pub., Lenexa, KS.

Simonne, E., D. Studstill, B. Hochmuth, T. Olczyk, M. Dukes, R. Muñoz-Carpena, and Y. Li. 2002. Drip irrigation: The BMP era - An integrated approach to water and fertilizer management in Florida, EDIS HS917, http://edis.ifas.ufl.edu/HS172.

Studstill, D., E. Simonne, R. Hochmuth, and T. Olczyk. 2006. Calibrating sap-testing meters. EDISHS 1074, http://edis.ifas.ufl.edu/HS328.

Water Management for Tomato

Monica Ozores-Hampton[1]
[1]University of Florida/IFAS, SWFREC, Immokalee, FL. ozores@ufl.edu

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.

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

Water Management		Irrigation scheduling method
Level	Rating	
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.

TOMATO WATER REQUIREMENT

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

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

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

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

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

Typical CF values for fully-grown tomato should not exceed 0.75 (Locascio and Smajstrla, 1996). A third method for estimated tomato crop water requirement is to use modified Bellani plates also known as atmometers. A common model of atmometer used in Florida is the ET_{gage}. This device consists of a canvas-covered ceramic 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 water plants. Water loss through evaporation can be read on a clear sight tube mounted on the side of the device. Evaporation from the ET_{gage} (ETg) was well correlated to ETo except on rainy days, but overall, the ET_{gage} tended to underestimate ETo (Irmak et al., 2005). On days with rainfall less than 0.2 inch/day, ETo can be estimated from ETg as: ETo = 1.19 ETg. When rainfall exceeds 0.2 inch/day, rain water wets the canvas which interferes with the flow of water out of the atmometers, and decreases the reliability of the measurement.

TOMATO IRRIGATION REQUIREMENT

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

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

IRRIGATION SCHEDULING FOR TOMATO

For seepage-irrigated crops, irrigation scheduling recommendations consist of

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

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

Tomato Growth Stage	Corresponding Weeks after Tranplanting[y]	Kc for Drip-Irrigated Crops
1	1-2	0.30
2	3-4	0.40
3	5-11	0.90
4	12	0.90
5	13	0.75

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

Table 4. Historical Penman-method reference ET (ETo) for four Florida locations (in gallons per acre per day)[z].

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

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

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

SOILS MOISTURE MEASUREMENT

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

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

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

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

Table 5. Estimated maximum water application (in gallons per acre and in gallons/100lfb) 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 of 1 ft	Gal/100 ft to wet depth of 1.5 ft	Gal/100 ft to wet depth of 2 ft	Gal/acre to wet depth of 1 ft	Gal/acre to wet depth of 1.5 ft	Gal/acre to wet depth of 2 ft
1.0	24	36	48	1,700	2,600	3,500
1.5	36	54	72	2,600	3,900	5,200

creasingly 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 22 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.

ADDITIONAL READINGS:

Cantliffe, D., P. Gilreath, D. Haman, C. Hutchinson, Y. Li, G. McAvoy, K. Migliaccio, T. Olczyk, S. Olson, D. Parmenter, B. Santos, S. Shukla, E. Simonne, C. Stanley, and A. Whidden. 2009. Review of nutrient management systems for Florida vegetable producers. EDIS HS1156, http://edis.ifas.ufl.edu/HS1156.

FDACS. 2005. Florida Vegetable and Agronomic Crop Water Quality and Quantity BMP Manual. Florida Department of Agriculture and Consumer Services http://www.floridaagwaterpolicy.com/PDFs/BMPs/vegetable&agronomicCrops.pdf

Irmak, S., M. Asce, M.D. Dukes, and J.M. Jacobs. 2005. Using modified Bellani plate evapotranspiration gauges to estimate short canopy reference evapotranspiration. J. Irr. Drainage Eng. (2):164-175.

Locascio, S.J. and A.G. Smajstrla. 1996. Water application scheduling by pan evaporation for drip-irrigated tomato. J. Amer. Soc. Hort. Sci. 121(1):63-68

Muñoz-Carpena, R. 2004. Field devices for monitoring soil water content. EDIS Bul. 343. http://edis.ifas.ufl.edu/AE266.

Simonne, E.H., D.W. Studstill, R.C. Hochmuth, G. McAvoy, M.D. Dukes and S.M. Olson. 2003. Visualization of water movement in mulched beds with injections of dye with drip irrigation. Proc. Fla. State Hort. Soc. 116:88-91.

Simonne, E.H., D.W. Studstill, T.W. Olczyk, and R. Munoz-Carpena. 2004. Water movement in mulched beds in a rocky soil of Miami-Dade County. Proc. Fla. State Hort. Soc 117:68-70.

Simonne, E. and B. Morgan. 2005. Denitrification in seepage irrigated vegetable fields in South Florida, EDIS, HS 1004, http://edis.ifas.ufl.edu/HS248.

Simonne, E.H., D.W. Studstill, R.C. Hochmuth, J.T. Jones and C.W. Starling. 2005. On-farm demonstration of soil water movement in vegetables grown with plasticulture, EDIS, HS 1008, http://edis.ifas.ufl.edu/HS251.

Simonne, E.H. and M.D. Dukes. 2009. Principles of irrigation management for vegetables, pp.17-23. In: S.M. Olson and E. Simonne (eds) 2009-2010 Vegetable Production Handbook for Florida, Vance Publ., Lenexa, KS.

Smajstrla, A.G. 1997. Simple water level indicator for seepage irrigation. EDIS Circ. 1188, http://edis.ifas.ufl.edu/AE085.

Stanley, C.D. and G.A. Clark. 2003. Effect of reduced water table and fertility levels on subirrigated tomato production in Southwest Florida. EDIS SL-210, http://edis.ifas.ufl.edu/SS429.

Weed Control in Tomato

Peter J. Dittmar, University of Florida/IFAS, Horticultural Sciences Dept., Gainesville, FL, pdittmar@ufl.edu.

Active Ingredient (a.i) lb. a.i./Acre (A)	Trade name Formulation/Acre	Weeds Controlled/Remarks
		PREPLANT / PREEMERGENCE
Carfentrazone up to 0.031	(Aim) 2EC or 1.9 EW up to 2 fl. oz.	Emerged broadleaf weeds. Apply as a pre-plant burn down for emerged broadleaf weeds. Use crop oil concentrate or nonionic surfactant at recommended rates. May be tank mixed with other herbicides.
EPTC 2.6	(Eptam) 7E 3 pts	Annual broadleaf, annual grass, and yellow/purple nutsedge. Labeled for transplanted tomatoes grown on low density mulch. Do not use of under high density, VIF, or metallized mulches. Do not transplant until 14 days after application. A 24c special local needs label for Florida.
Flumioxazin up to 0.128	(Chateau) 51 WDG up to 4 oz.	Annual broadleaf and grass weeds. Apply to row middles of raised plastic mulched beds that are at least 4 inches higher than the treated row middle and 24 inch 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 burn down herbicide to control emerged weeds.
Fomesafen 0.25 – 0.38	(Reflex) 2 EC 1.0 – 1.5 pt.	Broadleaf and grass control and nutsedge. Label is a 24(C) local indemnified label and a waiver of liability must be signed for use. Transplanted crop only. If applying to the row middles only, prevent the spray from contacting the plastic.
Glyphosate 0.3-1.0	Various formulations consult labels	Emerged broadleaf and grass weeds. Apply as a preplant burn down. Consult label for individual product directions.
Halosulfuron 0.024 - 0.05	(Sandea, Profine) 75 DG 0.5 - 1 oz.	Broadleaf control and yellow/purple nutsedge suppression. Total of 2 application of halosulfuron per season.
Imazosulfuron 0.19 to 0.3	(League) 75 DG 4 – 6.4 oz.	Broadleaf weeds and nutsedge. Apply under the plastic mulch. Transplant after 1 day after application. Only 1 application per year either PRE or POST.
Lactofen 0.25 - 0.5	(Cobra) 2 EC 16 - 32 fl. oz	Broadleaf weeds. 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. Cobra contacting green foliage or fruit can cause excessive injury. Drift of Cobra treated soil particles onto plants can cause contact injury. A minimum of 24 fl. oz. is required for residual control. Add a crop oil concentrate or non-ionic surfactant for control of emerged weeds. Limit of 1 PRE and 1 POST application per growing season. PHI 30 days.
S-metolachlor 1.0 to 1.3	(Brawl, Dual Magnum, Medal) 7.62 EC 1.0 - 1.33 pt.	Annual broadleaf and grass weeds and yellow nutsedge. Apply to row middles. Label rates are 1.0 – 1.33 pts./A if organic matter is less than 3%. Research has shown that the 1.33 pt. may be too high in some Florida soils except in row middles. Use on a trial basis.
Napropamide 1.0 - 2.0	(Devrinol) 50 DF 2 - 4 lb.	Annual broadleaf and grass weeds. For direct-seed or transplanted tomatoes. Apply to well worked soil that is dry enough to permit thorough incorporation to a depth of 1 to 2 inches. Incorporate same day as applied.
Oxyfluorfen 0.25 - 0.5	(Goal) 2 XL 1 -2 pt. (GoalTender) 4 E 0.5 - 1 pt.	Must have a 30-day treatment-planting interval for transplanted tomatoes. Apply as a preemergence broadcast to preformed beds or banded treatment at 1 – 2 pt./A or 0.5 to 1 pt./A for Goaltender. Mulch may be applied any time during the 30-day interval.
Paraquat 0.5 - 1.0	(GramoxoneInteon) 2 SL 2.0 - 4.0 pt (Firestorm) 3 SL 1.3 - 2.7 pt	Emerged broadleaf and grass weeds. Apply as a preplant burn down treatment. Use a nonionic surfactant.
Pelargonic Acid	(Scythe) 4.2 EC 3 – 10% v/v	Emerged broadleaf and grass weeds. Apply as a preplant burn down treatment. Product is a contact, nonselective, foliar applied herbicide with no residual control. May be tank mixed with soil residual compounds.
Pendimethalin 0.48 – 0.72	(Prowl H_2O) 3.8 1.0 – 1.5	May be applied pre-transplant, but not under mulch. May be applied at 1.0 to 1.5 pt./A to row middles. Do not exceed 3.0 pt./A/year. PHI 70 days.
Rimsulfuron 0.03 - 0.06	(Matrix FNV, Matrix SG, Pruvin) 25 WDG 2.0 – 4.0 oz.	Annual broadleaf weeds. Read label for specific grass species controlled. Requires 0.5 to 1 inch 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.

