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Is it Time for a Transgenic Tomato Variety?!

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INTRODUCTION

Of the many diseases that can affect tomato (*Solanum lycopersicum* L.) in Florida, the most consistent problem for growers is bacterial spot caused by races T4 and T3 of *Xanthomonas perforans*. Conventional breeding for resistance has been ongoing for over 30 years, and despite a concerted effort, to date no varieties have been released. The major reasons for the lack of success are changing races of the pathogen, complex genetic control of resistance, and unfavorable associations of resistance with undesirable characteristics such as small fruit size, late maturity, and low yield (Hutton et al., 2010a; 2010b). In contrast bacterial spot resistant pepper (*Casicum annum* L.) varieties are common (Rowell et al., 2001). This is because resistance is controlled by single dominant hypersensitive genes (Sahin and Miller, 1996). There is a problem with development of virulent strains of *Xanthomonas* on pepper, so several hypersensitive genes have been utilized to provide resistance to most of these races. When a virulent strain overcomes the resistance on a grower's farm in one year, and the same variety is grown the next year, it is usually the case that the resistance holds up–apparently due to fitness problems with the virulent pathogen strain that occurred the previous year (Wichmann et al., 2005). One of the pepper resistance genes, *Bs2*, was transferred to the tomato variety VF 36 in the late 1990s (Tai et al., 1999). The *Bs2* gene is a good candidate as a resistance gene in tomato due to the predominance of tomato infecting *Xanthomonas* isolates that have the effector *AvrBs2* (Kearney et al., 1990). We have had good results for both bacterial spot resistance and improved yield in several years of testing where VF 36 with *Bs2* is compared to VF 36 (Horvath et al., 2012; Scott et al., 2011). However, VF 36 is an old California bred tomato unadapted to Florida, and it is very susceptible to bacterial spot. More recently, the *Bs2* gene has been introduced into Fla. 8000, a Florida adapted inbred that has resistance to bacterial spot race T3 and is heat-tolerant. It has also been introduced into Fla. 8111, a large-fruited globe tomato that is quite sensitive to bacterial spot but has other desirable characteristics. The conventional hybrid, Fla. 8314, has these two lines as parents and has been widely trialed throughout Florida. Compared to other hybrids examined by the senior author, this hybrid has demonstrated the most reliable marketable fruit production; but it has not been released due to its susceptibility to race T4, and because its fruit size is slightly smaller than varieties such as Florida 47. The objective of this paper is to present recent trial data comparing Fla. 8000 and Fla. 8314 to the newly *Bs2* transformed versions of these.

MATERIALS AND METHODS

Trials were conducted in Fall 2011 and Spring 2012 at the Gulf Coast Research & Education Center (GCREC). In each season seed was sown in the greenhouse and transplants were then field set in completely randomized block designs. In Fall 2011 plants were set in the field on August 19. There were 3 blocks with 12 plants per plot. 22 genotypes were trialed in the experiment, but yield was taken from only six of them as seen in **Table 1**. In Spring 2012 transplants were set in the field on March 30. The planting was late to allow for heavier bacterial spot pressure during the high temperature and rainy June weather. There were 4 blocks and 7 plants per plot. There were 22 genotypes as seen in **Table 2**. Conventional growing and spray practices were used, except that no copper sprays were applied to allow for the bacteria to infect the plants. Plants in either trial were rated for disease severity on Sept. 15, 2011 or on June 18, 2012, using the Horsfall-Barratt scale where 1=0%; 2=0-3%; 3=3-6%; 4=6-12%; 5=12-25%; 6=25-50%; 7=50-75%; 8=75-87%; 9=87-93%; 10=1 93-97%;11=97-100%; and 12=100% defoliation. Fruit at breaker and beyond were harvested three times for the fall trial on Nov. 16, Nov. 22, and Nov. 30; and three times for the spring trial on June 11, June 18, and June 26. Data for the spring harvests are not complete at the time of this writing, but will be presented at the Tomato Institute meeting.

RESULTS & DISCUSSION

In Fall 2011 there was some bacterial spot infection on *Bs2*-containing genotypes, and confirmed that these strains had mutations in *avrBs2*. Despite this, total marketable yields and yields of extra-large fruit of genotypes with *Bs2* were significantly greater than their counterpart lines without *Bs2* as well as Florida 47 (**Table 1**); in fact, yields were doubled. Whereas average fruit size of Fla. 8314 was not statistically different than its *Bs2* counterpart, the *Bs2* versions of Fla. 8000 showed some increase in fruit size over the non-transgenic version of this line, with the hemizygous version having the greatest fruit size. Yields of extra-large fruit were remarkably greater for the *Bs2* containing genotypes over their respective counterparts. Under these conditions, non-transgenic Fla.

Table 2. Bacterial spot disease severity for tomato inbreds and hybrids with and without the *Bs2* pepper gene, GCREC Spring 2012.

Genotype	Disease Severity [z]	
VF36	9.25	a[Y]
Fla.8111B	8.75	a
Florida 47	7.38	b
Sebring	7.13	bc
Xv4F1	6.5	b-d
Fla.8000	6.5	b-d
Florida 91	6.25	b-e
Fla.8314	6.25	b-e
Xv4 line	6.13	c-e
Sanibel	5.67	ed
104009-29 (susc)	5.25	e
104009-8 Bs2	2.75	f
VF36 Bs2 hemi.	2.5	f
104009-13 Bs2	2.5	f
VF36 Bs2 homo.	2.5	f
104009-5	2.45	f
104009-26	2.25	f
Fla. 8111B Bs2 homo.	2.25	f
Xv4-Bs2 F_1	2.25	f
Fla.8314 Bs2 homo.	2.0	f
104009-12 Bs2	2.0	f
Fla>8000 Bs2 homo.	2.0	f

[z]Horsfall- Barratt scale, higher number means more disease.
[Y]Mean separation in column by Duncan's Multiple Range Test at p≤0.05.

Table 1. Total and extra-large marketable yield, fruit size and cull weights for tomato inbreds and hybrids with and without the pepper *Bs2* gene, Fall 2011, GCREC.

Entry[z]	Marketable yield (25 lb box/A) Total	Marketable yield (25 lb box/A) Extra-large	Fruit Size (oz.)	Culls (% by wt.)
Fla. 8000 *Bs2* homo	2362 a[y]	906 bc	5.1 cd	27
Fla. 8314 *Bs2* homo	2237 ab	1232 a	5.6 a-c	21
Fla. 8000 *Bs2* hemi	1918 b	1060 ab	5.8 ab	26
Florida 47	1099 c	682 c	6.2 a	23
Fla. 8314	1093 c	588 c	5.5 bc	23
Fla. 8000	1028 c	253 d	4.8 d	28

[z]Genotype with *Bs2* gene indicated by *Bs2*, hemi = 1 copy, homo = 2 copies.
[y]Mean separation in columns by Duncan's multiple range test at P< 0.05.

8314 did not have significantly different total yield or extra-large yield than Florida 47, although its overall fruit size was significantly less than that of Florida 47. However, the introduction of *Bs2* into Fla. 8314 resulted in nearly double the extra-large yield and more than twice the total yield of Florida 47. Thus, the main problems with Fla. 8314, its somewhat smaller fruit size and its bacterial spot sensitivity, were both eliminated by the introduction of *Bs2*.

In Spring 2012, very heavy bacterial spot pressure developed late in the season during a rainy period in the first part of June (**Table 2**). There was no sign of the virulent strains that appeared in Fall 2011. Similar observations have been made with pepper crops where virulent strains often do not infect subsequent crops (Sally Miller, personal communications). Under this heavy disease pressure there was virtually no disease on genotypes with *Bs2* (**Table 2**). Genotypes with *Bs2* were significantly more resistant than their respective non-transgenic counterparts and the commercialcontrols. Analysis of the yield data has not yet been completed. Some factors that are expected to have impacted yield in this trial are (i) the late onset of disease after most fruit had already set, (ii) the heavy June rains which caused a high rate of culls to fruit cracking in the first and second picks, and (iii) tropical storm Debbie which resulted in a high rate of culls to check and fruit cracking in the third pick. Observations at the second pick indicated Fla. 8314 with *Bs2* held up well and the yield of extra-large fruit appeared greater than other genotypes. Lines with a race T4 hypersensitive gene alone (Xv4 lines) did not have good resistance under these high temperature conditions (Astua-Monge et al., 2000).

Our data indicates Florida tomato growers could get a significant yield advantage by growing *Bs2* GMO varieties like Fla. 8314. Not only would there be a yield boost, but copper sprays could be eliminated, saving money and avoiding environmental concerns. Furthermore, we are putting TYLCV resistance into Fla. 8111(Hutton et al., 2012) and soon could have a Fla. 8314 hybrid with resistance to both bacterial spot and TYLCV. Other hybrids will also be evaluated with *Bs2* in the near future and some of these will also have resistance to fusarium crown rot. However, the question is, will buyers accept a GMO tomato? Presently there are perceived fears of this technology in food, although no one seems to worry that the same technology is widely used in the pharmaceutical industry. Anyone who eats bell peppers has already consumed the *Bs2* gene. It would seem that a marketing campaign touting the environmental benefits due to pesticide reduction and the innocuous presence of the pepper gene would make a good case for bringing forth a transgenic variety. This technology could be a boon to the Florida industry that has had its share of troubles over the past few years. We want to proceed to be able to provide the variety, and then what happens with it is beyond our control. Persons having interest in working with this material or in getting it deregulated should contact any of the authors.

LITERATURE CITED

Astua-Monge, G., G.V.Minsavage, R.E. Stall, C.E. Vallejos, M.J. Davis, and J.B. Jones. 2000. Xv4-avrxv4: A new gene-for-gene interaction identified between Xanthomonascampestrispv. Vesicatoria race T3 and the wild tomato relative Lycopersiconpennellii. MPMI 13(12) 1346-1355.

Hutton, S.F and J.W. Scott. 2011. Tomato breeding at University of Florida: Present status and future directions. Proc. Florida Tomato Institute. PRO 527:19-20.

Hutton, S.F., Scott J.W, and J.B. Jones. 2010a. Inheritance of resistance to bacterial spot race T4 from three tomato breeding lines with differing resistance backgrounds. J. Amer. Soc. Hort. Sci. 135(2):150–158. 2010.

Hutton, S.F., J.W. Scott, W. Yang, S. Sim, D.M. Francis, and J.B. Jones. 2010b. Identification of QTL Associated with Resistance to Bacterial Spot Race T4 in Tomato. Theor. Appl. Genet. 121 (7):1275-1287.

Horvath, D.M, R.E. Stall, J.B Jones, M.H. Pauly, G.E. Vallad, D. Dahlbeck, B.J. Staskawicz, and J.W. Scott. 2012. Transgenic resistance confers effective field level control of bacterial spot disease in tomato. PLoS One (in press).

Kearney, B.and B.J. Staskawicz. 1990. Widespread distribution and fitness contribution of *Xanthomonascampestrisavirulence* gene *avrBs2*. Nature 346: 385-386.

Rowell, B.,R. Jones, W. Nesmith, A. Satanek, and J. Snyder. 2001. Bacterial spot resistance, yield, and quality of bell and specialty peppers. HortTechnology 11: 648-657.

Sahin, F.and S.A. Miller. 1996. Characterization of Ohio strains of Xanthomonascampestrispvvesicatoria, causal agent of bacterial spot of pepper. Plant Dis 80:773–778

Scott, J.W., G.E. Vallad, R.E. Stall, J.B. Jones, D. Dahlbeck, and B.J. Staskawicz. 2011. Bacterial spot race T4 resistance and yield enhancement in tomatoes conferred by the pepper Bs2 gene in Florida field trials. ActaHorticulturae 914:437-440.

Tai, T.H., D. Dahlbeck, E.T. Clark, P. Gajiwala, and R. Pasion. 1999. Expression of the *Bs2* pepper gene confers resistance to bacterial spot disease in tomato. ProcNatlAcadSci USA 96: 14153-14158.

Wichmann, G., D. Ritchie, C.S. Kousik, and J. Bergelson. 2005. Reduced genetic variation occurs among genes of the highly clonal plant pathogen *Xanthomonasaxonopodispv*. Vesicatoria, including the effector gene *avrBs2*. App EnvMicrobiol 71:2418-2432.