Trifluralin 0.5	(Treflan HFP, Trifluralin, Trifluralin HF) 4EC 1 pt. (Treflan TR-10) 5 lb.	Annual broadleaf and grass weeds. Do not apply in Dade County. Incorporate 4 inches or less within 8 hours of application. Results in Florida are erratic on soils with low organic matter and clay contents. Note label precautions against planting noncrops within 5 months. Do not apply after transplanting.
	POSTEMERGENCE	
Carfentrazone up to 0.031	(Aim) 2 EC or 1.9 EW up to 2 oz.	Emerged broadleaf weeds. Apply as hooded application to row middles only. Use crop oil concentrate or non-ionic surfactant at recommended rates. May be tank mixed with other herbicides. PHI 0 days.
Clethodim 0.09 – 0.25 0.07 - 0.25	(Select, Arrow) 2 EC 6 - 16 fl. oz. (Select Max) 1 EC 9 - 32 fl. oz.	Perennial and annual grass weeds. Use higher rates under heavy grass pressure or larger grass weeds. Use a crop oil concentrate at 1% vv in the finished spray volume. Nonionic surfactant with Select Max. PHI 20 days.
DCPA 6.0 - 7.5	(Dacthal) W-75 8.0 - 10 lb. (Dacthal) 6 F 8.0 - 10 pt.	Apply to weed-free soil 6 to 8 weeks after crop is established and growing rapidly or to moist soil in row middles after crop establishment. Note label precautions against replanting non-registered within 8 months.
Halosulfuron 0.024 - 0.05	(Sandea, Profine 75) 75 DG 0.5 to 1 oz.	Small seeded broadleaf and nutsedge. One over-the-top application 14 days after transplanting at 0.5 to 0.75 oz. product and/or postemergence application(s) of up to 1 oz. product to row middles. Include a nonionic surfactant. PHI 30 days.
Imazosulfuron 0.19 to 0.3	(League) 75 DG 4 – 6.4 oz.	Broadleaf weeds and nutsedge. Apply 3 to 5 days after transplanting through early bloom. Include an approved surfactant if weeds are emerged. Only 1 application per year either PRE or POST. PHI 21 days.
Lactofen 0.25 - 0.5	(Cobra) 2 EC 16 to 32 fl. oz.	Broadleaf weeds. Apply to row middles only with shielded or hooded sprayers. Cobra contacting green foliage or fruit can cause excessive injury. Drift of Cobra treated soil particles onto plants can cause contact injury. A minimum of 24 fl. oz. is required for residual control. Add a crop oil concentrate or non-ionic surfactant for control of emerged weeds. Limit of 1 PRE and 1 POST application per growing season. PHI 30 days.
S-metolachlor 1.0 to 1.3	(Brawl, Dual Magnum, Medal) 7.62 EC 1.0 to 1.33 pt.	Annual broadleaf and grass weeds and yellow nutsedge. Apply to row middles. Label rates are 1.0 – 1.33 pt./A if organic matter is less than 3%. Research has shown that the 1.33 pt. may be too high in some Florida soils except in row middles. Use on a trial basis. PHI 60 days for rates 1.67 pt. or less/A/year. PHI 90 days for rates 1.68 to 2.0 pts./A/year.
Metribuzin 0.25 – 0.5	(Sencor DF, TriCor DF) 75 WDG 0.33 to 0.67 lb. (Sencor 4, Metri) 4 F 0.5 to 1 pt.	Controls small emerged weeds. Apply after transplants are established or direct-seeded plants reach 5 to 6 true leaf stage. Apply in single or multiple application 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. In row middles, can apply 0.25 – 1.0 lb. a.i./A. PHI 7 days.
Paraquat 0.5	(Gramaxone Inteon) 2 SL 2 pt. (Firestorm) 3 SL 1.3 pt	Emerged broadleaf and grass weeds. Direct spray over emerged weeds 1 to 6 inches tall in row middles between mulched beds. Use a nonionic surfactant. Use low pressure and shields to control drift. Do not apply more than 3 times per season. PHI 30 days.
Pelargonic Acid	(Scythe) 4.2 EC 3 - 10%	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. Has a greenhouse and growth structure label.
Rimsulfuron 0.02 – 0.03	(Matrix FNV, Matrix SG, Pruvin) 25 WDG 1.0 - 2.0 oz.	Broadleaf and grass weed. 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 to 1 inch of rainfall or irrigation within 5 days of application for activation. For POST weed control, include a crop oil concentrate or nonionic surfactant. PHI 45 days.
Sethoxydim 0.19 - 0.28	(Poast) 1.5 EC 1.0 to 1.5 pt.	Controls growing grass weeds. A total of 4.5 pts. /A applied in one season. Include a crop oil concentrate. Unsatisfactory results may occur if applied to grasses under stress. PHI 20 days.
Trifloxysulfuron 0.0047 – 0.0094	(Envoke) 75 DG 0.1 - 0.2 oz.	Broadleaf and nutsedge control. Direct spray solution to the base of transplanted tomato plants. Apply at least 14 days after transplanting and before fruit set. Include a nonionic surfactant in the spray mix. Apply before fruit set. PHI 45 days.
	POST HARVEST	
Paraquat 0.62 -0.94	(Gramaxone Inteon) 2 SL 2.4 – 3.75 pt. (Firestorm) 3 SL 1.6 – 2.5 pt.	Broadcast spray over the top of plants after last harvest. Use a nonionic surfactant. Thorough coverage is required to ensure maximum herbicide burn down. Do not use treated crop for human or animal consumption.
Diquat 0.38	(Reglone 2 L 1.5 pt.	Broadcast spray over the top of plants after last harvest. Use a nonionic surfactant. Thorough coverage is required to ensure maximum herbicide burn down. Do not use treated crop for human or animal consumption.

Tomato Fungicides

Sorted by disease and then in order by FRAC group corresponding to the mode of action. Biopesticides are listed in a separate table for convenience. (Updated June 2012).

Gary E. Vallad, UF/IFAS Gulf Coast REC., gvallad@ufl.edu

Be sure to read a current product label before applying any product.

Pertinent Disease or Pathogen	Fungicide Group[1]	Chemical (active ingredients)	Max. Rate/Acre		Min. Days to		Remarks[2]
			Applic.	Season	Harvest	Reentry	
Anthracnose	M1	(copper compounds) Many brands available: Badge SC, Badge X2, Basic Copper 50W HB, Basic Copper 53, C-O-C-S WDG, Champ DP, Champ F2 FL, Champ WG, Champion WP, C-O-C DF, C-O-C WP, Copper Count N, Cuprofix Ultra 40D, Cueva, Kentan DF, Kocide 3000, Kocide 2000, Kocide DF, Nordox, Nordox 75WG, Nu Cop 50WP, Nu Cop 3L, Nu Cop 50DF, Nu Cop HB	SEE INDIVIDUAL LABELS		1	Varies from 4 hr to 2 days.	Mancozeb enhances bactericidal effect of fix copper compounds.
	M3	(mancozeb) Many brands available: Dithane DF, Dithane F45, Dithane M45, Kover-all, Manzate FL, Manzate Pro-Stik, Penncozeb 4FL, Penncozeb 75DF, Penncozeb 80WP	SEE INDIVIDUAL LABELS		5	1	
	M3	Ziram 76DF (ziram)	4 lb	23.7 lb	7	2	Do not use on cherry tomatoes.
	M3 & M1	ManKocide (mancozeb + copper hydroxide)	5 lb	112 lb	5	2	
	M5	(chlorothalonil) Many brands available: Bravo Ultrex, Bravo Weather Stik, Bravo Zn, Chloronil 720, Echo 720, Echo 90 DF, Echo Zn, Equus 500 Zn, Equus 720 SST, Equus DF, Initiate 720	SEE INDIVIDUAL LABELS		0	0.5	Use higher rates at fruit set and lower rates before fruit set.
(suppression)	7	Fontelis (penthiopyrad)	24 fl oz	72 fl oz	0	0.5	For Disease suppression only. No more than 2 sequential applications before rotating with another effective fungicide from a different FRAC group. See label for additional instructions pertaining to greenhouse useage.
	9 & 3	Inspire Super (cyprodinil + difenoconazole)	20 fl oz	47 fl oz	0	0.5	Limit is 5 apps per season with no more than 2 sequential apps. Must tank mix or alternate with another effective fungicide from another FRAC group. Has up to a 8 month plant back restriction with off label crops.
	11	Heritage Quadris FL (azoxystrobin)	3.2 oz 6.2 fl oz	1.6 lb 37 fl oz	0 0	4 hr 4 hr	Must alternate or tank mix with a fungicide from a different FRAC group; use of an adjuvant or tank mixing with EC products may cause phytotoxicity; avoid applications until 21 days after transplanting or 35 days after seeding, or within +/- 6 days of a postemergence broadcast application of Sencore®.
	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; do not apply until 21 days after transplanting or 35 days after seeding; avoid applications within +/- 6 days of a postemergence broadcast application of Sencore®.
	11 & 3	Quadris Top (azoxystrobin + difenoconazole)	8 fl oz	47 fl oz	0	0.5	Do not apply until 21 days after transplant or 35 days after seeding. Limit is 4 apps per season with no more than 2 sequential apps. Must tank mix or alternate with another effective fungicide from another FRAC group.
	11 & 7	Priaxor (pyraclostrobin + fluxapyroxad)	8 fl oz	24 fl oz	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.