Grafting for Management of Bacterial Wilt and Root-Knot Nematodes in Tomato Production

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INTRODUCTION

Bacterial wilt of tomato caused by the soil-borne bacterium *Ralstonia solanacearum* race 1 (biovar 1, phylotype II) is widely distributed in the southeastern United States and causes considerable crop losses of up to 50-100% under ideal conditions for disease incidence. Crop rotation as a disease management strategy is effective but can be difficult because *R. solanacearum* can infect over 200 plant species. Although resistance is available in tomato cultivars 'Hawaii 7996', 'Hawaii 7997', and 'Hawaii 7998', these cultivars have not been widely accepted due to poor horticultural traits such as small fruit, a trait linked with bacterial wilt disease resistance.

Root-knot nematodes (*Meloidogyne* spp.) are also a major issue in tomato production that can lead to high yield losses. For decades root-knot nematodes have been managed with soil fumigants, primarily methyl bromide. The use of methyl bromide is nearly finished in the United States due to its phase out under the Montreal Protocol. Producers are currently seeking alternatives to soil fumigation to manage soil-borne pests in tomato. Many recent studies worldwide have pointed out the possibilities of using grafting with resistant rootstocks as a sustainable and eco-friendly practice for bacterial wilt and root-knot nematode management.

Grafting has been practiced for decades in Asia and the Mediterranean as a technique to manage soil-borne diseases. Grafted plants now account for 81% and 54% of the vegetable acreage in Korea and Japan, respectively. Grafting has recently been gaining popularity in the United States, partly due to the loss of methyl bromide and the increased restrictions of using soil fumigants. The study presented here was focused on testing numerous new hybrid rootstocks available to growers and evaluated in two geographic locations, Florida and Virginia for resistance to tomato bacterial wilt and root-knot nematodes.

MATERIALS AND METHODS

Experimental locations. Field studies were conducted at the University of Florida, North Florida Research and Education Center, Quincy, Florida; and Virginia Tech, Eastern Shore Agricultural Research and Extension Center, Painter, Virginia.

Experimental treatments for bacterial wilt field trials. In all trials the tomato variety 'BHN 602' (BHN Seed, Immokalee, FL) was used as a scion for grafted treatments as well as the non-grafted and self-grafted control. All trials included non-grafted and self-grafted treatments. The 2009 spring trial in Virginia included two rootstocks; 'RST-04-105-T' (DP seeds, Yuma, AZ)and 'RST-04-106-T'(DP seeds). The 2010 spring trial in Virginia included six rootstocks; 'RST-04-106-T', 'Cheong Gang'(Seminis Vegetable Seeds, St. Louis, MO), 'Jjak Kkung'(Seminis Vegetable Seeds), 'BHN 998'(BHN Seed), 'BHN 1053'(BHN Seed), and 'BHN 1054'(BHN Seed). The spring 2010 trial in Florida included 'RST-04-106-T', 'Cheong Gang', 'Jjak Kkung', and 'Hawaii 7998'(Public breeding material, University of Florida). The fall 2010 Florida trial included 'RST-04-106-T', 'Cheong Gang', 'Jjak Kkung', 'BHN 998', 'BHN 1053', 'BHN 1054', and 'Hawaii 7998'.

Experimental treatments for root-knot nematode field trials. In all trials the tomato variety 'BHN 602' was used as a scion for grafted treatments as well as the non-grafted and self-grafted control. All trials included non-grafted and self-grafted treatments. The 2011 fall trials in Florida and Virginia included three rootstocks;'RST-04-106-T', 'BHN 998' and 'BHN 1054'.

Transplant production and grafting for field trials. Seedlings were grafted utilizing a modified Japanese tube graft at the two-leaf stage. Recent research has indicated that grafting in this manner resulted in rootstock re-growth. Due to the vigor of the rootstocks used this type of growth would necessitate pruning on a bi-weekly basis, which would be unsuitable for commercial field production. Thus, all grafted treatments were grafted below the rootstock cotyledons to prevent rootstock re-growth. Seedlings were grown pre and post grafting in expanded polystyrene trays of the inverted pyramid design with cell size 4.4 x 4.4 x 6.3 cm. Soil-less media was used for the production of all transplants. After grafting was performed, seedlings were placed in a high humidity chamber with controlled temperature to heal the graft union. After one week, seedlings were removed from the chamber and placed in a greenhouse for 10-14 days until transplanting. Due to grafting below the rootstock cotyledon, care was taken at planting to maintain the graft union above the soil line.

Bacterial wilt field experiments. Four field trials were conducted in Florida and Virginia during 2009 and 2010. Two of these trials were conducted on a commercial tomato farm in Painter, VA during the spring of 2009 and 2010. Soil type was Bojac sandy loam with pH 6.2. Two trials were conducted at the University of Florida North Florida Research and Education Center in Quincy, FL during the spring and fall of 2010. Soil type was Norfolk sandy loam with pH 6.3. Experimental plots at both locations consisted of non-fumigated raised beds covered with black polyethylene mulch for spring plantings and white polyethylene mulch for fall plantings. Bed dimensions at Virginia were 20.3 cm tall by 76.2 cm wide. Beds were spaced 1.8 m apart and plants were spaced 45.7 cm within the row. Bed dimensions at Florida were 12.7 cm tall by 76.2 cm wide. Beds were spaced 1.8 m apart and plants were spaced 50.8 cm within the row. Inorganic fertilizers were applied to experimental plots based on soil test results and cooperative extension recommendations for respective states. The Virginia field plots had a history of bacterial wilt and were not inoculated. The Florida field plots did not have a history of bacterial wilt. To ensure disease development in the Florida field trial, experimental plots were inoculated with *R. solanacearum* Rs 5 strain. The strain was cultured by the methods described above. Seventy-five ml of an aqueous solution containing 107 CFU/ml of *R. solanacearum* was poured in each plant hole one day prior to transplanting. This created an initial bacterial population in the range of 105-106 CFU/g of soil. Grafted seedlings were transplanted on 29 May 2009 and 30 April 2010 in Virginia and 20 April 2010 and 11 August 2010 in Florida. Each entry in the Virginia and Florida trials consisted of four replications with 30 and 18 plants respectively in each replication. All experiments were arranged as randomized complete block design. The bacterial wilt incidence was calculated at weekly intervals as the percentage of plants that had completely wilted. The cause of the wilting was confirmed using *R. solanacearum* specific Immunostrips®. Disease incidence data is presented as percent incidence as recorded just after the final harvest. Experimental plots were maintained throughout the season with standard crop protection practices for commercial tomato production. Twelve plants from the center of each plot were marked independent of their disease status, and fruits were harvested from these plants at a mature green/early breaker stage and graded by USDA Grades. Two to three harvests were made for each trial, which is typical of commercial tomato production in both states.

Root-knot nematodes field experiments. Two field trials were conducted in Florida and Virginia in fall 2011. The plot conditions were as described above. The Florida field trial location had a natural inoculum of *M. incognita.* Yellow summer squash seed was planted during the spring of 2010. The squash crop was maintained as a host crop for the nematodes following current production guidelines. After the growing season the squash plants were mowed to the ground with a tractor-mounted rotary mower. At the Virginia field trial location, the soil at the base of the squash plants was inoculated with ~5000 *M. incognita* eggs/plant one month after emergence. Grafted and non-grafted tomato seedlings were then transplanted into the same beds to evaluate root-knot nematode resistance. Each entry in the Virginia and Florida trials consisted of four replications with 20 and 14 plants respectively in each replication. All experiments were arranged as randomized complete block design. Tomatoes were harvested once and graded into USDA size categories. The plastic mulch was removed prior to assessing root galling. Ten plants from each plot were then carefully dug using shovels. Root

Table 1. Bacterial wilt incidence and yield of 'BHN 602' non-grafted or grafted on to rootstocks for bacterial wilt resistance in a field naturally infested with *R. solanacearum* in Painter, VA. The experiment was conducted in spring 2010.

Entry [z]	Fruit yield ($kg•ha^{-1}$) Medium	Large	Extra large	Total marketable	Bacterial wilt incidence (%) [y]
BHN 1054	5,420 a [x]	16,371 ab	58,158 ab	79,950 a	5.0 c
Cheong Gang	4,113 ab	14,211 bc	60,605 a	78,928 a	6.5 c
BHN 998	4,648 a	14,013 bc	55,645 ab	74,306 a	10.5 c
RST-04-106-T	5,136 a	19,176 a	56,139 ab	80,451 a	13.0 c
BHN 1053	2,459 b	9,852 c	46,551 ab	58,863 ab	43.5 b
Jjak Kkung	4,357 a	9,954 c	35,813 b	50,123 b	56.0 ab
Non-grafted	474 c	1,938 d	13,959 c	16,371 c	85.5 ab
Self-grafted	0 c	0 d	0 c	0 c	97.0 a
LSD (0.05)	1,855	4,390	20,705	24,075	21.1
P > F	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

[z]Each entry consisted of 4 replications with 30 plants in each replication, and the experiment was arranged as a randomized complete block design.
[y]Percentage bacterial wilt incidence at the time of harvest.
[x]Column means followed by the same letter are not significantly different at P ≤ 0.05 based on Least Significant Difference (LSD). ns = not significant

systems from excavated plants were then carefully rinsed to remove soil. Washed root systems were rated for root-knot galling using root-gall-index (RGI), which is a rating from 0 - 10 based upon galling severity (0 = complete and healthy root system with no infestation, 10 = plant and roots are dead).

Statistical analysis. The field studies were set-up in a randomized complete block design. The data was analyzed using ANOVA, and the means were compared using least significant difference. The analysis was performed with SAS (SAS version 9.1, SAS Institute Inc., Cary, NC).

RESULTS

Bacterial wilt trials. The use of rootstocks with resistance to bacterial wilt had a significant effect on tomato fruit yield and bacterial wilt incidence in the conducted field studies (**Tables 1-3**). Studies illustrated the benefits of grafting susceptible tomato scions onto resistant hybrid rootstocks when planted into soils heavily infested with *R. solanacearum*. Disease incidence was greatly reduced and tomato fruit yield was maintained at levels acceptable to commercial producers. These data indicate that several commercially available hybrid rootstocks have high levels of bacterial wilt resistance. 'Cheong Gang', 'BHN 1054', and 'BHN 998' were the most adapted rootstocks with respect to bacterial wilt resistance and resulting tomato fruit yield.

Root-knot nematode trials. In the Florida field trials hybrid rootstocks 'RST-04-106-T', 'BHN 998' and 'BHN 1054' had significantly lower Root-Gall-Index (RGI), than self-grafting control and non-grafted 'BHN 602' (**Table 4**). There were significant differences in tomato yields of 'BHN 998' and 'BHN 1054' treatments compared to 'self-grafted' and 'non-grafted' treatments. 'RST-04-106-T' did not have a significant yield impact compared to the 'non-grafted control'.

In the Virginia trial, there were varying levels of root-knot nematode resistance between rootstocks. Plants grafted on 'RST-04-106-T' had the lowest RGI, followed by 'BHN 998', and 'BHN 1054' (data not shown). 'BHN 1054' had the highest RGI among rootstocks. There were significant differences in tomato yields between treatments for all yield categories, although yields were very low. All treatments grafted on resistant rootstocks had similar marketable yields. In addition, plants grafted on 'RST-04-106-T' and 'BHN 998' had higher marketable tomato yields than the non-grafted 'BHN 602'.

Table 2. Bacterial wilt incidence and yield of 'BHN 602' non-grafted or grafted on to rootstocks for bacterial wilt resistance in a field artificially inoculated with *R. solanacearum* in Quincy, FL. The experiment was conducted in spring 2010.