(suppression)	19	Ph-D WDG (polyoxin D zinc salt)	6.2 oz	31.0 oz	0	4 hr	Limit is 5 apps. on 10-14 day interval. Alternate with a non-FRAC code 19 fungicide.
	40 & 3	Revus Top (mandipropamid + difenoconazole)	7 fl oz	28 fl oz	1	0.5	Limit is 4 apps per season; no more than 2 sequential apps. Not labeled for transplants.
Bacterial canker	M1	(copper compounds) Many brands available: Badge SC, Badge X2, Basic Copper 50W HB, Basic Copper 53, C-O-C-S WDG, Champ DP, Champ F2 FL, Champ WG, Champion WP, C-O-C DF, C-O-C WP, Copper Count N, Cuprofix Ultra 40D, Cueva, Kentan DF, Kocide 3000, Kocide 2000, Kocide DF, Nordox, Nordox 75WG, Nu Cop 50WP, Nu Cop 3L, Nu Cop 50DF, Nu Cop HB	SEE INDIVIDUAL LABELS		1	Varies by product from 4 hr to 2 days.	Mancozeb enhances the bactericidal effect of fix copper compounds.
(suppression)	11 & 27	Tanos (famoxadone + cymoxanil)	8 oz	72 oz	3	0.5	Do not alternate or tank mix with other FRAC group 11 fungicides.
Bacterial spot and Bacterial speck	M1	(copper compounds) Many brands available: Badge SC, Badge X2, Basic Copper 50W HB, Basic Copper 53, C-O-C-S WDG, Champ DP, Champ F2 FL, Champ WG, Champion WP, C-O-C DF, C-O-C WP, Copper Count N, Cuprofix Ultra 40D, Cueva, Kentan DF, Kocide 3000, Kocide 2000, Kocide DF, Nordox, Nordox 75WG, Nu Cop 50WP, Nu Cop 3L, Nu Cop 50DF, Nu Cop HB	SEE INDIVIDUAL LABELS		1	Varies by product from 4 hr to 2 days.	Mancozeb enhances the bactericidal effect of fix copper compounds.
	M3	(mancozeb) Many brands available: Dithane DF, Dithane F45, Dithane M45, Kover-all, Manzate FL, Manzate Pro-Stik, Penncozeb 4FL, Penncozeb 75DF, Penncozeb 80WP	SEE INDIVIDUAL LABELS		5	1	Bacterial spot control only when tank mixed with a copper fungicide.
	M3 & M1	ManKocide (mancozeb + copper hydroxide)	5 lb	112 lb	5	2	
(suppression)	11 & 27	Tanos (famoxadone + cymoxanil)	8 oz	72 oz	3	0.5	Do not alternate or tank mix with other FRAC group 11 fungicides.
	25	Agri-mycin 17 Ag Streptomycin Bac-Master (streptomycin sulfate)	200 ppm	-	-	0.5	See label for details. For transplant production only. Many isolates are resistant to strepto-mycin.
	P	Actigard (acibenzolar-S-methyl)	0.75 oz	4.75 oz	14	0.5	Begin applications within one week of trans-planting or emergence. Make up to 8 weekly, sequential applications.
Black mold (Alternaria spp.)	7	Endura (boscalid)	12.5 oz	25 oz	0	0.5	Alternate with non-FRAC code 7 fungicides, see label
	7	Fontelis (penthiopyrad)	24 fl oz	72 fl oz	0	0.5	No more than 2 sequential applications before rotating with another effective fungicide from a different FRAC group. See label for additional instructions pertaining to greenhouse useage.
	9 & 3	Inspire Super (cyprodinil + difenoconazole)	20 fl oz	47 fl oz	0	0.5	Limit is 5 apps per season with no more than 2 sequential apps. Must tank mix or alternate with another effective fungicide from another FRAC group. Has up to a 8 month plant back restriction with off label crops.
	11 & 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; do not apply until 21 days after transplanting or 35 days after seeding; avoid applications within +/- 6 days of a postemergence broadcast application of Sencore®.
	11 & 3	Quadris Top (azoxystrobin + difenoconazole)	8 fl oz	47 fl oz	0	0.5	Do not apply until 21 days after transplant or 35 days after seeding. 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	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.
	40 & 3	Revus Top (mandipropamid + difenoconazole)	7 fl oz	28 fl oz	1	0.5	4 apps per season; no more than 2 sequential apps. Not labeled for transplants.
Botrytis, Gray Mold	M5	(chlorothalonil) Many brands available: Bravo Ultrex, Bravo Weather Stik, Bravo Zn, Chloronil 720, Echo 720, Echo 90 DF, Echo Zn, Equus 500 Zn, Equus 720 SST, Equus DF, Initiate 720	SEE INDIVIDUAL LABELS		0	0.5	Use higher rates at fruit set and lower rates before fruit set.
	7	Fontelis (penthiopyrad)	24 fl oz	72 fl oz	0	0.5	No more than 2 sequential applications before switching to another effective fungicide with a different mode of action. See label for additional instructions pertaining to greenhouse useage.
	7	Endura (boscalid)	12.5 oz	25 oz	0	0.5	Alternate with non-FRAC code 7 fungicides.
	9	Scala SC (pyrimethanil)	7 fl oz	35 fl oz	1	0.5	Use only in a tank mix with another effective non-FRAC code 9 fungicide; Has a 30 day plant back with off label crops.
	9 & 12	Switch 62.5WG (cyprodinil + fludioxonil)	14 oz	56 oz per year	0	0.5	After 2 appl. Alternate with non-FRAC code 9 or 12 fungicides for next 2 applications. Has a 30 day plant back with off label crops.
(suppression)	11	Cabrio 2.09 F (pyraclostrobin)	16 fl oz	96 fl oz	0	0.5	Only 2 sequential appl. Allowed. Limit is 6 appl/crop. Must alternate or tank mix with a fungicide from a different FRAC group.
(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	Botran 75 W (dichloran)	1 lbs per 100 gal.	5.33 lb	10	0.5	Greenhouse use only. Limit is 4 applications. Seedlings or newly set transplants may be injured.
	19	Ph-D WDG (polyoxin D zinc salt)	6.2 oz	31.0 oz	0	4 hr	Limit is 5 apps. on 10-14 day interval. Alternate with a non-FRAC code 19 fungicide.
Buckeye rot	M1 + 4	Ridomil Gold Copper (copper hydroxide + mefenoxam)	2 lb	6 lb	14	2	Limited to 3 apps per season. Tankmix with mancozeb.
	11	Heritage Quadris FL (azoxystrobin)	3.2 oz 6.2 fl oz	1.6 lb 37 fl oz	0	4 hr	Must alternate or tank mix with a fungicide from a different FRAC group; use of an adjuvant or tank mixing with EC products may cause phytotoxicity; avoid applications until 21 days after transplanting or 35 days after seeding, or within +/- 6 days of a postemergence broadcast application of Sencore®.
	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; do not apply until 21 days after transplanting or 35 days after seeding; avoid applications within +/- 6 days of a postemergence broadcast application of Sencore; see label.
(suppression)	11 & 27	Tanos (famoxadone + cymoxanil)	8 oz	72 oz	3	0.5	Do not alternate or tank mix with other FRAC group 11 fungicides.
	22 & M3	Gavel 75DF (zoaximide + mancozeb)	2.0 lb	16 lb	5	2	See label
Early blight	M1	(copper compounds) Many brands available: Badge SC, Badge X2, Basic Copper 50W HB, Basic Copper 53, C-O-C-S WDG, Champ DP, Champ F2 FL, Champ WG, Champion WP, C-O-C DF, C-O-C WP, Copper Count N, Cuprofix Ultra 40D, Cueva, Kentan DF, Kocide 3000, Kocide 2000, Kocide DF, Nordox, Nordox 75WG, Nu Cop 50WP, Nu Cop 3L, Nu Cop 50DF, Nu Cop HB	SEE INDIVIDUAL LABELS		1	Varies by product from 4 hr to 2 days.	Mancozeb or maneb enhances bactericidal effect of fix copper compounds. See label for details.

M3	(mancozeb) Many brands available: Dithane DF, Dithane F45, Dithane M45, Kover-all, Manzate FL, Manzate Pro-Stik, Penncozeb 4FL, Penncozeb 75DF, Penncozeb 80WP	SEE INDIVIDUAL LABELS		5	1	
M3	Ziram 76DF (ziram)	4 lbs	23.7 lb	7	2	Do not use on cherry tomatoes.
M3 & M1	ManKocide (mancozeb + copper hydroxide)	5 lb	112 lb	5	2	
M5	(chlorothalonil) Many brands available: Bravo Ultrex, Bravo Weather Stik, Bravo Zn, Chloronil 720, Echo 720, Echo 90 DF, Echo Zn, Equus 500 Zn, Equus 720 SST, Equus DF, Initiate 720	SEE INDIVIDUAL LABELS		0	0.5	Use higher rates at fruit set and lower rates before fruit set.
4 & M5	Ridomil Gold Bravo 76.4 W (chlorothalonil + mefenoxam)	3 lb	12 lb	14	2	Limit is 4 appl./crop.
7	Endura (boscalid)	12.5 oz	25 oz	0	0.5	Alternate with non-FRAC code 7 fungicides.
7	Fontelis (penthiopyrad)	24 fl oz	72 fl oz	0	0.5	No more than 2 sequential applications before switching to another effective fungicide with a different mode of action. See label for additional instructions pertaining to greenhouse useage.
9	Scala SC (pyrimethanil)	7 fl oz	35 fl oz	1	0.5	Use only in a tank mix with another effective non-FRAC code 9 fungicide ; Has a 30 day plant back with off label crops.
9 & 3	Inspire Super (cyprodinil + difenoconazole)	20 fl oz	47 fl oz	0	0.5	Limit is 5 apps per season with no more than 2 sequential apps. Must tank mix or alternate with another effective fungicide from another FRAC group. Has up to a 8 month plant back restriction with off label crops.
9 & 12	Switch 62.5WG (cyprodinil + fludioxonil)	14 oz	56 oz per year	0	0.5	After 2 apps. alternate with non-FRAC code 9 or 12 fungicides for next 2 applications. Has a 30 day plant back with off label crops.
11	Heritage Quadris FL (azoxystrobin)	3.2 oz 6.2 fl oz	1.6 lb 37 fl oz	0	4 hr	Must alternate or tank mix with a fungicide from a different FRAC group; use of an adjuvant or tank mixing with EC products may cause phytotoxicity; avoid applications until 21 days after transplanting or 35 days after seeding, or within +/- 6 days of a postemergence broadcast application of Sencore®.
11	Cabrio 2.09 F (pyraclostrobin)	16 fl oz	96 fl oz	0	0.5	Only 2 sequential apps. allowed. Limit is 6 apps/crop. Must alternate or tank mix with a fungicide from a different FRAC group.
11	Flint (trifloxystrobin)	4 oz	16 oz	3	0.5	Limit is 5 apps/crop. Must alternate or tank mix with a fungicide from a different FRAC group.
11	Evito Aftershock (fluoxastrobin)	5.7 fl oz	22.8 fl oz	3	0.5	Limit is 4 apps/crop. Must alternate or tank mix with a fungicide from a different FRAC group.
11	Reason 500 SC (fenamidone)	8.2 oz	24.6 lb	14	0.5	Must alternate with a fungicide from a different FRAC group. See supplemental label for restrictions and details.
11 & M5	Quadris Opti (azoxystrobin + chlorothalonil)	1.6 pt	8 pt	0	0.5	Must alternate with a non-FRAC code 11 fungicide; use of an adjuvant may cause phytotoxicity; do not apply until 21 days after transplanting or 35 days after seeding; avoid applications within +/- 6 days of a postemergence broadcast application of Sencore®.
11 & 3	Quadris Top (azoxystrobin + difenoconazole)	8 fl oz	47 fl oz	0	0.5	Do not apply until 21 days after transplant or 35 days after seeding. 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	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	Ph-D WDG (polyoxin D zinc salt)	6.2 oz	31.0 oz	0	4 hr	Limit is 5 apps. on 10-14 day interval. Alternate with a non-FRAC code 19 fungicide.
	22 & M3	Gavel 75DF (zoaximide + mancozeb)	2.0 lb	16 lb	5	2	
	28	Previcur Flex (propamocarb hydrochloride)	1.5 pt	7.5 pt	5	0.5	Must tank mix with chlorothalonil or mancozeb.
	28	Promess (propamocarb hydrochloride)	1.5 pt	7.5 pt	5	0.5	Must tank mix with chlorothalonil or mancozeb.
	40 & 3	Revus Top (mandipropamid + difenoconazole)	7 fl oz	28 fl oz	1	0.5	Limit is 4 apps per season; no more than 2 sequential apps. Not labeled for transplants.
Late blight	M1	(copper compounds) Many brands available: Badge SC, Badge X2, Basic Copper 50W HB, Basic Copper 53, C-O-C-S WDG, Champ DP, Champ F2 FL, Champ WG, Champion WP, C-O-C DF, C-O-C WP, Copper Count N, Cuprofix Ultra 40D, Cueva, Kentan DF, Kocide 3000, Kocide 2000, Kocide DF, Nordox, Nordox 75WG, Nu Cop 50WP, Nu Cop 3L, Nu Cop 50DF, Nu Cop HB	SEE INDIVIDUAL LABELS		1	Varies by product from 4 hr to 2 days.	
	M3	(mancozeb) Many brands available: Dithane DF, Dithane F45, Dithane M45, Kover-all, Manzate, Manzate Pro-Stik, Penncozeb 4FL, Penncozeb 75DF, Penncozeb 80WP	SEE INDIVIDUAL LABELS		5	1	
	M3 & M1	ManKocide (mancozeb + copper hydroxide)	5 lb	112 lb	5	2	
	M5	(chlorothalonil) Many brands available: Bravo Ultrex, Bravo Weather Stik, Bravo Zn, Chloronil 720, Echo 720, Echo 90 DF, Echo Zn, Equus 500 Zn, Equus 720 SST, Equus DF, Initiate 720	SEE INDIVIDUAL LABELS		0	0.5	Use higher rates at fruit set and lower rates before fruit set.
	4 & M3	Ridomil MZ 68 WP (mefenoxam + mancozeb)	2.5 lb	7.5 lb	5	2	Limit is 3 apps./crop.
	4 & M1	Ridomil Gold Copper 64.8 W (mefenoxam + copper hydroxide)	2 lb	6 lb	14	2	Limit is 3 apps./crop. Tank mix with mancozeb fungicide.
	4 & M5	Ridomil Gold Bravo 76.4 W (chlorothalonil + mefenoxam)	3 lb	12 lb	14	2	Limit is 4 apps./crop.
	11	Heritage Quadris FL (azoxystrobin)	3.2 oz 6.2 fl oz	1.6 lb 37 fl oz	0	4 hr	Must alternate or tank mix with a fungicide from a different FRAC group; use of an adjuvant or tank mixing with EC products may cause phytotoxicity; avoid applications of Heritage/Amistar until 21 days after transplanting or 35 days after seeding, or within +/- 6 days of a postemergence broadcast application of Sencore®.
	11	Cabrio 2.09 F (pyraclostrobin)	16 fl oz	96 fl oz	0	0.5	Only 2 sequential appl. Allowed. Limit is 6 appl/crop. Must alternate or tank mix with a fungicide from a different FRAC group.
	11	Flint (trifloxystrobin)	4 oz	16 oz	3	0.5	Limit is 5 appl/crop. Must alternate or tank mix with a fungicide from a different FRAC group.
	11	Evito Aftershock (fluoxastrobin)	5.7 fl oz	22.8 fl oz	3	0.5	Limit is 4 appl/crop. Must alternate or tank mix with a fungicide from a different FRAC group.
	11	Reason 500 SC (fenamidone)	8.2 oz	24.6 lb	14	0.5	Must alternate with a fungicide from a different FRAC group.