Entry [z]	Fruit yield (kg•ha^{-1}) Medium	Large	Extra large	Total marketable	Bacterial wilt incidence (%) [y]
RST-04-106-T	4,022	10,065 b [x]	40,840	54,927 a	0.0 c
Cheong Gang	4,171	11,895 a	36,129	52,195 a	0.0 c
Jjak Kkung	4,575	10,170 ab	36,049	50,794 a	0.0 c
Hawaii 7998	6,019	9,682 bc	30,164	45,865 ab	0.0 c
Self-grafted	5,162	8,179 b	33,532	46,874 ab	2.7 b
Non-grafted	3,589	8,567 bc	28,263	40,419 b	7.5 a
LSD (0.05)	ns	1,728	ns	9,059	2.4
P > F	*0.1147*	*0.0041*	*0.1160*	*0.0428*	*<0.0001*

[z] Each entry consisted of 4 replications with 18 plants in each replication, and the experiment was arranged as a randomized complete block design.
[y] Percentage bacterial wilt incidence at the time of harvest.
[x] Column means followed by the same letter are not significantly different at P ≤ 0.05 based on Least Significant Difference (LSD). ns = not significant

Table 3. Bacterial wilt incidence and yield of 'BHN 602' non-grafted or grafted on to rootstocks for bacterial wilt resistance in a field artificially inoculated with *R. solanacearum* in Quincy, FL. The experiment was conducted in fall 2010.

Entry [z]	Fruit yield (kg•ha^{-1}) Medium	Large	Extra large	Total marketable	Bacterial wilt incidence (%) [y]
Cheong Gang	3,026 ab [x]	7,455 ab	18,293 abc	28,733 ab	28.4 d
BHN 998	2,663 ab	5,661 b	21,870 ab	30,194 ab	40.0 cd
BHN 1054	3,929 a	11,313 a	32,486 a	47,728 a	40.6 cd
Hawaii 7998	1,311 bc	2,877 bc	7,595 bc	11,784 bc	53.6 bc
RST-04-106-T	1,320 bc	2,916 bc	7,160 bc	11,395 bc	57.8 bc
Jjak Kkung	1,385 bc	2,264 bc	3,785 bc	7,434 bc	67.9 b
BHN 1053	1,505 bc	3,060 bc	10,494 b	15,059 bc	76.1 ab
Non-grafted	102 c	75 c	199 c	376 c	93.8 a
Self-grafted	43 c	73 c	117 c	232 c	93.9 a
LSD (0.05)	2,142	5,374	19,096	25,914	24.7
P > F	0.0136	0.0040	0.0241	0.0132	<0.0001

[z] Each entry consisted of 4 replications with 18 plants in each replication, and the experiment was arranged as a randomized complete block design.
[y] Percentage bacterial wilt incidence at the time of harvest.
[x] Column means followed by the same letter are not significantly different at P ≤ 0.05 based on Least Significant Difference (LSD)

Table 4. Root-Gall Index and yield of BHN 602 non-grafted or grafted on to rootstocks for root-knot nematode resistance at a fieldtrial in Quincy, FL. The experiment was conducted in fall 2011.

Entry [z]	Fruit yield (kg•ha^{-1}) Medium	Large	Extra large	Total marketable	Root-Gall Index [y]
RST-04-106-T	6,511 bc [x]	11,905 ab	22,449 b	40,864 bc	1.2 b
BHN 998	9,167 a	14,299 a	28,556 a	52,022 a	1.4 b
BHN 1054	7,816 ab	15,076 a	23,788 ab	46,680 ab	1.4 b
Self-grafted	5,413 c	8,532 b	13,380 c	27,325 d	5.7 a
Non-grafted	6,058 bc	10,496 b	18,593 bc	35,148 cd	5.6 a
LSD (0.05)	2,165.1	3,559.2	5,303.9	9,722.5	0.9775
P > F	0.0112	0.0049	<0.0001	0.0002	<0.0001

[z] Each entry consisted of 4 replications with 14 plants in each replication, and the experiment was arranged as a randomized complete block design.
[y] Percentage bacterial wilt incidence at the time of harvest.
[x] Column means followed by the same letter are not significantly different at P ≤ 0.05 based on Least Significant Difference (LSD)

CONCLUSION

Studies presented here illustrate the benefits of grafting in reducing bacterial wilt and root-knot nematode damage of a susceptible tomato variety 'BHN 602'. Disease incidence was greatly reduced and tomato fruit yield was effectively maintained using grafting as a management practice. Data indicate that several commercially available hybrid rootstocks have high levels of resistance to bacterial wilt and root-knot nematodes. Further studies are in progress in 2012 with new grafting combinations for bacterial wilt and root-knot nematode management in tomato production.

REFERENCE

McAvoy, T., J. Freeman, S. Rideout,S.M. Olson, and M.L. Paret. 2012. Grafting using hybrid rootstocks for management of bacterial wilt in field tomato production. HortScience 47:621-625.

Effectiveness of Tomato and Watermelon Water and Nutrient BMPs

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INTRODUCTION

Tomato production on Florida's sandy soils with low water and nutrient holding capacities requires careful management of water and nutrients to reduce off-site transport to surface and ground waters and maintain profitable yields. Tomato and watermelon are the two most important vegetable crops with regards to area and fertilizer nitrogen (N) and phosphorus (P) inputs. Leaching of N and P is of special concern in south Florida due to shallow water table environments. Best management practices (BMPs) for vegetable and row crop production, described in the "Water Quality/Quantity Best Management Practices for Florida's Vegetable and Agronomic Crops" manual (FDACS, 2005), includes a wide array of water and nutrient management practices for tomato and watermelon. The goal of these BMPs is to protect surface and ground water quality while maintaining economic viability. Although numerous BMPs have been recommended in the manual, their effectiveness with regards to yield and water quality has not been quantified (Shukla et al., 2010).

Nutrient leaching is enhanced for the seepage irrigated tomato and watermelon production areas. Seepage irrigation systems involve artificially raising the water table so that moisture can be delivered into the root zone by capillary forces. Soil moisture-based water table management and use of recommended N and P fertilizer rates are two key BMPs for seepage irrigated tomato and watermelon production systems. However, these two BMPs have not been field tested. This lack of field verification has limited their wide-scale acceptance. A three-year (2004-2006) study was conducted at the Southwest Florida Research and Education Center (SWFREC), University of Florida Institute of Food and Agricultural Sciences (UF/IFAS), Immokalee, FL to field-test irrigation and nutrient BMPs by comparing N and P leaching, water use, and yields from the industry average with two BMP-based inputs for the seepage irrigated tomato - watermelon rotation system. The three production systems evaluated were: 1) industry average of water and nutrient (N, P, and K) inputs with seepage irrigation (*Industry*); 2) BMP-based water and nutrient inputs with seepage irrigation (*BMP-seep*); and 3) 2 with subsurface drip, a potential water saving alternative to seepage irrigation (*BMP-subdrip*).

MATERIALS AND METHODS

Watermelon was grown during spring of 2004 and 2005; tomato was grown during fall 2004, 2005, 2006 and spring 2006. Two replications of three treatments (*Industry, BMP-seep,* and *BMP-subdrip*) were implemented in a vegetable field (six experimental plots). Each plot was 0.6 acre. To minimize mixing of water and nutrient among six plots, all plots were lined on all four sides by installing high density polyethylene (HDPE) liners. Each liner extended from the soil surface down into the top of the spodic (organic hardpan) layer.

Water and Nutrient Treatments. A grower survey was conducted to determine the average water and nutrient inputs (termed as *Industry* average) used for tomato and watermelon production in South Florida. Soil moisture levels in the plastic mulch beds at several vegetable farms were measured and the average value (18%) was defined as the target soil moisture level for the industry system. This target soil moisture was achieved by managing the water table. The groundwater levels for the two BMP systems were managed based on keeping the soil moisture close to the field capacity. On occasions, the soil moisture for the three systems, especially for the BMPs, exceeded the target values due to rainfall.

The industry average fertilizer rates for watermelon and tomato were 265 and 373 (N), 170 and 162 (P_2O5), and 459 and 673 (K_2O) lb/ac, respectively (Shukla et al., 2004; Hendricks and Shukla, 2011). The N rates for *BMP-seep* and *BMP-subdrip* treatments for watermelon and tomato were 150 and 200 (N) lb/ac,while P and K rates were determined from the soil tests.

Measurements and Analyses. Yields, water use, and N (NH_4, NO_3, and TKN) and P [total P (TP)] concentrations in shallow groundwater were measured. Nutrient concentrations in soil (NH_4, NO_3, TKN, and Mehlich-1 P) and plant [Total N (TN) and TP] were also measured. Soil moisture at multiple depths in each plot were measured using capacitance probes. Shallow and deep wells, installed below and above the hardpan (spodic layer), were used to monitor the water table and take water quality samples. Drainage from each plot was estimated using the water levels measured at a V-notch weir installed in a drain-box that collected drainage. Water use was calculated as the difference between irrigation volume and drainage loss. The water use as calculated here includes deep percolation losses through the spodic layer.

The experimental design for this study was a randomized complete block design for three treatments with two replications and at least two sub-samples depending on the response variable (i.e., yield and shallow ground water dissolved inorganic N (DIN), NH_3-N, TKN, TN, and TP. The means and standard errors were analyzed using ANOVA, the linear mixed model procedure was applied to all response variables. Statistical significance was tested at $\alpha \leq 0.05$. Values for $0.05 < p < 0.1$ were interpreted as some evidence of a treatment effect.

RESULTS

Water Use. The *BMP-subdrip* system used the least water (37 in) followed by *BMP-seep* (68 in) and *Industry* (74 in). The *BMP-subdrip* used 46 and 50% less water compared to the *BMP-seep* and *Industry*. Seasonal averages showed that *Industry* and *BMP-seep* were at times comparable. Note that for simplicity, the term 'water use' here includes percolation losses (water use = evapotranspiration + percolation).

Yield. For tomato, the average crop yield for the treatments (**Table 1**) during spring 2006 was 2,817 box/acre, which is 28% greater than the largest average yield for the treatments from the fall crop seasons (2,209 box/acre during fall 2006). Fall 2005 recorded the lowest average yield for treatments (787 box/acre) out of all the crop seasons. This was due to wind and flood damage from Hurricane Wilma (October 24, 2005) that generated 8 in of rainfall in one day.

Although the overall and seasonal (except fall 2005) averages for tomato yield for the *Industry* treatment were numerically higher than the two BMP treatments, the differences in yield were not statistically significant. Results indicate that use of BMP-based water and nutrient inputs is not likely to reduce the yield. Grower feedback on the results indicated the increased yield from the *Industry* treatment to be economically important. However, long-term experiments will need to be conducted to detect statistically significant differences, if present.

Despite large numerical differences for watermelon, *Industry* treatment did not produce significantly higher yields (no. and lb/

Table 1. Average tomato yield for Industry, BMP-seep, and BMP-subdrip water and nutrient input treatments for fall 2004, 2005, 2006 and spring 2006.

		Seasonal Yield	Seasonal Average
		----------------------(box/ac)*--------------------------	
Season	Treatment		
Fall 2004**			1,882
	Industry	1,885	
	BMP-seep	1,815	
	BMP-subdrip	1,946	
Significance			
	p-Values	0.8067	
Fall 2005**			787
	Industry	659	
	BMP-seep	853	
	BMP-subdrip	849	
Significance			
	p-values	0.7406	
Spring 2006†			2,817
	Industry	3,224	
	BMP-seep	2,635	
	BMP-subdrip	2,592	
Significance			
	p-values	0.1042	
Fall 2006†			2,209
	Industry	2,449	
	BMP-seep	2,089	
	BMP-subdrip	2,088	
Significance			
	p-values	0.2925	

*1 box = 25 lb, yields are sum of all grades (medium, large, and extra-large), ** 2harvests, † 3 harvests.

Table 2. Yields for watermelon grown under Industry, BMP-seep, and BMP-subdripwater and fertilizer inputs for the spring 2004 and 2005 growing seasons.