	11 & M5	Quadris Opti (azoxystrobin + chlorothalonil)	1.6 pt	8 pt	0	0.5	Must alternate with a non-FRAC code 11 fungicide; use of an adjuvant may cause phytotoxicity; do not apply until 21 days after transplanting or 35 days after seeding; avoid applications within +/- 6 days of a postemergence broadcast application of Sencore®.
(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.
	21	Ranman (cyazofamid)	2.75 oz	16oz	0	0.5	Limit is 6 apps./crop.
	22 & M3	Gavel 75DF (zoaximide + mancozeb)	2.0 lb	16 lb	5	2	
	27	Curzate 60DF (cymoxanil)	5 oz	30 oz per year	3	0.5	Must tank mix with another effective product.
	28	Previcur Flex (propamocarb hydrochloride)	1.5 pt	7.5 pt	5	0.5	Must tank mix with Chlorothalonil or mancozeb.
	28	Promess (propamocarb hydrochloride)	1.5 pt	7.5 pt	5	0.5	Must tank mix with Chlorothalonil or mancozeb.
	33	Aliette 80 WDG (fosetyl-al)	5 lb	20lb	14	0.5	See label for warnings concerning the use of copper compounds.
	40	Forum (dimethomorph)	6 oz	30 oz	4	0.5	Only 2 sequential appl. See label for details
	40	Revus (mandipropamid)	8 fl oz	32 fl oz	1	4 hr	Supplemental label; No more than 2 sequential appl.; See label
	40 & 3	Revus Top (mandipropamid + difenoconazole)	7 fl oz	28 fl oz	1	0.5	4 apps per season; no more than 2 sequential apps; do not use on varieties with mature fruit less than 2 inches in diameter. Not labeled for transplants. See label
	43	Presidio (Fluopicolide)	4 fl oz	12 fl oz/per season	2	0.5	4 apps per season; no more than 2 sequential apps. 10 day spray interval; Tank mix with another labeled non-FRAC code 43 fungicide; 18 month rotation with off label crops; see label.
	45 & 40	Zampro (ametoctradin + dimethomorph)	14 fl oz	42 fl oz	4	0.5	Addition of a spreading or penetrating adjuvant is recommended to improve performance. Limit of 3 applications per season.
Leaf mold	M3	(mancozeb) Many brands available: Dithane DF, Dithane F45, Dithane M45, Koverall, Manzate, Manzate Pro-Stik, Penncozeb 4FL, Penncozeb 75DF, Penncozeb 80WP	SEE INDIVIDUAL LABELS		5		
	M5	(chlorothalonil) Many brands available: Bravo Ultrex, Bravo Weather Stik, Bravo Zn, Chloronil 720, Echo 720, Echo 90 DF, Echo Zn, Equus 500 Zn, Equus 720 SST, Equus DF, Initiate 720	SEE INDIVIDUAL LABELS		0	0.5	Use higher rates at fruit set and lower rates before fruit set, see label
	9 & 3	Inspire Super (cyprodinil + difenoconazole)	20 fl oz	47 fl oz	0	0.5	Do not use on varieties with mature fruit less than 2 inches (cherry and grape types). 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	Do not apply until 21 days after transplant or 35 days after seeding. 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. Do not apply to varieties with mature fruit less than 2 inches (cherry and grape types). Has up to a 1 year plant back restriction for certain off label crops ; see label.

	11 & 27	Tanos (famoxadone + cymoxanil)	8 oz	72 oz	3	0.5	Do not alternate or tank mix with other FRAC group 11 fungicides. See label for details
	22 & M3	Gavel 75DF (zoaximide + mancozeb)	2.0 lb	16 lb	5	2	
	40 & 3	Revus Top (mandipropamid + difenoconazole)	7 fl oz	28 fl oz	1	0.5	4 apps per season; no more than 2 sequential apps. Not labeled for transplants.
Grey leaf spot	M1	(copper compounds) Many brands available: Badge SC, Badge X2, Basic Copper 50W HB, Basic Copper 53, C-O-C-S WDG, Champ DP, Champ F2 FL, Champ WG, Champion WP, C-O-C DF, C-O-C WP, Copper Count N, Cuprofix Ultra 40D, Cueva, Kentan DF, Kocide 3000, Kocide 2000, Kocide DF, Nordox, Nordox 75WG, Nu Cop 50WP, Nu Cop 3L, Nu Cop 50DF, Nu Cop HB	SEE INDIVIDUAL LABELS		1	Varies by product from 4 hr to 2 days.	Mancozeb or maneb enhances bactericidal effect of fix copper compounds.
	M3	(mancozeb) Many brands available: Dithane DF, Dithane F45, Dithane M45, Kover-all, Manzate, Manzate Pro-Stik, Penncozeb 4FL, Penncozeb 75DF, Penncozeb 80WP	SEE INDIVIDUAL LABELS		5	1	
	M3 & M1	ManKocide (mancozeb + copper hydroxide)	5 lb	112 lb	5	2	
	M5	(chlorothalonil) Many brands available: Bravo Ultrex, Bravo Weather Stik, Bravo Zn, Chloronil 720, Echo 720, Echo 90 DF, Echo Zn, Equus 500 Zn, Equus 720 SST, Equus DF, Initiate 720	SEE INDIVIDUAL LABELS		0	0.5	Use higher rates at fruit set and lower rates before fruit set.
	4 & M5	Ridomil Gold Bravo 76.4 W (chlorothalonil + mefenoxam)	3 lb	12 lb	14	2	Limit is 4 apps./crop.
	9 & 3	Inspire Super (cyprodinil + difenoconazole)	20 fl oz	47 fl oz	0	0.5	Do not use on varieties with mature fruit less than 2 inches (cherry and grape types). Limit is 5 apps per season with no more than 2 sequential apps. Must tank mix or alternate with another effective fungicide from another FRAC group. Has up to a 8 month plant back restriction with off label crops.
	11	Flint (trifloxystrobin)	4 oz	16 oz	3	0.5	Limit is 5 apps/crop. Must alternate or tank mix with a fungicide from a different FRAC group.
	11 & 3	Quadris Top (azoxystrobin + difenoconazole)	8 fl oz	47 fl oz	0	0.5	Do not apply until 21 days after transplant or 35 days after seeding. Limit is 4 apps per season with no more than 2 sequential apps. Must tank mix or alternate with another effective fungicide from another FRAC group. Has up to a 1 year plant back restriction for certain off label crops.
	22 & M3	Gavel 75DF (zoaximide + mancozeb)	2.0 lb	16 lb	5	2	
	40 & 3	Revus Top (mandipropamid + difenoconazole)	7 fl oz	28 fl oz	1	0.5	4 apps per season; no more than 2 sequential apps. Not labeled for transplants.
Phytophthora crown rot, Phytophthora root rot (Phytophthora spp.)	4	Ridomil Gold SL Ultra Flourish (mefenoxam)	1 pt 2 pt	3 pt 6 pt	28 7	2* 2*	Do not apply more than 6 lb mefenoxam/A per crop to the soil. *There is a reentry interval exemption if material is soil-injected or soil-incorporated.
	4	Metastar 2E (metalaxyl)	2 qt	6 qt	2	28	Soil applied by drip injection.
	11	Reason 500 SC (fenamidone)	8.2 oz	24.6 lb	14	0.5	Must alternate with a fungicide from a different FRAC group. (Phytophthora capsici-suppression only)
	14	Terramaster 4EC (etridiazole)	7 fl oz	27.4 fl oz	3	0.5	Greenhouse use only.
	21	Ranman (cyazofamid)	2.75 fl oz	16.5 fl oz	0		Apply to the base of plant at the time of transplanting. Make additional applications on a 7 to 10 day schedule if conditions are favorable for disease.

	28	Previcur Flex (propamocarb hydrochloride)	SEE LABEL		5	0.5	GREENHOUSE APPLICATION: 6 apps/crop cycle. Do not mix with other products. Can cause phytotoxicity if applied in intense sunlight.
	33	Aliette 80 WDG Linebacker WDG (fosetyl-aluminum)	5 lb	2 lb	14	0.5	See label for warnings concerning the use of copper compounds.
	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.
Powdery mildew	M2	(sulfur) Many brands available: Cosavet DF, Kumulus DF, Micro Sulf, Microfine Sulfur, Microthiol Disperss, Sulfur 6L, Sulfur 90W, Super Six, That Flowable Sulfur, Tiolux Jet, Thiosperse 80%, Wettable Sulfur, Wettable Sulfur 92, Yellow Jacket Dusting Sulfur, Yellow Jacket Wettable Sulfur	SEE INDIVIDUAL LABELS		1	1	Follow label closely, may cause leaf burn if applied during high temperatures.
	3	Rally 40WSP Nova 40 W Sonoma 40WSP (myclobutanil)	4 oz	1.25 lb	0	1	Note that a 30 day plant back restriction exists.
	7	Fontelis (penthiopyrad)	24 fl oz	72 fl oz	0	0.5	No more than 2 sequential applications before switching to another effective fungicide with a different mode of action. See label for additional instructions pertaining to greenhouse useage.
	9 & 3	Inspire Super (cyprodinil + difenoconazole)	20 fl oz	47 fl oz	0	0.5	Limit is 5 apps per season with no more than 2 sequential apps. Must tank mix or alternate with another effective fungicide from another FRAC group. Has up to a 8 month plant back restriction with off label crops.
	9 & 12	Switch 62.5WG (cyprodinil + fludioxonil)	14 oz	56 oz per year	0	0.5	After 2 apps alternate with non-FRAC code 9 or 12 fungicides for next 2 applications. Has a 30 day plant back with off label crops.
	11	Heritage Quadris FL (azoxystrobin)	3.2 oz 6.2 fl oz	1.6 lb 37 fl oz	0	4 hr	Must alternate or tank mix with a fungicide from a different FRAC group; use of an adjuvant or tank mixing with EC products may cause phytotoxicity; avoid applications until 21 days after transplanting or 35 days after seeding, or within +/- 6 days of a postemergence broadcast application of Sencore®.
	11	Cabrio 2.09 F (pyraclostrobin)	16 fl oz	96 fl oz	0	0.5	Only 2 sequential apps. allowed. Limit is 6 appl/crop. Must alternate or tank mix with a fungicide from a different FRAC group.
	11	Flint (trifloxystrobin)	4 oz	16 oz	3	0.5	Limit is 5 apps/crop; must alternate or tank mix with a fungicide from a different FRAC group.
	11 & M5	Quadris Opti (azoxystrobin + chlorothalonil)	1.6 pt	8 pt	0	0.5	Must alternate with a non-FRAC code 11 fungicide; use of an adjuvant may cause phytotoxicity; do not apply until 21 days after transplanting or 35 days after seeding; avoid applications within +/- 6 days of a postemergence broadcast application of Sencore®.
	11 & 3	Quadris Top (azoxystrobin + difenoconazole)	8 fl oz	47 fl oz	0	0.5	Do not apply until 21 days after transplant or 35 days after seeding. 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	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.