Year	Treatment	Diploid		Triploid*	
		(melons/acre)	(cwt/acre)	(melons/acre)	(cwt/acre)
2004	*Industry*	3,993	758	2,935	444
	BMP-seep	2,995	538	1,755	261
	BMP-subdrip	2,662	475	2,421	349
Significance	*p-value*	0.331	0.261	0.420	0.336
2005	*Industry*	--	--	2,460 a	345 a
	BMP-seep	--	--	1,532 b	193 b
	BMP-subdrip	--	--	1,643 b	214 b
Significance	*p-value*	--	--	0.037	0.031

* Columns with numbers having the same letters are not significantly different at the p< 0.05 level. 1cwt/acre = 100 lb/ac.

acre) of diploid or triploid watermelons during 2004 compared with *BMP-seep* or *BMP-subdrip* (**Table 2**). In contrast, *Industry* had significantly higher yields (no. and lb/acre) of triploid watermelons during 2005 compared with *BMP-seep* or *BMP-subdrip*. The *Industry* treatment in 2005 produced about 60 and 80% higher yields (lb/acre) than *BMP-seep* and *BMP-subdrip*, respectively. Yield differences where likely the result of high N and K losses for the spring 2005 growing season which received three times greater rainfall depths compared with spring 2004 season. Under higher than average rainfall conditions, the use of BMP water and nutrient input is likely to reduce the watermelon yields. Overall, use of BMP nutrient inputs under average rainfall conditions is not likely to reduce watermelon yield.

The ability to detect significant differences in watermelon yield was enhanced by higher rainfall in the 2005 season compared with 2004, indicating the importance of maintaining adequate levels of nutrients in the root zone of a seepage irrigated crop (Hendricks et al., 2007). Results suggest that watermelon growers may need to apply higher fertilizer levels particularly during wet years; however, because of the lack of statistical differences in 2004, more study is warranted.

Groundwater Quality. The mean concentrations of DIN, NH_3-N, TKN, and TN in shallow groundwater were significantly higher for the *Industry* treatment compared with the two BMP treatments ($p \leq 0.05$; **Table 3**). Additionally, there was moderate evidence of a treatment effect ($p = 0.055$) for NO_3-N for *Industry* (28 ppm) which was almost twice the values observed for *BMP-seep* (12 ppm) and *BMP-subdrip* (15 ppm) (**Table 3**).The mean DIN concentration for *Industry* was significantly higher ($p = 0.02$) than *BMP-seep* (147 % higher) and *BMP-subdrip* (95 % higher) (**Table 3**). There was no statistical difference in the deep groundwater (below spodic layer) N concentrations between the three treatments (Hendricks and Shukla, 2011). The lack of differences in the deep groundwater was mainly caused by mixing of groundwater from all treatments and outside the field. Overall, results show that compared to *Industry, BMP-seep* and *BMP-subdrip* can reduce the TN concentrations in shallow groundwater by more than 50%.

Shallow groundwater TP concentration for the *Industry* was significantly higher ($p \leq 0.05$) than *BMP-seep* and *BMP-subdrip* treatments. The average TP concentrations for the two BMP treatments were 33% lower than the *Industry*. Overall, the BMP-based inputs can reduce the leaching of TP to the groundwater.

The reduced N and P leaching observed for the two BMP systems is a combined effect of irrigation as well as fertilizer management. Higher water table maintained for the *Industry* reduced the water storage capacity of soil compared to the two BMP treatments. Higher water table also increased the frequency of water table reaching the soil surface which resulted in saturation of the bottom part of crop beds. As the water table receded, the nutrients were flushed out of the root zone.

CONCLUSION

- BMPs evaluated in this study did not result in statistically significant lower tomato yields compared to the Industry average.
- Under normal rainfall conditions, the BMPs did not result in statistically significant lower watermelon yields compared to the Industry average.
- Wetter conditions during the spring season may reduce the watermelon yield. Further research is needed to develop nutrient management strategies for wetter conditions.
- The BMPs reduced the water use for tomato and watermelon production.
- The BMPs reduced the N and P concentrations in groundwater by 50 and 33%, respectively compared to the *Industry*.

Overall, results from this study indicate

Table 3. Means and standard errors for dissolved inorganic nitrogen (DIN), nitrate plus nitrite nitrogen (NO_x-N), ammoniacal nitrogen (NH_3-N), total kjeldahl nitrogen (TKN), total nitrogen (TN), and total phosphorus (TP) concentrationsin the shallow groundwater for the *Industry*, *BMP-seep*, and *BMP-subdrip* treatments for the 2004-2006 period.

Treatment	N Species Concentration and p-values*					
	DIN	NO_x-N	NH_3-N	TKN	TN	TP
	ppm					
Industry	37 ± 5a	28 ± 3a†	10 ± 2a	10 ± 2a	38 ± 5a	3.09 ± 0.17a
BMP-seep	15 ± 2b	12 ± 2b	3 ± 1b	4 ± 1b	16 ± 2b	2.10 ± 0.11b
BMP-subdrip	19 ± 3b	15 ± 2b	4 ± 1b	6 ± 1b	21 ± 3b	2.05 ± 0.09b
p-value	0.020	0.055	<0.001	0.001	0.010	0.002

*Columns with numbers having the same letters are not significantly different at the $p< 0.05$ level. † significant at the $p = 0.1$ level.

that under average rainfall conditions, use of BMPs evaluated in this study can reduce N and P leaching to groundwater and water use without adversely impacting crop yields. For tomato, no differences in yields were observed irrespective of the rainfall conditions. Long-term studies are needed to detect the differences in tomato yield, if present. Reduced N and P leaching to the groundwater from the BMP-based water and nutrient inputs are likely to reduce surface water N and P loads.

REFERENCES

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

Hendricks, G.S., and S. Shukla. 2011. Water and Nitrogen Management Effects on Water and Nitrogen Fluxes in Florida Flatwoods. Journal of Environmental Quality 40(6):1844-1856.

Hendricks, G. S., Shukla, S., Cushman, K. E., Obreza, T. A., Roka, F. M., Portier, K. M. & McAvoy, E. J. 2007. Florida watermelon production affected by water and nutrient management.HortTechnology. 17:328-335.

Shukla, S., B.J. Boman, R.C. Ebel, P.D. Roberts, and E.A. Hanlon. 2010. Reducing unavoidable nutrient losses from Florida's horticultural crops. HortTechnology 20:52-66.

Shukla, S., G.S. Hendricks, T.A. Obreza, and E. McAvoy. 2004. Evaluation of water and nutrient BMPs for vegetable production with seepage irrigation in southwest Florida. Rep. WRP-SP-03.Florida Department of Agriculture and Consumer Services, Tallahassee, FL; Southwest Florida Water Management District, Brooksville, FL.

Evaluation of Potassium Rates and Sources for Tomato Production in West-Central Florida

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POTASSIUM FERTILIZATION

Potassium (K) is one of the two most absorbed essential nutrients for tomato (*Solanum lycopersicum*) plant growth and development. In Florida, the crop is grown with one of two irrigation systems: seepage (subsurface) or seepage and drip. In the former system, all the fertilizer is applied exclusively before planting. Preplant fertilizers for tomato production are applied in two procedures: a) broadcast to the soil ("cold mix"), and b) banded on bed tops ("hot mix"). The "cold mix" usually consists of 25% to 35% of all the nitrogen (N) and K, and all the micronutrients. The rest of the N and K are applied in one or two bands on bed tops. Tomato growers obtain granular fertilizer from suppliers that blend formulas according to soil analysis recommendations and use sulfate of potash (SOP; 0-0-50 + 17% S), muriate of potash (MOP; 0-0-60), and potassium nitrate (13-0-45) as the most common K sources. However, MOP (salt index = 116) has a very elevated salt index in comparison with that for SOP (salt index = 46). High salt injury has been observed routinely when all or the majority of preplant K is obtained from MOP in tomato fields of southwest and west-central Florida, which has forced growers to be careful when applying MOP. However, in the last decade K application rates have changed dramatically. This is partially due to the steady increase of worldwide fertilizer prices, and specifically because traditionally SOP has been more expensive than MOP. Therefore, this situation opens an opportunity to reevaluate the use of MOP in K fertilizer blends at lower rates than those used at the beginning of the current century. The objective of this study was to compare the performance of tomato under different preplant K rates and sources.

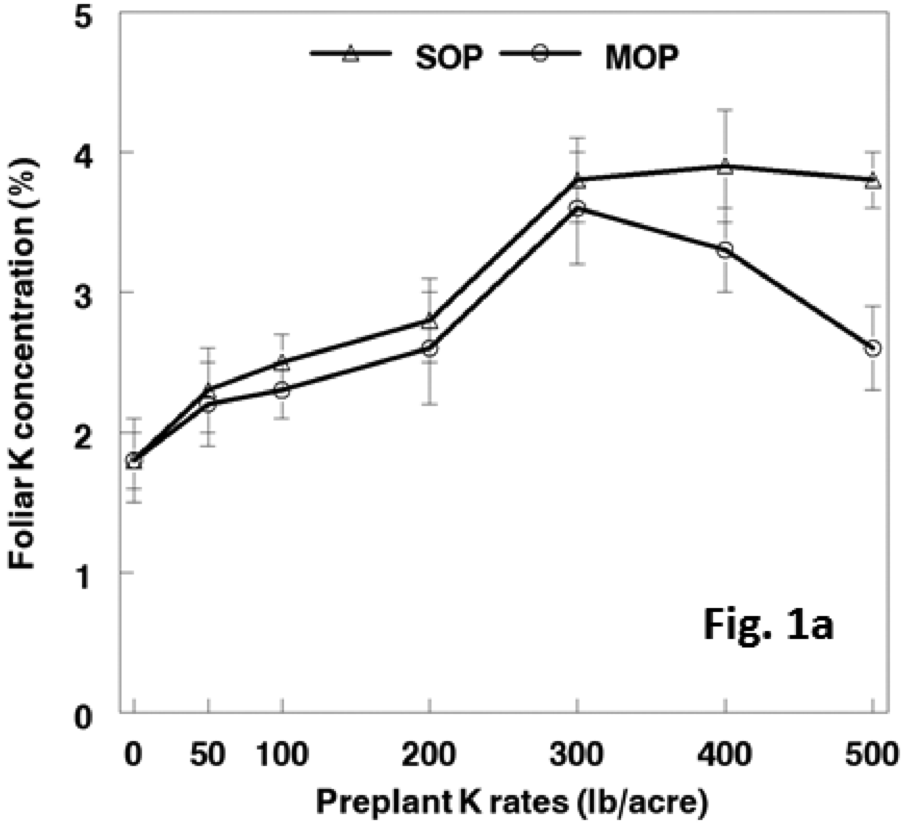
FIELD STUDIES WITH K RATES AND SOURCES

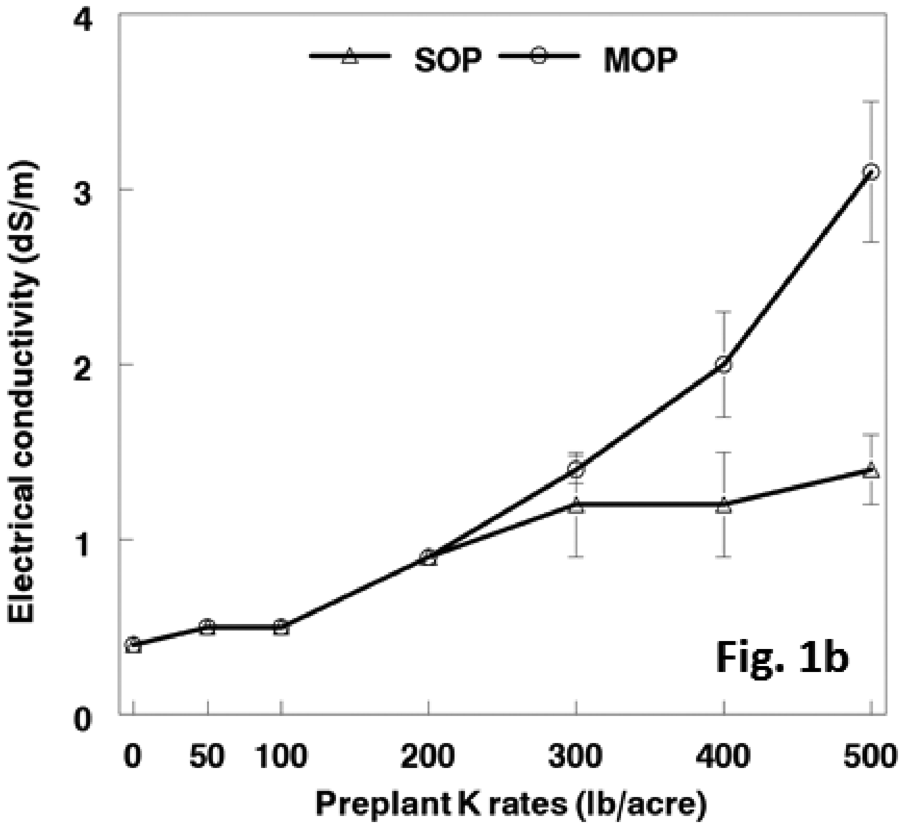
Procedures. Two studies were conducted during fall 2009 and 2010 at the Gulf Coast Research and Education Center of the University of Florida in Balm, FL. The soil at the experimental site was a deep Spodosol with <1.5% organic matter and pH of 6.8. A standard bedder was used to create raised beds that were 5 ft apart at the center, 8 inches high, 28 inches wide across the top and 32 inches wide at base. Raised beds were fumigated with a 50:50 (v:v) methyl bromide and chloropicrin mixture at 170 lb/acre to eliminate weeds, nematodes, and soil pathogens in late July of each year. 'Tygress' tomato seedlings at the four true-leaf stage were transplanted in a single row with 2-ft spacing between plants in the third week of August of each year. Tomato plants were established and grown with seepage irrigation only, using daily volumes that fluctuated between 10,000 and 14,000 gal/acre per day, depending on the local potential evapotranspiration and rainfall. All other crop management was conducted according to current recommendations for tomato production.