	19	Ph-D WDG (polyoxin D zinc salt)	6.2 oz	31.0 oz	0	4 hr	Limit is 5 apps. on 10-14 day interval. Alternate with a non-FRAC code 19 fungicide.
	40 & 3	Revus Top (mandipropamid + difenoconazole)	7 fl oz	28 fl oz	1	0.5	4 apps per season; no more than 2 sequential apps. Not labeled for transplants.
Pythium diseases (Pythium spp.)	4	Ridomil Gold GR Ridomil Gold SL Ultra Flourish (mefenoxam)	20 lb 2 pt 2 pt	40 lb 3 pt 6 pt	28 7 7	2* 2* 2	*There is a reentry interval exemption if material is soil-injected or soil-incorporated.
	4	Metastar 2E (metalaxyl)	2 qt	6 qt	28	2	Soil applied by drip injection.
	14	Terramaster 4EC (etridiazole)	7 fl oz	27.4 fl oz	3	0.5	Greenhouse use only.
	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.
Rhizoctonia root rot, Rhizoctonia fruit rot (Rhizoctonia solani)	M5	(chlorothalonil) Many brands available: Bravo Ultrex, Bravo Weather Stik, Bravo Zn, Chloronil 720, Echo 720, Echo 90 DF, Echo Zn, Equus 500 Zn, Equus 720 SST, Equus DF, Initiate 720	SEE INDIVIDUAL LABELS		0	0.5	Use higher rates at fruit set and lower rates before fruit set.
(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.
Target spot	M5	(chlorothalonil) Many brands available: Bravo Ultrex, Bravo Weather Stik, Bravo Zn, Chloronil 720, Echo 720, Echo 90 DF, Echo Zn, Equus 500 Zn, Equus 720 SST, Equus DF, Initiate 720	SEE INDIVIDUAL LABELS		0	0.5	Use higher rates at fruit set and lower rates before fruit set.
	4 & M5	Ridomil Gold Bravo 76.4 W (chlorothalonil + mefenoxam)	3 lb	12 lb	14	2	Limit is 4 appl./crop.
	7	Endura (boscalid)	12.5 oz	25 oz	0	0.5	Alternate with non-FRAC code 7 fungicides.
	7	Fontelis (penthiopyrad)	24 fl oz	72 fl oz	0	0.5	No more than 2 sequential apps. before switching to another effective fungicide with a different mode of action. See label for additional instructions pertaining to greenhouse useage.
	9	Scala SC (pyrimethanil)	7 fl oz	35 fl oz	1	0.5	Use only in a tank mix with another effective non-FRAC code 9 fungicide; has a 30 day plant back with off label crops.
	9 & 3	Inspire Super (cyprodinil + difenoconazole)	20 fl oz	47 fl oz	0	0.5	Limit is 5 apps./season with no more than 2 sequential apps. Must tank mix or alternate with another effective fungicide from another FRAC group. Has up to a 8 month plant back restriction with off label crops.

	11	Heritage Quadris FL (azoxystrobin)	3.2 oz 6.2 fl oz	1.6 lb 37 fl oz	0	4 hr	Must alternate or tank mix with a fungicide from a different FRAC group; use of an adjuvant or tank mixing with EC products may cause phytotoxicity; avoid applications until 21 days after transplanting or 35 days after seeding, or within +/- 6 days of a postemergence broadcast application of Sencore®.
	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; do not apply until 21 days after transplanting or 35 days after seeding; avoid applications within +/- 6 days of a postemergence broadcast application of Sencore®.
	11 & 3	Quadris Top (azoxystrobin + difenoconazole)	8 fl oz	47 fl oz	0	0.5	Do not apply until 21 days after transplant or 35 days after seeding. 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	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.
	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.
Septoria leaf spot	M1	(copper compounds) Many brands available: Badge SC, Badge X2, Basic Copper 50W HB, Basic Copper 53, C-O-C-S WDG, Champ DP, Champ F2 FL, Champ WG, Champion WP, C-O-C DF, C-O-C WP, Copper Count N, Cuprofix Ultra 40D, Cueva, Kentan DF, Kocide 3000, Kocide 2000, Kocide DF, Nordox, Nordox 75WG, Nu Cop 50WP, Nu Cop 3L, Nu Cop 50DF, Nu Cop HB	SEE INDIVIDUAL LABELS		1	Varies by product from 4 hr to 2 days.	
	M3	(mancozeb) Many brands available: Dithane DF, Dithane F45, Dithane M45, Koverall, Manzate, Manzate Pro-Stik, Penncozeb 4FL, Penncozeb 75DF, Penncozeb 80WP	SEE INDIVIDUAL LABELS		5		
	M3	Ziram 76DF (ziram)	4 lbs	23.7 lb	7	2	Do not use on cherry tomatoes.
	M3 & M1	ManKocide (mancozeb + copper hydroxide)	5 lbs	112 lb	5	2	
	M5	(chlorothalonil) Many brands available: Bravo Ultrex, Bravo Weather Stik, Bravo Zn, Chloronil 720, Echo 720, Echo 90 DF, Echo Zn, Equus 500 Zn, Equus 720 SST, Equus DF, Initiate 720	SEE INDIVIDUAL LABELS		0	0.5	Use higher rates at fruit set and lower rates before fruit set.
	4 & M5	Ridomil Gold Bravo 76.4 W (chlorothalonil + mefenoxam)	3 lb	12 lb	14	2	Limit is 4 apps./crop.
	7	Fontelis (penthiopyrad)	24 fl oz	72 fl oz	0	0.5	No more than 2 sequential apps. before switching to another effective fungicide with a different mode of action. See label for additional instructions pertaining to greenhouse useage.
	9 & 3	Inspire Super (cyprodinil + difenoconazole)	20 fl oz	47 fl oz	0	0.5	Limit is 5 apps per season with no more than 2 sequential apps. Must tank mix or alternate with another effective fungicide from another FRAC group. Has up to a 8 month plant back restriction with off label crops.

	11	Heritage Quadris FL (azoxystrobin)	3.2 oz 6.2 fl oz	1.6 lb 37 fl oz	0	4 hr	Must alternate or tank mix with a fungicide from a different FRAC group; use of an adjuvant or tank mixing with EC products may cause phytotoxicity; avoid applications until 21 days after transplanting or 35 days after seeding, or within +/- 6 days of a postemergence broadcast application of Sencore®.
	11	Cabrio 2.09 F (pyraclostrobin)	16 fl oz	96 fl oz	0	0.5	Only 2 sequential appl. Allowed. Limit is 6 apps/crop. Must alternate or tank mix with a fungicide from a different FRAC group.
	11	Flint (trifloxystrobin)	4 oz	16 oz	3	0.5	Limit is 5 apps/crop. Must alternate or tank mix with a fungicide from a different FRAC group.
	11	Reason 500 SC (fenamidone)	8.2 oz	24.6 lb	14	0.5	Must alternate with a fungicide from a different FRAC group.
	11 & M5	Quadris Opti (azoxystrobin + chlorothalonil)	1.6 pt	8 pt	0	0.5	Must alternate with a non-FRAC code 11 fungicide; use of an adjuvant may cause phytotoxicity; do not apply until 21 days after transplanting or 35 days after seeding; avoid applications within +/- 6 days of a postemergence broadcast application of Sencore®.
	11 & 3	Quadris Top (azoxystrobin + difenoconazole)	8 fl oz	47 fl oz	0	0.5	Do not apply until 21 days after transplant or 35 days after seeding. 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	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.
	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.
Southern blight	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 & 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.
Timber Rot, Sclerotinia stem rot, or White mold (Sclerotinia sclerotiorum)	11	Heritage Quadris FL (azoxystrobin)	3.2 oz 6.2 fl oz	1.6 lb 37 fl oz	0	4 hr	Must alternate or tank mix with a fungicide from a different FRAC group; use of an adjuvant or tank mixing with EC products may cause phytotoxicity; avoid applications of Heritage/Amistar until 21 days after transplanting or 35 days after seeding, or within +/- 6 days of a postemergence broadcast application of Sencore®.
	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	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.

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

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

Tomato Biopesticides and Other Disease Control Products

Ordered alphabetically by commercial name. (Updated May 2013).

Dr. Gary E. Vallad, UF/IFAS Gulf Coast REC, gvallad@ufl.edu

Be sure to read a current label before applying any product.

Product (active ingredient), Fungicide Group1	Max. Rate/ Acre/ Applic.	Pertinent Diseases or Pathogens	Minimum Days to:		OMRI	
			Harvest	Reentry	Listed	Remarks2
Actinovate *(Streptomyces lydicus* WYEC 108), NC	12 oz	*Alternaria spp., Anthracnose, Bacterial diseases, Botrytis, Early blight, Late blight, Phytophthora spp., Powdery mildew, Pythium spp., Rhizoctonia, Fusarium spp., Rhizoctonia, Phytophthora spp., Pythium spp.*	0	1 hr	Yes	See label for application recommendations.
AgriPhage (bacteriophage), NC	2 pt/100 gal	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	5 lb/100 gal	Anthracnose, Botrytis, Phoma, Powdery mildew, Septoria leaf spot	0	4 hr	No	See label for specific rates and application recommendations.
BioCover, (Oil, petroleum), NC	1 gal/100 gal	Insect transmitted diseases	0	4 hr	No	See label for specific rates, application recommendations, and precautions regarding use with other pesticides.
Cease (*Bacillus subtilis* strain QST 713), 44	6 qt/100 gal, foliar 8 qt/100 gal, soil applied	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.
Double Nickel 55, Double Nickel LC (*Bacillus amyloliquefaciencs* strain D747), 44	**See labels**	*Alternaria* spp., Anthracnose, Bacterial diseases, Botrytis, Early blight, Late blight, *Phytophthora* spp., Powdery mildew, *Pythium* spp., Rhizoctonia, Fusarium spp., Rhizoctonia, Phytophthora spp., Pythium spp.	0	4 hr	Yes	See label for additional rates and recommendations for foliar and soil application rates and details for specific diseases. Use as a soil drench at transplant and periodically throughout the season. Can also be used as a seed treatment. See label for details.
Glacial Spray Fluid, (Oil, petroleum), NC	1 gal/100 gal	Insect transmitted diseases	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	3 qt	Potato Virus Y, Tobacco Etch Virus, Cucumber Mosaic Virus	0	4 hr	Yes, but only for one label.	See label for specific rates, application recommendations, and precautions regarding use with other pesticides.
Kaligreen (potassium bicarbonate), NC	3 lbs	Powdery mildew	0	4 hr	Yes	See label for specific rates and application recommendations.
Milstop (potassium bicarbonate), NC	5 lbs/100 gal	Anthracnose, *Alternaria* spp., Botrytis, Powdery mildew	0	1 hr	Yes	See label for specific rates and application recommendations.
Oxidate (hydrogen peroxide), NC	1 gal/100 gal 1.25 fl oz/gal, soil drench	*Alternaria* spp., Anthracnose, Bacterial diseases, Botrytis, Early blight, Late blight, *Phytophthora* spp., Powdery mildew, *Pythium* spp., Rhizoctonia, Fusarium spp.	0	1 hr for enclosed areas; until spray dries in open field areas.	No	See label for additional rates and recommendations for transplant production and details for specific diseases. Use as a soil drench at transplant and periodically throughout the season. Can also be used as a seed treatment. See label for details.
(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	See labels	*Alternaria* spp., *Anthracnose*, *Bacterial diseases*, *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	5 oz	*Fusarium* spp., Rhizoctonia, *Pythium* spp.	0	4 hr	Yes	Can be applied to plant as a direct drench, furrow spray, chemigation, or in transplant starter solution. See label for details.
Purespray Green (Oil, petroleum), NC	1.5 gal/100 gal	Alternaria leaf spot, Powdery mildew, Insect transmitted diseases	0	4 hr	Yes	See label for specific rates, application recommendations, and precautions regarding use with other pesticides.
Regalia SC (extract of *Reynoutria sachalinensis*), P	1 % (v/v) solution	Bacterial canker , Bacterial speck, Bacterial spot, Botrytis, Early blight, *Phytophthora* spp., Powdery mildew, Target spot, Late blight	0	4 hr	Yes	Tank mix with other effective fungicides for improved disease control under heavy pressure. See label for details.
RootShield Granular (*Trichoderma harzianum* Rifai strain KRL-AG2), NC	12 lbs, in furrow 1.5 lbs/cubic yard, planting mixes.	*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	5 oz/100 gal, drench or soil applied 32 oz, in furrow or transplant solution	*Fusarium* spp., Rhizoctonia, *Pythium* spp.	0	Until spray has dried.	Yes	Can be applied as a greenhouse soil drench, or by chemigation in field and greenhouse operations. In furrow or transplant starter solution.
Serenade ASO, Serenade Max, (*Bacillus subtilis* strain QST 713), 44	6 qt 3 lbs	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	6 qt, soil drench 13.2 fl oz/ 1,000 row ft in furrow	*Fusarium* spp., *Phytophthora* spp., *Pythium* spp., *Rhizoctonia* spp., *Verticillium* spp.	0	4 hr	Yes	Formulation compatible with soil drench, in-furrow, and chemigation applications. Mix with other effective fungicides for improved disease control. See label for details.
Sil-Matrix (potassium silicate), NC	4 qt	Broad spectrum fungicide	0	4 hr	No	Must be used in a rotational program with other fungicides when conditions are conducive for disease development. See label for details.
Soilgard 12G (Gliocladium virens GI-21), NC	2 lb/100 gal, transplant drench 10 lbs/100 gal, soil applied	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	4 qt	Early Blight, Downy mildew, Late Blight, Powdery mildew	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	3 pt/100 gal	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.
Tenet (Trichoderma asperellum ICC 012; Trichoderma gamsii ICC 080), NC	5 lbs	*Fusarium* spp., *Phytophthora* spp., *Pythium* spp., *Rhizoctonia* spp., *Sclerotium* rolfsii, *Sclerotinia* spp., 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	See label	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	1 % v/v solution	*Alternaria* spp., Anthracnose, Botrytis, Early blight, Powdery mildew	0	4 hr	Yes	See label for specific rates, application recommendations, and precautions regarding use with other pesticides.
Vacciplant (laminarin), P	14.4 fl oz	Anthracnose, Bacterial speck, Bacterial spot, Early blight, Phytophthora blight, Powdery mildew	0	4 hr	No	Start applications preventively, when weather conditions are favorable for disease development. Repeat applications until disease conditions end. Add a labeled copper product to VacciPlant if the disease symptoms appear.

[1]FRAC code (fungicide group): Number (33 and 44) and letters (NC and P) are used to distinguish the fungicide mode of action groups. All fungicides within the same group (with same number or letter) indicate same active ingredient or similar mode of action. This information must be considered for the fungicide resistance management decisions. However, products with NC or P are considered low risk and don't require any rotation unless specifically directed on the label. NC = not classified, includes mineral oils, organic oils, potassium bicarbonate, and other materials of biological origin; P = host plant defense inducers. Source: FRAC Code List 2013; http://www.frac.info/ (FRAC = Fungicide Resistance Action Committee).
[2]Information provided in this table applies only to Florida. Be sure to read a current product label before applying any product. The use of brand names and any mention or listing of commercial products or services in the publication does not imply endorsement by the University of Florida Cooperative Extension Service nor discrimination against similar products or services not mentioned.

Selected Insecticides Approved for Use on Insects Attacking Tomatoes

Susan Webb, University of Florida/IFAS, Entomology and Nematology Dept., Gainesville, FL,sewe@ufl.edu

Trade Name (Common Name)	Rate (product/acre)	REI (hours)	Days to Harvest	Insects	MOA Code[1]	Notes
Acramite-50WS (bifenazate)	0.75-1.0 lb	12	3	twospotted spider mite	un	One application per season. Field grown only.
Actara (thiamethoxam)	2.0-5.5 oz	12	0	aphids, Colorado potato beetle, flea beetles, leafhoppers, stinkbugs, whitefly	4A	Maximum of 11 oz/acres per season. Do not use following a soil application of a Group 4A insecticide.
Admire Pro (imidacloprid)	7-10.5 fl oz (for rates for other brands, see labels)	12	21	aphids, Colorado potato beetle, flea beetles, leafhoppers, thrips (foliar feeding thrips only), whitefly	4A	Most effective if applied to soil at transplanting. Admire Pro limited to 10.5 fl oz/acre.
Admire Pro (imidacloprid)	0.6 fl oz/1000 plants	12	0 (soil)	aphids, whitefly	4A	Greenhouse Use: 1 application to mature plants, see label for cautions.
Admire Pro (imidacloprid)	0.44 fl oz/10,000 plants	12	21	aphids, whitefly	4A	Planthouse: 1 application. See label.
Agree WG (Bacillus thuringiensis subspecies aizawai)	0.5-2.0 lb	4	0	armyworms, hornworms, loopers, tomato fruitworm	11A	Apply when larvae are small for best control. Can be used in greenhouse. OMRI-listed[2].
*Agri Mek SC (abamectin)	1.75-3.5 fl oz	12	7	broad mite, Colorado potato beetle, *Liriomyza* leafminers, spider mite, Thrips palmi, tomato pinworm, tomato russet mite	6	Do not make more than 2 sequential applications. Do not apply more than 10.25 fl oz per acre per season.
*Ambush 25W (permethrin)	3.2-12.8 oz	12	up to day of harvest	beet armyworm, cabbage looper, Colorado potato beetle, granulate cutworm, hornworms, southern armyworm, tomato fruitworm, tomato pinworm	3A	**Do not use on cherry tomatoes.** Do not apply more than 1.2 lb ai/acre per season (76.8 oz). Not recommended for control of vegetable leafminer in Florida.
*Asana XL (0.66EC) (esfenvalerate)	2.9-9.6 fl oz	12	1	beet armyworm (aids in control), cabbage looper, Colorado potato beetle, cutworms, flea beetles, grasshoppers, hornworms, potato aphid, southern armyworm, tomato fruitworm, tomato pinworm, whitefly, yellowstriped armyworm	3A	Not recommended for control of vegetable leafminer in Florida. Do not apply more than 0.5 lb ai per acre per season, or 10 applications at highest rate.
Assail 70WP (acetamiprid) Assail 30 SG	0.6-1.7 oz 1.5-4.0 oz	12	7	aphids, Colorado potato beetle, thrips, whitefly	4A	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 apply more than 4 times per season or apply more often than every 7 days.
Avaunt (indoxacarb)	2.5-3.5 oz	12	3	beet armyworm, hornworms, loopers, southern armyworm, tomato fruitworm, tomato pinworm, suppression of leafminers	22	Do not apply more than 14 ounces of product per acre per crop. Minimum spray interval is 5 days.
Aza-Direct (azadirachtin)	1-2 pts, up to 3.5 pts, if needed	4	0	aphids, beetles, caterpillars, leafhoppers, leafminers, mites, stink bugs, thrips, weevils, whitefly	un	Antifeedant, repellant, insect growth regulator. OMRI-listed[2].
Azatin XL (azadirachtin)	5-21 fl oz	4	0	aphids, beetles, caterpillars, leafhoppers, leafminers, thrips, weevils, whitefly	un	Antifeedant, repellant, insect growth regulator.
*Baythroid XL (beta-cyfluthrin)	1.6-2.8 fl oz	12	0	beet armyworm[(1)], cabbage looper, Colorado potato beetle, dipterous leafminers[(2)], flea beetles, hornworms, potato aphid, southern armyworm[(1)], stink bugs, tomato fruitworm, tomato pinworm, variegated cutworm , thrips (except Thrips palmi), whitefly adults[(2)]	3A	[(1)] 1st and 2nd instars only [(2)] Suppression Do not apply more than 16.8 fl oz per acre per season.
Belay 50 WDG (clothianidin)	1.6-2.1 oz. (foliar application	12	7	aphids, Colorado potato beetle, flea beatles, leafhoppers, leafminers (suppression), Lygus, stink bugs, whiteflies (suppression)	4A	Do not apply more than 6.4 oz per acre per season. Do not use adjuvant. Toxic to bees. Do not release irrigation water from the treated area.
Belay 50 WDG (clothianidin)	4.8-6.4 oz (soil application)	12	Apply at planting	aphids, Colorado potato beetle, flea beetles, leafhoppers, leafminers (suppression), Lygus, foliar feeding thrips, whiteflies (suppression)	4A	Do not apply more than 6.4 oz per acre per season. See label for application instructions. Do not release irrigation water from the treated area.
Beleaf 50 SG (flonicamid)	2.0-2.8 oz	12	0	aphids, plant bugs	9C	Do not apply more than 8.4 oz/acre per season. Begin applications before pests reach damaging levels.