Treatments were combinations of two K sources (SOP and MOP) and five K rates (0, 50, 100, 200, 300, 400, and 500 lb/acre). Treatments were arranged in a randomized complete block design with six replications. Either SOP (50% K_2O ≈ 42% K) or MOP (60% K_2O ≈ 50% K) were applied as two 2-inch deep bands located 12 inches apart on top of raised beds before soil fumigation and plastic mulch application. Elemental S was used to balance S content in SOP. Other nutrients were applied at non-limiting rates on bed tops using recommended rates based upon growth stages and interpretation of pre-season soil test results. Soil samples were collected for electrical conductivity (EC) at 4 weeks after transplanting (WAT), which is a measure of soil salinity. Plant tissue samples for K leaf concentrations were collected at 4 WAT using ten most-recently matured tomato leaves adjacent to an inflorescence. Tomato fruit were harvested twice at 10 and 12 WAT during both seasons, and they were graded as extra-large and total marketable, according to the current standards for size categories. Marketable tomato fruit weight was calculated as the sum of all marketable fruit, including the extra-large grade. All collected measurements were subjected to an analysis of variance to determine single-factor and interactions significance ($P<0.05$) using a general linear model, as well as the effects of linear contrasts through regression analysis. Individual treatment means were separated with standard error bars.

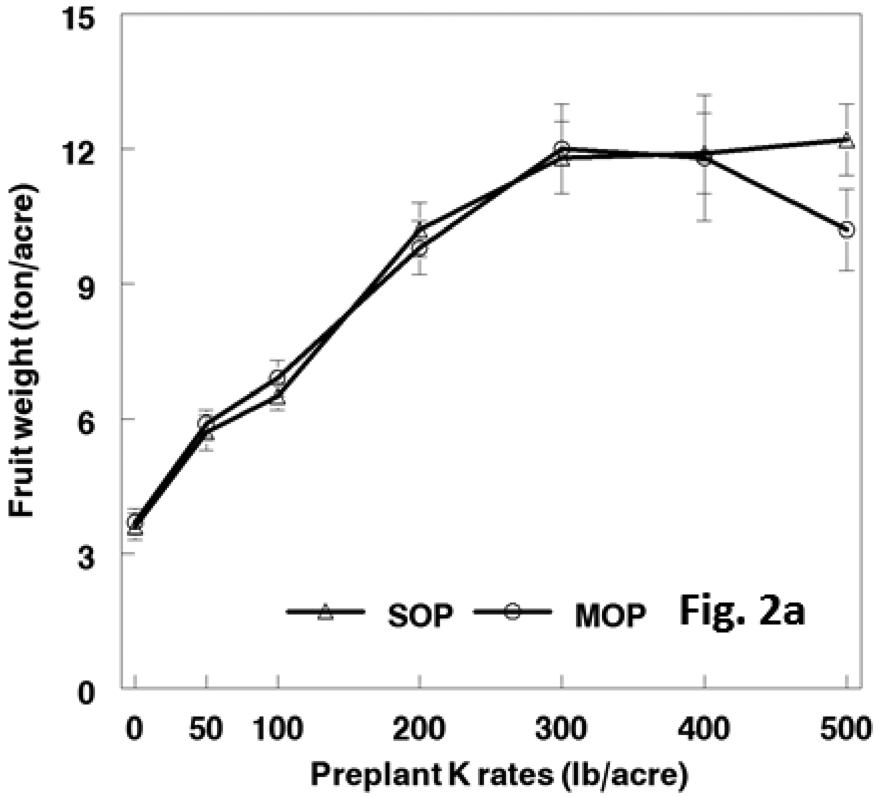
Results and Conclusions. Sources and rates of preplant K had significant influence on foliar K concentrations at 4 WAT (**Fig. 1a**). Foliar K concentrations increased steadily as K rates increased from 0 to 300 lb/acre, regardless of the utilized preplant K source. However, K concentrations in newly-opened mature leaves declined from approximately 3.6% at 300 lb/acre of K to about 2.6% with 500 lb/acre when MOP was used. In contrast, these K concentrations remained unchanged (approximately 3.8% K) at the same rate range when SOP was applied to the soil. It has been indicated that the K sufficiency for tomato plants during blooming is between 2.5% and 5%, which suggested that K supply was not a growth-limiting factor during these concentration fluctuations, thus not reducing crop performance. In this case, plants had foliar K concentrations of 2.5% or higher consistently in plots treated with application rates of 200 lb/acre of either source. The soil EC at 4 WAT was affected by K sources and rates (**Fig. 1b**). When SOP was used as the preplant K source, the soil EC remained ≤1.5 dS/m, regardless of the K rate. However, the preplant application of MOP steadily increased the soil EC across K rates, reaching a maximum of 3.1 dS/m with 500 lb/acre of K and surpassing the reference soil EC threshold for tomato production of 2.5 dS/m. However, there were no differences in soil EC between the two K sources at rates from 0 to 300 lb/acre of K.

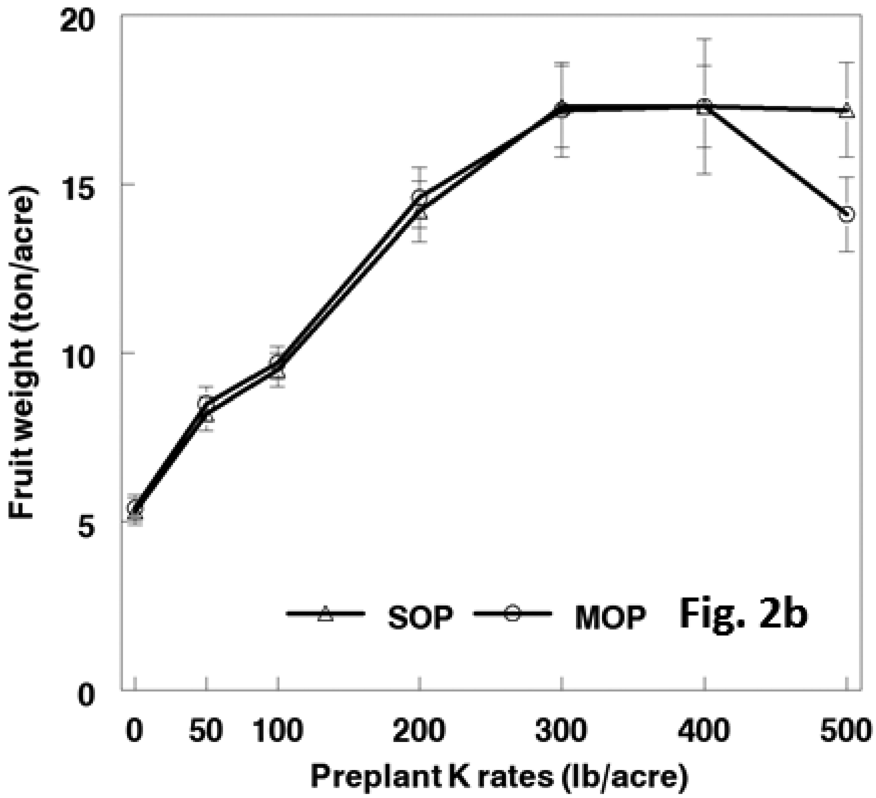
Total extra-large and marketable fruit weight in plots treated with SOP and MOP followed the same patterns from 0 to 400 lb/acre of K (**Fig. 2a and 2b**). However, as the preplant K rate increased from 400 to 500 lb/acre, marketable fruit weight remained constant in plots treated with SOP, whereas there was an abrupt drop in yield in those that received preplant MOP at 500 lb/acre. This result is explained by the significant increase in soil EC when applying 500 lb/acre





Figures 1a and 1b. Effects of preplant potassium (K) sources and rates on foliar K concentrations (Fig. 1a) and on soil electrical conductivity (Fig. 1b) at 4 weeks after transplanting. SOP = sulfate of potash (50% K_2O ≈ 42% K) and MOP = muriate of potash (60% K_2O ≈ 50% K). Values separated with error bars.





Figures 2a and 2b. Effects of preplant potassium (K) sources and rates on extra-large (Fig. 2a) and total marketable fruit weight (Fig. 2b). SOP = sulfate of potash (50% $K_2O \approx 42\%$ K) and MOP = muriate of potash (60% $K_2O \approx 50\%$ K). Values separated with error bars.

of MOP (3.1 dS/m), which becomes a limitation for tomato growth and fruit setting. Under seepage irrigation conditions, this study revealed that tomato growers could replace certain current K fertilizer blends for bed banded applications with more MOP without risking significant injury (e.g., a total K rate of 400 lb/acre could result from a 50:50 mix of both sources). It is recommended to monitor the soil EC routinely during the first 6 weeks to make sure it remains below the 2.5 dS/m threshold.

Effects of Potassium Rates in Yield, Fruit Quality, Plant Biomass and Uptake on Mature-Green Tomatoes in Seepage Irrigation

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Potassium (K) plays a role in transporting sugars produced in the leaf by photosynthesis to the developing plant biomass (root, stem and leaves) and tomato fruit. Deficiency of K in tomato plants causes leaves to turn dark brown, yellowish to white necrotic dots develop near the leaf margins of the older leaves, which merge into brown necrotic areas around the leaf margins. Adequate K nutrition has also been shown to reduce the severity of diverse physiological disorders such as uneven and blotchy ripening, irregular shape and hollow fruit, high level of internal white tissue (IWT), yellow shoulder, gray wall, and decreased lycopene (Hartz, 1999; Hartz et al., 2002). However, the occurrence of these disorders has been frequent, but unpredictable.

Tomatoes have a relatively high K requirement compared to nitrogen (N) with over 268 lb/acre per season being utilized in processing tomatoes (Hartz et al., 2002). Potassium is needed throughout the season and is a major component of fruit at approx. 250 mg/100 g of fruit, a very high concentration compared to phosphorus at 25 - 40 mg/100 g of fruit. There is usually 2.3 to 3.3 lb of K uptake into the plant for every ton of tomato harvested and the demand is highest during fruit balking (Bose et al., 2006).

Potassium soil test based fertilizer application is essential in Florida sandy soils with exchangeable soil K ranging from very low to medium (Olson et al., 2010; Hochmuth and Cordasco, 2008). Current UF/IFAS K_2O fertilizer recommendations for tomatoes range from 0 to 225 lb/acre for soils testing 'very high' (> 125 ppm) to 'very low' (< 20 ppm) as determined using 'Mehlich-1' laboratory soil extractant. Supplemental K_2O fertilizer applications above the base recommendation are allowed only in specific situations. However, based on a survey, is not uncommon for tomato growers to use as much as 450 to 650 lb/K_2O/acre dependent upon rainfall, field conditions and fertilizer prices. Additionally, some tomato growers believe that higher K_2O rates increase tomato post-harvest quality and shelf life. Therefore, the objectives of this study was to evaluate the effect of K rate on tomato petiole sap content, plant biomass, K uptake, yield and fruit quality on spring tomatoes grown in seepage irrigation.