Belt SC (flubendiamide)	1.5 fl oz	12	1	Beet armyworm, cabbage looper, cutworm species, fall armyworm, southern armyworm, tomato fruitworm, tomato hornworm, tomato pinworm, yellow striped armyworm	28	Do not apply more that 1.5 oz per acre per 3-day interval. Do not apply more than 4.5 oz per acre per crop season.
Biobit HP (Bacillus thuringiensis subspecies kurstaki)	0.5-2.0 lb	4	0	caterpillars (will not control large armyworms)	11A	Treat when larvae are young. Good coverage is essential. Can be used in the greenhouse. OMRI-listed[2].
BotaniGard 22 WP, ES (Beauveria bassiana)	WP: 0.5-2 lb/100 gal ES: 0.5-2 qt 100/gal	4	0	aphids, thrips, whitefly	--	May be used in greenhouses. Contact dealer for recommendations if an adjuvant must be used. Not compatible in tank mix with fungicides.
*Brigade 2EC (bifenthrin)	2.1-5.2 fl oz	12	1	aphids, armyworms, corn earworm, cutworms, flea beetles, grasshoppers, mites, stink bug spp., tarnished plant bug, thrips, whitefly	3A	Make no more than 4 applications per season. Do not make applications less than 10 days apart.
CheckMate TPW-F (pheromone)	1.2-6.0 fl oz	0	0	tomato pinworm	--	For mating disruption - See label.
Closer SC (sulfoxaflor)	1.5-4.5 fl oz	12	1	aphids, plant bugs, sweepotato (silverleaf) whitefly, suppression of thrips	4C	Do not apply more than 4 times per crop or more than two times in succession. Maximum of 17 fl oz per acre per year.
Confirm 2F (tebufenozide)	6-16 fl oz	4	7	armyworms, black cutworm, hornworms, loopers	18	Product is a slow acting IGR that will not kill larvae immediately. Do not apply more than 64 fl oz per acre per season.
Coragen (rynaxypyr)	3.5-7.5 fl oz	4	1	beet armyworm, Colorado potato beetle, fall armyworm, hornworms, leafminer larvae, loopers, southern armyworm, tomato fruitworm, tomato pinworm	28	Can be applied by drip chemigation or as a soil application at planting. See label for details. Do not apply more than 15.4 fl oz per acre per crop.
Courier 40SC (buprofezin)	9-13.6 fl oz	12	1	leafhoppers, mealybugs, planthoppers, whitefly nymphs	16	Apply when a threshold is reached of 5 whitefly nymphs per 10 leaflets from the middle of the plant. Product is a slow-acting IGR that will not kill nymphs immediately. No more than 2 applications per season. Allow at least 5 days between applications.
Crymax WDG (Bacillus thuringiensis subspecies kurstaki)	0.5-2.0 lb	4	0	armyworms, loopers, tomato fruitworm, tomato hornworm, tomato pinworm	11A	Use high rate for armyworms. Treat when larvae are young.
*Danitol 2.4 EC (fenpropathrin)	10.67 fl oz	24	3 days, or 7 if mixed with Monitor 4	beet armyworm, cabbage looper, fruitworms, potato aphid, silverleaf whitefly, stink bugs, thrips, tobacco hornworm, tomato pinworm, twospotted spider mite, yellowstriped armyworm	3A	Use alone for control of fruitworms, stink bugs, tobacco hornworm, twospotted spider mites, and yellowstriped armyworms. Tank mix with Monitor 4 for all others, especially whitefly. Do not apply more than 0.8 lb ai per acre per season. Do not tank mix with copper.
Deliver (Bacillus thuringiensis subspecies kurstaki)	0.25-1.5 lb	4	0	armyworms, cutworms, loopers, tomato fruitworm, tomato pinworm	11A	Use higher rates for armyworms. OMRI-listed[2].
*Diazinon AG500; *50 W (diazinon)	AG500: 1-4 qt 50W: 2-8 lb	48	preplant	cutworms, mole crickets, wireworms	1B	Incorporate into soil - see label.
Dimethoate 4 EC (dimethoate)	0.5-1.0 pt	48	7	aphids, leafhoppers, leafminers	1B	Will not control organophosphate-resistant leafminers.
DiPel DF (Bacillus thuringiensis subspecies kurstaki)	0.5-2.0 lb	4	0	caterpillars	11A	Treat when larvae are young. Good coverage is essential. Can be used for organic production.
Distance (pyriproxyfen)	6 fl oz/100 gal 3-6 fl oz/100 gal	12	1	immature whiteflies fungus gnats and shore flies	7C	**Greenhouse-grown tomatoes only.** Do not apply to tomato varieties small than 1" in diameter. See label for application method for fungus gnats and shore flies.
Durivo (thiamethoxam, chlorantraniliprole)	10-13 fl oz	12	30	aphids, beet armyworm, Colorado potato beetle, fall armyworm, flea beetles, hornworms, leafhoppers, loopers, southern armyworm, thrips, tomato fruitworm, tomato pinworm, whitefly, yellowstriped armyworm	4A, 28	Several methods of soil application – see label.
*Endigo ZC (lambda-cyhalothrin, thiamethoxam)	4.0-4.5 fl oz	24	5	aphids, blister beetles, cabbage looper, Colorado potato beetle, cucumber beetle adults, cutworms, fall, southern, and yellowstriped armyworm (1st and 2nd instars), flea beetles, grasshoppers, hornworms, leafhoppers, plant bugs, stink bugs, tomato fruitworm, vegetable weevil adult	3A, 4A	Do not exceed a total of 19.0 fl oz per acre per season. See label for limites on each active ingredient.
Entrust SC (spinosad)	3-10 fl oz	4	1	armyworms, Colorado potato beetle, flower thrips, hornworms, *Liriomyza* leafminers, loopers, other caterpillars, tomato fruitworm, tomato pinworm	5	Do not apply more than 29 fl oz per acre per crop. OMRI-listed[2].

Esteem Ant Bait (pyriproxyfen)	1.5-2.0 lb	12	1	red imported fire ant	7C	Apply when ants are actively foraging.
Extinguish ((S)-methoprene)	1.0-1.5 lb	4	0	fire ants	7A	Slow acting IGR (insect growth regulator). Best applied early spring and fall where crop will be grown. Colonies will be reduced after three weeks and eliminated after 8 to 10 weeks. May be applied by ground equipment or aerially.
Fulfill (pymetrozine)	2.75 oz	12	0 - if 2 applications 14 - if 3 or 4 applications	green peach aphid, potato aphid, suppression of whitefly	9B	Do not make more than four applications. (FL-040006) 24(c) label for growing transplants also (FL-03004).
Grandevo (Chromobacterium subtsugae)	1.0-3.0 lb	4	0	armyworms, hornworms, loopers, tomato fruitworm, tomato pinworm, variegated cutworm, aphids, mites, thrips, whiteflies	-	Thorough coverage is necessary for effective control.
*Hero (Bifenthrin, zeta-cypermethrin)	4.5-11.2 oz	12	1	armyworms, cabbage looper, Colorado potato beetle, cucumber beetle, cutworms, flea beetles, grasshoppers, hornworms, leafhoppers, stink bugs, tobacco budworm, tomato fruitworm, tomato pinworm, vegetable leafminer, twospotted spider mite, thrips, whiteflies	3A	Check label for maximum seasonal totals.
Intrepid 2F (methoxyfenozide)	4-16 fl oz	4	1	beet armyworm, cabbage looper, fall armyworm, hornworms, southern armyworm, tomato fruitworm, true armyworm, yellowstriped armyworm, suppression of tomato fruitworm and tomato pinworm	18	Do not apply more than 64 fl oz per acre per season. Product is a slow-acting IGR that will not kill larvae immediately.
Javelin WG (Bacillus thuringiensis subspecies kurstaki)	0.12-1.5 lb	4	0	most caterpillars, but not Spodoptera species (armyworms)	11A	Treat when larvae are young. Thorough coverage is essential. OMRI-listed[2].
Kanemite 15 SC (acequinocyl)	31 fl oz	12	1	twospotted spider mite	20B	Do not use less than 100 gal per acre. Make no more than 2 applications at least 21 days apart.
Knack IGR (pyriproxyfen)	8-10 fl oz	12	7	immature whitefly	7C	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.
Kryocide (cryolite)	8-16 lb	12	14	armyworm, blister beetle, cabbage looper, Colorado potato beetle larvae, flea beetles, hornworms, tomato fruitworm, tomato pinworm	un	Minimum of 7 days between applications. Do not apply more than 64 lbs per acre per season.
*Lannate LV, *SP (methomyl)	LV: 1.5-3.0 pt SP: 0.5-1.0 lb	48	1	aphids, armyworm, beet armyworm, fall armyworm, hornworms, loopers, southern armyworm, tomato fruitworm, tomato pinworm, variegated cutworm	1A	Do not apply more than 21 pt LV/acre/crop (15 for tomatillos) or 7 lb SP/acre/crop (5 lb for tomatillos).
Malathion 5 Malathion 8 F (malathion)	1.0-2.5 pt 1.5-2 pt	12	1	aphids, *Drosophila*, spider mites	1B	8F Can be used in greenhouse.
*Monitor 4EC (methamidophos) [24(c) labels] FL-800046 FL-900003	1.5-2 pts	96	7	aphids, fruitworms, leafminers, tomato pinworm(1), whitefly(2)	1B	(1) Suppression only (2) Use as tank mix with a pyrethroid for whitefly control. Do not apply more than 8 pts per acre per crop season, nor within 7 days of harvest.
Movento (spirotetramat)	4.0-5.0 fl oz	24	1	aphids, psyllids, whitefly	23	Maximum of 10 fl oz/acre per season.
M Pede 49% EC (Soap, insecticidal)	1-2% V/V	12	0	aphids, leafhoppers, mites, plant bugs, thrips, whitefly	--	OMRI-listed2.
*Mustang (zeta cypermethrin)	2.4-4.3 oz	12	1	beet armyworm, cabbage looper, Colorado potato beetle, cutworms, fall armyworm, flea beetles, grasshoppers, green and brown stink bugs, hornworms, leafminers, leafhoppers, *Lygus* bugs, plant bugs, southern armyworm, tobacco budworm, tomato fruitworm, tomato pinworm, true armyworm, yellowstriped armyworm. Aids in control of aphids, thrips and whitefly.	3A	Not recommended for vegetable leafminer in Florida. Do not make applications less than 7 days apart. Do not apply more than 0.3 lb ai per acre per season.
Neemix 4.5 (azadirachtin)	4-16 fl oz	12	0	aphids, armyworms, hornworms, psyllids, Colorado potato beetle, cutworms, leafminers, loopers, tomato fruitworm (corn earworm), tomato pinworm, whitefly	un	IGR, feeding repellant. OMRI-listed[2].

NoMate MEC TPW (pheromone)		0	0	tomato pinworm	--	For mating disruption - See label.
Oberon 2SC (spiromesifen)	7.0-8.5 fl oz	12	1	broad mite, twospotted spider mite, whiteflies (eggs and nymphs)	23	Maximum amount per crop: 25.5 fl oz/acre. No more than 3 applications.
Platinum Platinum 75 SG (thiamethoxam)	5-11 fl oz 1.66-3.67 oz	12	30	aphids, Colorado potato beetles, flea beetles, leafhoppers, thrips, tomato pinworm, whitefly	4A	Soil application. See label for rotational restrictions. Do not use with other neonicotinoid insecticides
Portal (fenpyroximate)	2.0 pt	12	1	mites, including broad mites	21A	Do not make more than two applications per growing season.
*Pounce 25 W (permethrin)	3.2-12.8 oz	12	0	beet armyworm, cabbage looper, Colorado potato beetle, dipterous leafminers, granulate cutworm, hornworms, southern armyworm, tomato fruitworm, tomato pinworm	3A	Do not apply to cherry or grape tomatoes (fruit less than 1 inch in diameter). Do not apply more than 0.6 lb ai per acre per season.
*Proaxis Insecticide (gamma-cyhalothrin)	1.92-3.84 fl oz	24	5	aphids(1), beet armyworm(2), blister beetles, cabbage looper, Colorado potato beetle, cucumber beetles (adults), cutworms, hornworms, fall armyworm(2), flea beetles, grasshoppers, leafhoppers, plant bugs, southern armyworm(2), spider mites(1), stink bugs, thrips(1), tobacco budworm, tomato fruitworm, tomato pinworm, vegetable weevil (adult), whitefly(1), yellowstriped armyworm(2)	3A	(1) Suppression only. (2) First and second instars only. Do not apply more than 2.88 pints per acre per season.
*Proclaim (emamectin benzoate)	2.4-4.8 oz	12	7	beet armyworm, cabbage looper, fall armyworm, hornworms, southern armyworm, tobacco budworm, tomato fruitworm, tomato pinworm, yellowstriped armyworm	6	No more than 28.8 oz/acre per season.
Provado 1.6F (imidacloprid)	3.8-6.2 fl oz	12	0	aphids, Colorado potato beetle, leafhoppers, whitefly	4A	Do not apply to crop that has been already treated with imidacloprid or thiamethoxam at planting. Maximum per crop per season 19 fl oz per acre.
Pyganic Crop Protection EC 5.0 (pyrethrins)	4.5-18.0 fl oz	12	0	aphids, beetles, caterpillars, grasshoppers, leafhoppers, leafminers, mites, plant bugs, thrips, whiteflies	3A	Pyrethrins degrade rapidly in sunlight. Thorough coverage is important. ORMI-listed[2]
Pylon Miticide-Insecticide	6.5-13.0 fl oz	12		armyworms, tomato pinworm, tomato fruitworm, hornworms, cabbage looper, towspotted spider mite, broad mite, western flower thrips, melon thrips	13	**Greenhouse-grown tomatoes only.** Do not use on tomatoes with mature fruit less than 1" in diameter. Use no more than 39 fl oz per acre per season.
Radiant SC (spinetoram)	5-10 fl oz.	4	1	armyworms (except yellow-striped), Colorado potato beetle, flower thrips, hornworms, *Liriomyza* leafminers, loopers, *Thrips palmi*, tomato fruitworm, tomato pinworm	5	Maximum of 34 fl oz per acre per season. For thrips, if additional treatment is needed after two applications, switch to an alternate mode of action (not group 5) for at least two applications.
Requiem 25EC (extract of *Chenopodium ambrosioides*)	2-4 qt	4	0	chili thrips, eastern flower thrips, Florida flower thrips, green peach aphid, *Liriomyza* leafminers, melon thrips, potato aphid, western flower thrips, silverleaf whitefly	un	Begin applications before pests reach damaging levels. Limited to 10 applications per crop cycle.
Rimon 0.83EC (novaluron)	9-12 fl oz	12	1	armyworms, Colorado potato beetle, foliage feeding caterpil-lars, loopers, tomato fruitworm, tomato hornworm, tomato pinworm, stink bugs, thrips, whiteflies (immatures only)	15	Do not apply more than 36 fl oz per acre per season. Minimum of 7 days between applications.
Safari 20 SG (dinotefuran)	7-14 oz	12	1	aphids, leafminers, whiteflies	4A	**For transplant production only.** Can be applied as foliar spray or soil drench.
Scorpion 35SL (dinotefuran)	Foliar: 2-7 fl oz Soil: 9-10.5 oz	12	Foliar: 1 Soil: 21	Colorado potato beetle, cucumber beetles, flea beetles, grasshop-pers, leafhoppers, leafminers, stink bugs, thrips, whiteflies, suppression of aphids	4A	Do not apply to vegetables grown for seed. Do not sue with other Group 4A insecticides. Can be applied as foliar spray OR soil drench, but not both. Toxic to bees.
Sevin 80S; XLR; 4F (carbaryl)	80S: 0.63-2.5 XLR; 4F: 0.5-2.0 A	12	3	Colorado potato beetle, cutworms, fall armyworm, flea beetles, lace bugs, leafhoppers, plant bugs, stink bugs(1), thrips(1), tomato fruitworm, tomato hornworm, tomato pinworm, sowbugs	1A	(1) suppression Do not apply more than seven times. Do not apply a total of more than 10 lb or 8 qt per acre per crop.
10% Sevin Granules (carbaryl)	20 lb	12	3	ants, centipedes, crickets, cutworms, earwigs, grasshoppers, millipedes, sowbugs, springtails	1A	Maximum of 4 applications, not more often than once every 7 days.
Sulfur (many brands)	See label	24	see label	tomato russet mite, twospotted spider mite	--	May burn fruit and foliage when temperature is high. Do not apply within 2 weeks of an oil spray or EC formulation.