MATERIALS AND METHODS

Two fertilizer trials using subsurface ('seepage irrigation') were conducted in the spring of 2010 and 2011 in a commercial tomato field near Palmetto, FL (27° 31' 16" N / 82° 34' 21" W). Soil type was EauGallie fine sand with an organic matter (OM) content of 2.0%, which was higher than the typical 1% OM content or less of most Florida sandy soils. The experimental design was a randomized complete block design with four replications. Soil K tested very low (< 20 ppm) and medium (36-60 ppm) in spring 2010 and 2011, respectively. In each trial, tomatoes were grown following industry standards for production practices (**Table 1**) and pesticide applications were made as needed in response to regular scouting reports according to UF/IFAS recommendations (Olson et al., 2010).

The soil was rototilled and the "bottom mix" was applied at a rate of 16, 96 and 30 lb/acre of N, P_2O_5, and K_2O on 19 Jan. 2010 and 31 Jan. 2011 as potassium sulfate (K_2SO_4), respectively. A total eight fertilization treatments were applied which was placed by hand in two grooves formed on the top shoulder of the bed or 'hot mix' using pre-calibrated cups at the following rates: 0, 60, 120, 180, 240, 360, 480, 720, and 960 lb/ K_2O/acre. Since 30 lb/K_2O/acre were already present in the "bottom mix", total rates were 30, 90, 150, 210, 330, 450, 690 and 930 lb/K_2O/acre. Potassium source in the bottom mix was K_2SO_4 and total N rate applied was 250 lb/acre N as ammonium nitrate.

Data Collection: Weather data were obtained from a Florida Automated Weather Network (FAWN) station located approximately 31 km from the experimental field at the UF/IFAS, Gulf Coast Research and Education Center in Balm, FL.

Monitoring wells were constructed from a 4-ft long, 4-inch diameter PVC pipe screened at the bottom (Smajstrla, 1997). A float was attached to one end of PVC pipe to serve as the water level indicator. Permanent marks were made every 1-inch to indicate the water table depth below the plastic mulch bed. Weekly observations of the ground water table depth were taken throughout the growing season.

Beginning at first flower, and continuing until second fruit harvest on a bi-weekly basis, six most recently matured leaves and petioles were collected in the spring of 2010 and 2011 to determine concentrations of K in fresh petiole sap by using ion-specific meters (Cardy, Spectrum Technologies, Inc., Plainfield, IL; Olson et al., 2010; Studstill et al., 2006).

Tomato yield including marketable mature-green and colored tomatoes were graded in the field according to USDA specifications for extra-large (5x6), large (6x6), and medium (6x7) fruit categories (USDA, 1997). Soil samples were collected using an auger (1-inch internal diameter) at the end of the crop cycle or third harvest on 8 June, 2010 at two (fertilizer band and bed centerline) locations in the tomato bed. Bed centerline samples were taken in the crop row

Table 1. Summary of cultural practices used in the spring potassium (K) rate trials in Palmetto, FL.

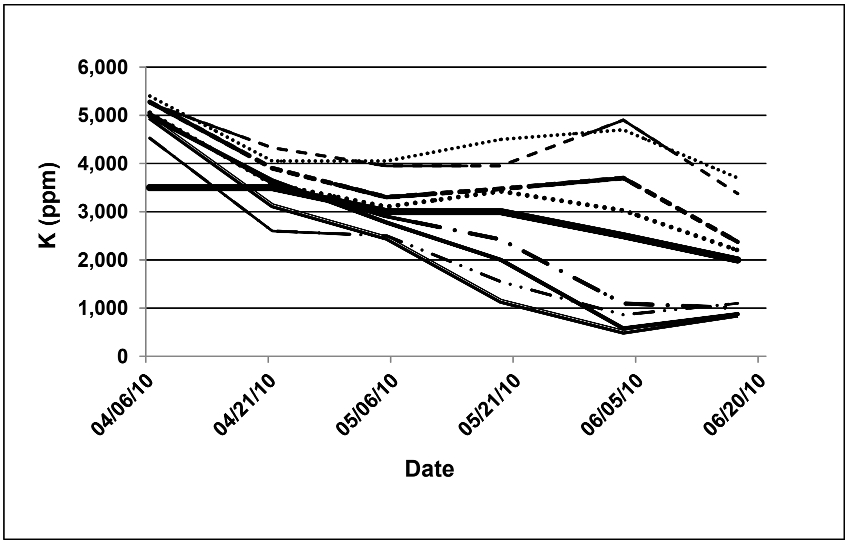
Cultural practice	2010	2011
Plant spacing (inches)	24	24
Bed spacing (feet)	6	6
Methyl Bromide: Chloropicrin and Telone/ Chloropicrin	50:50 @ 200lb/acre	40:60 @ 250lb/acre
Mulch	Black	Black
Planted length (feet)	3 beds of 30 (15 plants)	3 beds of 30 (15 plants)
Harvest length (feet)	34 (10 plants)	34 (10 plants)
Replications	3	4
Bed width (inches)	36	36
Transplant date	9 Mar.	8 Mar.
Harvest dates	1 and 8 June	19 May and 1 June

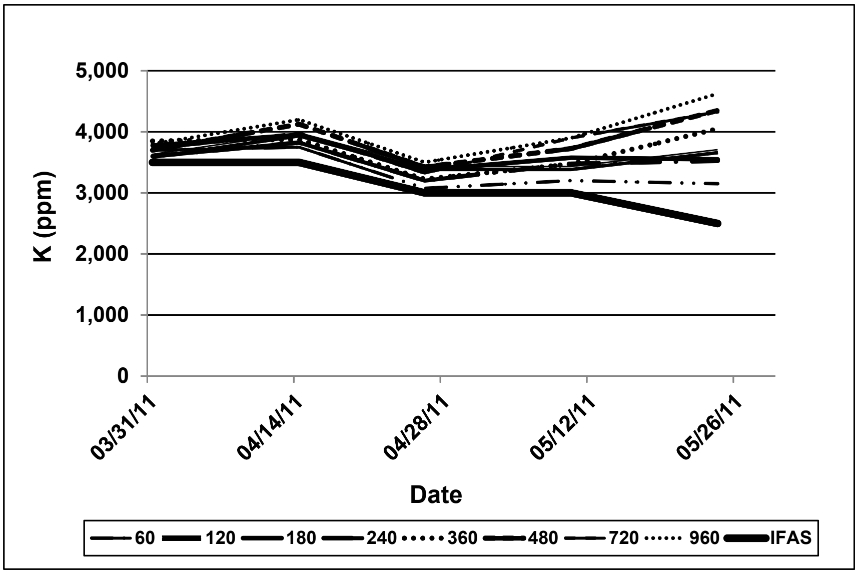
in-between two tomato plants and band at approximately 12-inches in from the edge of the bed. The sample cores were divided into two depths at each sample location: 0 - 4 and 4 - 8 inches (top and bottom layers, respectively). The soil samples were oven dried at 105°C for 24 h until further analyses. Soil K was extracted by Mehlich-1 solution (Mehlich, 1953). Mehlich-1 K analyzed by using an ion coupled plasma spectrophotometer (model 7400, Perkin-Elmer, Waltham, Massachusetts, USA).

On 30, 60 and 90 days after transplanting (DAT), the roots, stems, leaves and fruits (at harvest) of one plant per K treatment were collected randomly and oven dried at 65°C until constant weight to determine dry matter accumulation (Mills and Jones, 1996) and analyzed for K content using a C:N analyzer and ICP-dry ashing (Hanlon et al., 1994).

In spring 2010, a subsample of ten table-ripe fruit were collected and allowed to ripen. At ripe stage tomatoes were sliced in two and evaluated for presence or absence of IWT. In spring 2011, a subsample of ten fruit at mature green stage was collected, washed with chlorinated water, dried and transported to the Gargiulo packing-house in Immokalee, FL to ripen with 8 days of ethylene treatment at 20°C with 85% to 90% relative humidity (Sargent et al., 2005). Then, ripe tomatoes were transported to UF/IFAS Vegetable Horticulture Laboratory in Immokalee, FL., were sliced in two and evaluated for presence or absence of IWT.

Statistical Analyses: Petiole sap K concentration data were analyzed using analysis of variance (ANOVA) and means were separated by Duncan Multiple Range Test, $P \leq 0.05$. A yield (spring 2010 and 2011), plant biomass and K-uptake, and K soil (spring 2010) response function (f (X)), which measured the change in crop yield, total plant biomass, total K-uptake, and soil K with a corresponding change in the K-rate, was estimated by using four response models: the polynomial functions included a linear ($y = a + bX$) and quadratic models ($y = a + bX + cX^2$) where y is the tomato yield and X = K fertilizer rate and a, b, and c are constants (Black, 1993). The segmented functions included the linear- plateau ($y = a + bX$ if X<K critical rate, y = plateau yield if X> K critical rate) and quadratic-plateau ($y = a + bX + cX^2$ if X<K critical rate, y = plateau yield if X> K critical rate) where y is the tomato yield and X =K rate added fertilizer and a, b, and c are constants. The functional form of the tomato yield and total plant biomass and K-uptake response curve was assumed to be quadratic-plateau based $P \leq 0.05$, R2 and the lowest 'Mean Square Error' (MSE). Maximum yields were determined at the intersection of the quadratic and plateau lines (SAS version 9.1, SAS Institute Inc., Cary, NC, 2009).





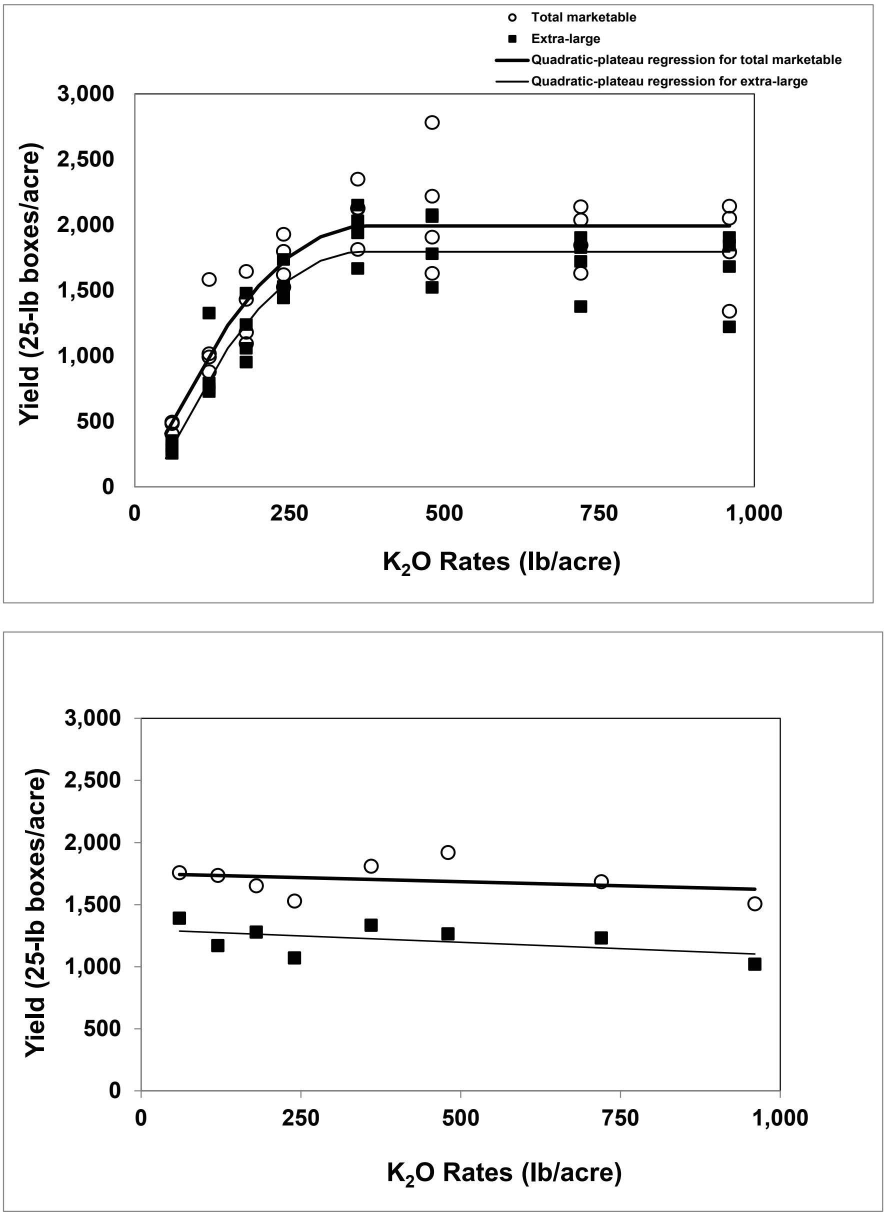
Figures 1a and 1b. Changes of potassium concentrations (ppm) in petiole sap with different potassium rates during spring 2010 (a) and 2011 (b) in Palmetto, FL.