TetraSan 5 WDG (etoxazole)	8-20 oz/100 gal or 16-40 oz/acre	12	1	spider mites	10B	**Greenhouse-grown tomatoes only.** Kills mite eggs and numphs, but not adults. Do not make more than 2 applications per crop and not less than 21 days apart.
*Thionex EC (endosulfan)	0.66-1.33 qt	48	2	aphids, blister beetle, cabbage looper, Colorado potato beetle, flea beetles, hornworms, stink bugs, tomato fruitworm, tomato russet mite, whitefly, yellowstriped armyworm	2	Do not exceed a maximum of 2.0 lb active ingredient per acre per season or apply more than 4 times. **Use ends Dec. 31, 2014 for field-grown tomatoes and July 31, 2012 for greenhouse crops (not permitted on current label).**
Trigard (cyromazine)	2.66 oz	12	0	Colorado potato beetle (suppression of), leafminers	17	No more than 6 applications per crop. Does not control CPB adults. Most effective against 1st & 2nd instar larvae.
Trilogy (extract of neem oil)	0.5-1.0% V/V	4	0	aphids, mites, suppression of thrips and whitefly	un	Apply morning or evening to reduce potential for leaf burn. Toxic to bees exposed to direct treatment. Do not exceed 2 gal/acre per application. OMRI-listed[2].
Ultra Fine Oil, Saf-T-Side, others JMS Stylet-Oil (oil, insecticidal)	1-2 gal/100 gal 3-6 qt/100 gal water (JMS)	4	0	aphids, beetle larvae, leafhoppers, leafminers, mites, thrips, whitefly, aphid-transmitted viruses (JMS)	-	Do not exceed four applications per season. Organic Stylet-Oil and Saf-T-Side are OMRI-listed[2].
Venom Insecticide (dinotefuran)	foliar: 1-4 oz	12	1	cucumber beetles, grasshoppers, stink bugs, suppression of green peach and potato aphids	4A	Use only one application method (soil or foliar). Limited to three applications per season. Toxic to honeybees.
Venom Insecticide (dinotefuran)	soil: 5-7.5 oz	12	21	Colorado potato beetle, flea beetles, grasshoppers, leafhoppers, leafminers, thrips, whiteflies, suppression of green peach and potato aphids		Use only one application method (soil or foliar). Must have supplemental label for rates over 6.0 oz/acre.
Vetica (flubendiamide and buprofezin)	12.0-17.0 fl oz	12	1	armyworms, cabbage looper, cutworms, garden webworm, saltmarsh caterpillar, tobacco budworm, tomato hornworm, tomato fruitworm, tomato pinworm, suppression of leafhoppers, mealybugs and whiteflies	28, 16	Do not apply more than 3 times per season or apply more than 38 fl oz per acre per season. Same classes of active ingredients as Synapse, Coragen, and Courier.
Voliam Flexi (thiamethoxam, chlorantraniliprole)	4-7 oz	12	1	aphids, beet armyworm, Colorado potato beetle, fall armyworm, flea beetles, hornworms, leafhoppers, loopers, southern armyworm, stink bugs, tobacco budworm, tomato fruitworm, tomato pinworm, whitefly, yellowstriped armyworm, suppression of leafminer	4A, 28	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. Do not exceed 14 oz per acre per season, or 0.172 lb ai of thiamethoxam-containing products or 0.2 lb ai of chlorantraniliprole-containing products per acre per season.
*Voliam Xpress (lamda-cyhalothrin, chlorantraniliprole)	5-9 fl oz	24	5	aphids, armyworms, Colorado potato beetle, cucumber beetle adults, flea beetles, leafhoppers, leafminers, stink bugs, thrips (suppression-does not include Western flower thrips), tobacco budworm, tomato fruitworm, tomato pinworm, suppression of whiteflies	3A, 28	Do not apply more than 31.0 fl oz Voliam Xpress or equivalent of lambda-cyhalothrin or chlorantraniliprole containing products per acre per season.
*Vydate L (oxamyl)	foliar: 2-4 pt	48	3	aphids, Colorado potato beetle, leafminers (except *Liriomyza trifoli*), whitefly (suppression only)	1A	Do not apply more than 32 pts per acre per season.
*Warrior II (lambda cyhalothrin)	0.96-1.92 fl oz	24	5	aphids(1), beet armyworm(2), cabbage looper, Colorado potato beetle, cutworms, fall armyworm(2), flea beetles, grasshoppers, hornworms, leafhoppers, leafminers(1), plant bugs, southern armyworm(2), stink bugs, thrips(3), tomato fruitworm, tomato pinworm, whitefly(1), vegetable weevil adults, yellowstriped armyworm(2)	3A	(1) suppression only (2) for control of 1st and 2nd instars only. Do not apply more than 0.36 lb ai per acre per season. (3) Does not control western flower thrips.
Xentari DF (*Bacillus thuringiensis* subspecies *aizawai*)	0.5-2 lb	4	0	caterpillars	11A	Treat when larvae are young. Thorough coverage is essential. May be used in the greenhouse. Can be used in organic production. OMRI-listed[2].

The pesticide information presented in this table was current with federal and state regulations at the time of revision. The user is responsible for determining the intended use is consistent with the label of the product being used. Use pesticides safely. Read and follow label instructions.

[1] Mode of Action codes for vegetable pest insecticides from the Insecticide Resistance Action Committee (IRAC) Mode of Action Classification v.7.2 February 2012. http://www.irac-online.org/wp-content/uploads/MoA-classification.pdf

1A. Acetylcholinesterase inhibitors, Carbamates (nerve action)
1B. Acetylcholinesterase inhibitors, Organophosphates (nerve action)
2A. GABA-gated chloride channel antagonists (nerve action)
3A. Sodium channel modulators—pyrethroids
4A. Nicotinic acetylcholine receptor agonists (nerve action)
5. Nicotinic acetylcholine receptor allosteric activators—spinosins (nerve action)
6. Chloride channel activators (nerve and muscle action)
7A. Juvenile hormone mimics (growth regulation)
7C. Juvenile hormone mimics (growth regulation)
9B & 9C. Selective homopteran feeding blockers
10B. Mite growth inhibitors (growth regulation)
11A. Microbial disruptors of insect midgut membranes
12B. Inhibitors of mitochondrial ATP synthase (energy metabolism)
15. Inhibitors of chitin biosynthesis, type 0, lepidopteran (growth regulation)
16. Inhibitors of chitin biosynthesis, type 1, homopteran (growth regulation)
17. Molting disruptor, dipteran (growth regulation)
18. Ecdysone receptor agonists (growth regulation)
20B. Mitochondrial complex III electron transport inhibitors (energy metabolism)
21A. Mitochondrial complex I electron transport inhibitors (energy metabolism)
22. Voltage-dependent sodium channel blockers (nerve action)
23. Inhibitors of acetyl Co-A carboxylase (lipid synthesis, growth regulation)
28. Ryanodine receptor modulators (nerve and muscle action)
un. Compounds of unknown or uncertain mode of action

[2] OMRI listed: Listed by the Organic Materials Review Institute for use in organic production.
* Restricted Use Only

Nematicides Registered for Use on Florida Tomato

Joseph W. Noling
Extension Nematology, UF/IFAS, Citrus Research & Education Center. Lake Alfred, FL, jnoling@ufl.edu

FUMIGANT NEMATICIDES

Product	Row Application (6' row spacing - 36" bed)[4]				
	Broadcast (Rate)	Recommended Chisel (Spacing)	Chisels (per row)	Rate/Acre	Rate/1000 Ft/Chisel
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
Dismethyl Disulfide	35-51 gal	12"	3	17.5-25.5	102-149 fl oz
PIC Chlor 60[1]	19.5 – 31.5 gal	12"	3	20-25 gal 250-300 lb	117-147 fl oz
Telone II[2]	9 -18 gal	12"	3	6-9.0 gal	35-53 fl oz
Telone EC[2]	9 -18 gal	Drip applied	See label for use guidelines and additional considerations		
Telone C-17[2]	10.8-17.1 gal	12"	3	10.8-17.1 gal	63-100 fl oz
Telone C-35[2]	13-20.5 gal	12"	3	13-20.5 gal	76-120 fl oz
Telone Inline[2]	13-20.5 gal	Drip applied	See label for use guidelines and additional considerations		
Metham Sodium	50-75 gal	5"	6	25-37.5 gal	73-110 fl oz

NON-FUMIGANT NEMATICIDES

Vydate L treat soil before or at planting with any other appropriate nematicide or a Vydate transplant water drench followed by Vydate foliar sprays at 7-14 day intervals through the season; do not apply within 7 days of harvest; refer to directions in appropriate "state labels", which must be in the hand of the user when applying pesticides under state registrations.

[1.] If treated area is tarped with impermeable film, dosage may be reduced by 40-50%.

[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 for tomato, pepper, eggplant and strawberry has been awarded for calendar years 2005 through 2012. Specific, certified uses and labeling requirements for CUE acquired methyl bromide must be satisfied prior to grower purchase and use in these crops. Product formulations are subject to change and availability. Some uses will not be available in 2013.

[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.

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 July 1, 2012 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. Additional products may become available or approved for use.

NOTES:

NOTES:

NOTES:

AD PAGE