RESULTS AND DISCUSSION

Weather conditions: Overall, weather data were typical from cold to warm and dry throughout the spring of 2010 and 2011. The maximum and minimum air temperatures were 84.4 and 61.6°F for 2010 and 81.8 and 58.4°F for 2011, respectively. No freeze events occurred during 2010 or 2011 seasons. Rainfall totals in the 2010 and 2011 seasons were similar to historical averages with accumulations of 10.7 and 9.6 inches, respectively. In spring 2010, one leaching rain event was found following UF/IFAS (University of Florida/Institute of Food and Agriculture Science) defined as 3 inches in 3 days or 4 inches in 7 days for tomatoes (Olson et al., 2010). With this rule a 30 lb/K_2O/acre supplemental fertilizer application will be allowed. However, no qualifying leaching rain event occurred in spring 2011.

Water table depth: Water table depths in the monitoring wells fluctuated between 12 to 15 inches at planting (first 4-weeks after planting) and 16 to 22 inches in both years during the season.

Plant nutritional status response to K rates: Since the year by K rate interactions was significant for petiole K on most sampling dates in 2010 or 2011 ($P \leq 0.05$), data were analyzed by year and not combined into one data set. Overall, K petiole sap concentration for spring 2010 indicated there was a response to increased K fertilizer rate (very low soil K; **Fig. 1a**), but there was no leaf K sap response with increase in K fertilizer rate for spring 2011 (medium soil K; **Fig. 1b**). In spring 2010, K petiole sap concentrations were above the UF/IFAS sufficiency values for all K rates in the first 5 WAT (weeks after transplant). However, K petiole sap concentration declined thereafter such that rates below 360 lb/K_2O/acre



Figures 2a and 2b. Total marketable and extra-large tomato yields (two harvest) with different potassium (K_2O) rates during spring 2010 (a) and 2011 (b) in Palmetto, FL.

were below UF/IFAS sufficiency levels. In spring 2011, sap K concentrations suggest that tomato plants maintained adequate levels (above UF/IFAS sufficiency values) of K even at the low K rates during the season.

Yield responses to N rates (spring 2010 and 2011): A significant year by K rate interaction occurred in both spring 2010 and 2011 for most of the yield components; therefore data were analyzed by year. Overall, the first and second harvests accounted for approximately for 95% and 5% and 69% and 31%, respectively of the total yield in 2010 and 2011. This is typical of commercial yield distributions when the first harvest represents the majority of the total harvest.

Extra-large, total marketable fruits (all sizes and categories combined) first harvest, second harvest and total marketable harvest (all categories and harvests combined) were analyzed using a quadratic-plateau, quadratic, linear-plateau and linear models in both years (data not shown). The lowest MSE occurred with the quadratic-plateau for first, second and total marketable yield was the best fit model for spring 2010 (very low soil K). Hence, it was used for the interpretation of tomato yield response to K rates (**Fig. 2a**). The quadratic model over-estimated the marketable yields and the linear-plateau under estimated the marketable yields in both years. The linear model produced the poorest fits among model in both years. However, no model was identified for any harvests or tomato category in spring 2011 (medium soil K; P>0.05). There was no response on tomato yield as the K rate increased (**Fig. 2b**).

The regression ANOVA tables using the quadratic plateau model for total extra-large first harvest and total marketable yield (all categories and harvests combined) showed a coefficient of determination (R^2) of 0.86 and 0.79, respectively. Calculated maximum marketable yields at total extra-large and total marketable harvest (all size categories and harvest combined) occurred at rates of 364 and 374 lb/ K_2O/acre in 2010 (**Fig 2a**). Locascio et al (1997) obtained the highest tomato yield with seepage irrigation at rates of 321 lb/ K_2O/acre in soils testing very low. These rates exceed the maximum recommended UF/IFAS rates of 225 lb/ K_2O/acre based on Mehlich-1.

Post-harvest evaluation: Visual evaluation of the internal tomato tissues indicated no presence of internal white tissue at any of the K rates in spring 2010 or 2011.

Residual K soil (spring 2010): End of the season or third harvest soil K content increased linearly as K rates increased (**Table 2**). Therefore, the highest K rate (960 lb/ K_2O/acre) had as much as 149.5 lb/ K_2O/ acre in the soil. Most of the K content was located at the bed center in the first 4-inches of the soil profile. This movement of K is a typical diffusion of nutrients from the hot-band to the bed center in a seepage irrigated crop in South Florida (Sato et al., 2009).

Potassium tomato partitioning (spring 2010): Total season plant biomass (roots, stems and leaves dry weight), total K plant biomass uptake (roots, stems and leaves content in dry tissue), total fruit dry (two marketable harvests combined), total fruit K-uptake (two marketable harvests combined), total dry weight and total K-uptake (plant biomass and fruit) were interpreted by a quadratic-plateau as the best fits model (**Table 3**). This model had the lowest MSE, and resulted in highly significant regression indicating increase in biomass and K uptake with increase in fertilizer K_20 rate. Calculated maximum for total dry weight and total K-uptake (plant biomass and fruit) occurred at rates of 362.4 and 663.1 lb/ K_2O/acre in 2010.

CONCLUSION

Based on one year of data on tomatoes grown in the spring season with seepage irrigation in very low soil test K, tomato petiole sap K concentrations were below UF/IFAS sufficiency levels at K_2O rates lower than 360 lb/acre. Similarly, plant biomass accumulation and tomato yield production increased with added fertilizer K_2O rate to approximately 380 lb/acre. These fertilizer rates are higher than current UF/IFAS recommendations for very low soil K tests, but are similar to previous field K fertilizer rate studies with seepage irrigation in South

Table 2. Soil potassium content at third harvest of tomato grown with different potassium (K_2O) rates in seepage irrigation during the spring 2010 in Palmetto, FL.

Treatment K_2O (lb/acre)	---------------------------------Soil K_2O (lb/acre)-----------------------				
	Hot-band		Bed-center		Total
	----------------------Soil depth (inches)----------------				
	0 – 4	4 - 8	0 – 4	4 – 8	
60	0.5	0.5	6.1	4.7	11.7
120	1.0	0.5	5.9	6.1	13.5
180	1.4	0.5	4.7	4.3	10.9
240	1.9	0.4	6.0	7.0	15.3
360	0.9	0.7	12.2	11.4	25.2
480	2.4	0.8	8.3	9.7	21.3
720	7.3	2.1	99.9	12.3	121.6
960	6.0	1.1	131.7	10.6	149.5
P. value	0.0001	0.02	0.0001	0.0001	0.0001
Regression	L	L	L	L	L

L = Linear regression

Table 3. Total tomato plant biomass, fruit, and potassium (K) uptake in response to different K rates during the spring 2010 in Palmetto, FL.

Treatment K_2O (lb/acre)	Total plant biomass		---------Fruit--------		Plant biomass and fruit	
	Biomass	K-uptake	Biomass	K-uptake	Biomass	K-uptake
	---------------------------------(lb/acre)---------------------------------					
60	1,865.6	13.75	611.1	19.31	2,476.7	33.06
120	1,887.0	24.39	1,438.4	52.14	3,325.4	76.52
180	2,110.8	30.81	1,632.0	35.16	3,742.8	65.96
240	2,883.7	55.56	2,113.0	83.39	4,996.7	138.95
360	2,939.7	79.39	2,618.1	117.92	5,557.9	197.31
480	2,793.1	91.61	2,631.8	127.22	5,424.9	218.83
720	2,457.3	106.07	2,296.0	132.98	4,753.3	239.06
960	2,358.7	102.22	2,159.9	131.20	4,518.6	233.42
P. value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Regression	QP	-	QP	-	QP	-
Maximum K_2O	350.9	-	369.6	-	362.4	-

QP = Quadratic-plateau regression

Florida. However, the study with medium soil test K indicated no response to added fertilizer K_2O rate, indicating that current UF/IFAS recommendation of 100 lb/K_2O/acre for soils with medium soil test K will be sufficient for optimal tomato production. These results would indicate that further K rate studies with seepage irrigation are warranted. Additional studies have been conducted and are being planned.

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REFERENCES

Black, C.A. 1993. Nutrient supplies and crop yields: response curve. In: Soil fertility evaluation and control. CRC Press, Inc. Boca Raton, Fl. USA.

Bose, P., D. Sanyal, and K. Majumdar. 2006. Balancing potassium, sulfur, and magnesium for tomato and chili grown on red lateritic soil. Better Crops 93(3):22-24.

Hanlon, E.A., J.G. Gonzalez, and J.M. Bartos. 1994. IFAS extension soil testing laboratroy chemical procedutes and training manual. UF/IFAS, Gainesville, FL.

Hartz, T.K. 1999. Potassium requirements for maximum yield and quality of processing tomato. Better Crops 83(2):26-28.

Hartz, T.K., C. Giannini, R.O. Miller, E.M. Miyao. 2002. Estimating soil potassium availability for processing tomato production. Commun. Soil Sci. Plant Anal. 33:1389-1400.

Hochmuth, G.J. and K. Cordasco. 2008. A summary of N, P, and K research with tomato in Florida.

EDIS HS759, 15 July 2012. http://edis.ifas.ufl.edu/pdffiles/CV/CV23600.pdf.

Lacascio, S.J. G.J. Hochmuth, S.M. Olson, R.C. Hochmuth, A.A. Csizinszky, and K.D. Shuler. 1997. Potassium sources and rate for polyethylene-mulched tomatoes. Hortscience 32:1204-1207.

Mehlich, A. 1953. Determination of P, Ca, Mg, K, Na, NH4. Raleigh (NC): North Carolina Department of Agriculture, Agronomic Division. Soil Testing Division Publication No. 1-53.

Mills, H.A. and J.B. Jones, Jr. 1996. Plant analysis handbook II. Macro Micro Publ., Athens, GA.

Olson, S.M., W.M. Stall, G.E. Vallad, S.E. Webb, S.A. Smith, E.H. Simonne, E. McAvoy, and B.M.

Santos. 2010. Tomato production in Florida, p. 295-316. In: S.M. Olson and B. Bielinski (eds.) 2010-2011 Vegetable production handbook for Florida, Vance Publishing, Lenexa, KS.

Ozores-Hampton, M.P., E. Simonne, E. McAvoy, P. Stansly, S. Shukla, P. Roberts, F. Roka, T. Obreza, K. Cushman, P. Gilreath, and D. Parmenter. 2006. Nitrogen BMP efforts with tomato production in Florida: Update for 2005-2006 Season. Proc. Fla. State Hort. Soc. 119:284-288.

Sargent, S.A., J.K. Brecht, and T. Olczyk. 2005. Handling Florida vegetables series: Round and roma tomato types. EDIS FL SS-VEC-928, 17 July 2012. http://edis.ifas.ufl.edu/vh079.

Sato, S., K. Morgan, M. Ozores-Hampton, and E.H. Simonne. 2009. Spatial and temporal distributions in sandy soils with seepage irrigation: II. Phosphorus and potassium. Soil Sci. Soc. Amer. J. 73:1053-1060.

Simonne, E.H. and G.J. Hochmuth. 2010. Soil and fertilizer management for vegetable production in Florida, p. 3-15. In: S.M. Olson and B. Santos (eds.) 2010-2011 Vegetable production handbook for Florida, Vance Pub., Lenexa, KS.

Smajstrla, A.G. 1997. Simple water level indicator for seepage irrigation. EDIS Circ. 1188, 17 July 2012. http://edis.ifas.ufl.edu/AE085.

Studstill, D., E.H. Simonne, R. Hochmuth and T. Olczyk. 2006. Calibrating sap-testing meters. EDIS Circ. 1074, 26 Mar. 2011. http://edis.ifas.ufl.edu/HS328.

U.S. Department of Agriculture. 1997. United States standards for grades of fresh tomatoes. Agr. Mktg. Serv. 26 March 2011. http://www.ams.usda.gov/standards/tomatfrh.pdf.

Use of Cultivation and Glyphosate During the Fallow Period and New Herbicide Registration in Tomato

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INTRODUCTION

Weed management has become more problematic with the phaseout of methyl bromide. Nutsedge continues to be one of the most common and problematic weeds in tomato production. Methyl bromide alternatives such as 1,3-dichloropropene plus 60% chloropicrin (1,3-D+pic) and Dimethyl disulfide plus chloropicrin (DMDS+pic) provide none to minimal control of nutsedge. Herbicides registered in tomato for nutsedge control include halosulfuron (Sandea, Profine), S-metolachlor (Dual Magnum, Brawl, Medal), and trifloxysulfuron (Envoke). These herbicides only provide partial control of yellow nutsedge. Glyphosate also provides nutsedge control, but should be applied only during the fallow period. The objective of this experiment was to develop a weed management program including MeBr alternative fumigants, herbicides, and weed control during the fallow period.

Table 1. Calendar of treatments.

Dates Site A/ Site B	Week after Initiation	Treatment: Cult.	Gly.	Cult.-Cult.	Gly.-Gly.	Cult.-Gly.	Gly.-Cult.	Gly.-Cult. Gly.	Non-treated
Feb. 25 / Mar. 25	0	← Initial cultivation →							
Apr. 4 / Apr. 30	5							Gly.	
Apr. 8 / May 6	6				Cult.	Gly.	Cult.	Gly.	
Apr. 30 / May 25	9	Cult. (4/30)	Gly. (5/2)					Cult. (4/30)	
May 2 /		Cult. (5/25)	Gly. (5/25)					Cult. (5/25)	
May 16 / Jun 12	11			Cult.	Gly.	Gly.	Cult.		
May 25 / Jun 22	13							Gly.	
Jun 23 / Jul 20	17	← Final cultivation →							
Jul 22 / Aug 17	21	← Fumigation →							
Aug 19 / Sep 14	25	← Herbicide →							
Aug 26 / Sep 21	26	← Transplanting →							
Sep 16 / Oct 12	29	← Herbicide →							

QP = Quadratic-plateau regression

MATERIALS & METHODS

The experiment was conducted at two sites at the University of Florida Gulf Coast Research and Education Center. Treatments were arranged in a factorial design with 8 fallow weed treatments x 3 fumigants x 2 herbicide programs. The 8 fallow weed treatments included: one cultivation (Cult.), one glyphosate application (Gly.), two cultivations (Cult.-Cult.), two glyphosate applications (Gly.-Gly.), cultivation followed by a glyphosate application (Cult.-Gly.), glyphosate application followed by cultivation (Gly.-Cult.), and a glyphosate application followed by cultivation followed by glyphosate application (Gly.-Cult.). Glyphosate was applied at 2 lb. ai./A. Fumigation treatments included a nontreated, 1,3-dichloropropene plus chloropicrin (1,3-D+pic) in a ratio of 40:60 at 300 lb./A, dimethyl disulfide plus chloropicrin (DMDS+pic) in a ratio 79:21 and applied at 60 gal./A. Sandea was applied at 0.75 oz/A preplant over the plastic and 3 weeks after transplanting. **Table 1** contains the application treatment dates for both sites A and B.

Nutsedge was counted at 7, 14, and 28 days after fumigation and 3 and 6 weeks after Sandea application.

RESULTS

Halosulfuron (Sandea) provided excellent control of nutsedge with less than 1 plant/square ft. at 6 WAT (**Table 2**). Yet differences between fallow treatments were observed. The Gly.-Cult.-Gly. and Cult.-Gly. fallow program provided greater control of nutsedge than the nontreated and cultivation alone fallow treatment. In plots not treated with Sandea, the fallow treatment Gly.-Cult.-Gly. had the lowest nutsedge emergence. In the non-Sandea plots, Gly.-Cult.-Gly. had the lowest nustsedge shoot emergence and was similar to the Gly.-Gly. fallow program. At the end of the experiment, total number of nutsedge tubers was lowest in the Gly.-Cult.-Gly treatment.

Table 2. Effect of fallow weed treatments and Sandea on nutsedge shoot emergence 6 weeks after transplanting and total number of tubers at the end of the experiment from plots not treated with Sandea.[z]

	Shoot emergence: No Sandea (shoots/ft.^{2})	Sandea (shoots/ft.^{2})	Total number[y] no. sample^{-1}
Nontreated	3.2 a[x]	0.9 a	26.8 a
Cult.	3.0 ab	0.9 a	26.9 a
Gly.	2.9 abc	0.6 b	24.7 ab
Cult. – Cult.	2.6 bc	0.5 b	21.1 ab
Gly. – Gly.	2.4 cd	0.6 b	19.9 bc
Cult. – Gly.	2.5 bc	0.3 bc	20.7 bc
Gly. – Cult.	2.7 abc	0.5 b	20.6 bc
Gly. – Cult. – Gly.	1.9 d	0.2	15.2 c

Cult.= cultivation; Gly.= glyphosate
[z]Data combined over fumigation treatment.
[y]Sample size was composed of five soil cores with 305 in^3.
[x]Treatment means within a column with the same letter designation are not significantly different using Fisher's Protected LSD test (P<0.05).

Table 3. Effect of fallow weed treatments and fumigants on nutsedge shoot emergence 6 weeks after transplanting.[z]

	Shoot emergence: No fumigant (shoots/ft.$^{-2}$)	1.3-D+ pic	DMDS+pic
Nontreated	3.1	3.9 a[y]	2.7 a
Cult.	2.8	3.4 ab	2.7 a
Gly.	3.2	3.4 ab	2.0 ab
Cult. – Cult.	2.9	3.4 ab	1.5 b
Gly. – Gly.	2.9	3.0 ab	1.3 bc
Cult. – Gly.	3.0	3.0 ab	1.5 b
Gly. – Cult.	2.8	3.7 a	1.5 bc
Gly. – Cult. – Gly.	2.8	2.3 b	0.7 c

Cult.= cultivation; Gly.= glyphosate; 1,3-D+pic = 1,3-dichloropropene plus chloropicrin; DMDS+pic = dimethyl disulfide plus chloropicrin.
[z]Data combined over fumigation treatment.
[y] Treatment means within a column with the same letter designation are not significantly different using Fisher's Protected LSD test (P<0.05).

Of the three fumigation treatments, DMDS+pic had the lowest nutsedge shoot emergence regardless of the fallow period program (**Table 3**). In the no fumigant plots, all the fallow period treatments had similar nutsedge emergence. The Gly.-Cult.-Gly. fallow program had the lowest

Table 4. Effect of fallow and fumigant treatments without halosulfuron application on total marketable yield at site A.

	Total marketable yield (lb./A.)		
	No fumigant	1,3-D +pic	DMDS +pic
Nontreated	33,547 ab[z]	25,695 abc	33279 b
Cult.	35,331 a	29,799 ab	33993 ab
Gly.	31,495 ab	22,840 bc	38811 ab
Cult. – Cult.	33,636 ab	24,803 abc	33904 ab
Gly. – Gly.	33,725 ab	26,141 abc	36669 ab
Cult. – Gly.	28,461 b	28,372 ab	35599 ab
Gly. – Cult.	33,457 ab	20,431 c	38275 ab
Gly. – Cult. – Gly.	33,993 ab	31,495 a	42379 a

Cult.= cultivation; Gly.= glyphosate; 1,3-D+pic = 1,3-dichloropropene plus chloropicrin; DMDS+pic = dimethyl disulfide plus chloropicrin.
[z]Treatment means within a column with the same letter designation are not significantly different using Fisher's Protected LSD test (P<0.05).

nutsedge population for both 1,3-D+pic and DMDS+pic. In sub-plots treated with DMDS+pic, Gly-.-Cult.-Gly. was similar to Gly.-Gly and Gly.-Cult.

Yields were greatest in plots sprayed with Sandea (data not shown). In plots not treated with Sandea, the greatest yield in the 1,3-D+pic and DMDS-pic received Gly-Cult.-Gly. during the fallow period and was similar to several other treatments (**Table 4**).

DISCUSSION

The most intense fallow program, Gly.-Cult.-Gly., provided the greatest control during the tomato production season. The no fallow treatment had the greatest nutsedge emergence and was similar to a single cultivation treatment. The Cult.-Gly. and Gly.-Cult. were lower than the Gly.-Cult.-Gly. program yet had lower number of nutsedge tubers at the end of the season and lower nutsedge emergence when combined with DMDS+pic. It is important to include a cultivation and glyphosate program in the field during the fallow period.

Response of Two Populations of Silverleaf Whitefly, *Bemisia Argentifoli* (Homoptera: Aleyrodidate) to Six Select Insecticides and Control of Tomato Yellow Leaf Curl Virus on Tomato

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The Silverleaf whitefly (SLW), *Bemisia argentifolii* Bellows & Perring, is an important pest of vegetable crops, especially in tropical and subtropical areas (Byrne et al. 1990, Gerling 1990, Perring et al. 1993). SLW has caused an economic loss of about $500 million just in California since 1991 (Perring et al. 1993). This insect transmits several viruses which cause serious diseases in various vegetable crops (Duffus & Flock 1982). These diseases plus honeydew secretion and the direct effects of feeding by SLW cause severe losses in yield and quality.

SLW inflicts heavy yield losses on tomato by vectoring Tomato Yellow Leaf Curl Virus (TYLCV). In 1997, TYLCV was first detected in south Florida (Polston et al., 1999). Since then TYLCV infections continue to be observed in many plantings of tomato. Plants infected at an early stage do not produce any marketable fruits.

Bean, *Phaseolus vulgaris* L., is another important crop for growers in south Florida who produced a record 1.7 million bushels of snap beans for the fresh market during the 1993-94 season. Harvested acreage has declined by 30% during the last 6 years. Bean Golden Mosaic Virus (BGMV), introduced into the Homestead area by hurricane "Andrew," is the principal limiting factor for growing beans in areas where SLW is present since it vectors this virus. At high levels of infection, BGMV causes a reduction of over 90% of marketable bean yield. Such catastrophic losses occur each year to late planted crops in Miami-Dade County.

Chemical insecticides are commonly used to manage SLW on tomatoes and beans. Amitraz was shown to be effective against all stages of SLW (Peregrine and Lemon 1986). The addition of Dyne-Amic (Helena Chemical Co.), a blend of organosilicone and methylated seed oil, increased efficacy of acetamiprid for SLW control (Chu et al. 1997). Elsworth et al. (1997), and Schuster and Polston (1999) found that Knack™ followed by Applaud™ and vice versa adequately controlled whiteflies.

In the present study, effectiveness of four conventional insecticides and two insect growth regulators (IGR) were evaluated against SLW in the laboratory. The primary objective was to compare the effectiveness of imidacloprid, thiamethoxam, acetamiprid, endosulfan, buprofezin and pyriproxyfen in managing SLW adults, eggs and crawlers acquiring TYLCV and BGMV. In addition, one field study was conducted using a new insecticide, Cyazypyr in a program with imidacloprid to manage SLW and its TYLCV transmission in tomatoes.

MATERIALS AND METHODS

A laboratory bioassay was conducted to determine the effectiveness of six commonly used insecticides against three life stages (adult, egg and crawler) of silverleaf whitefly (SLW) reared in two environmental conditions consisting of TYLCV infested tomato and BGMV infested bean. In a field study, cyazypyr, an anthranilic diamide insecticide, was included in a management program with imidacloprid to manage Silverleaf whitefly and TYLCV transmission.

Laboratory study. Studies were conducted using a leaf-dip bioassay to compare the effectiveness of four conventional insecticides and two insect growth regulators (IGR) in managing silverleaf whiteflies (**Table 1**).

Plantlet preparation. Sweet potato leaves, *Ipomoea batatas* (L.) Lam., with the petioles intact were collected from a greenhouse at the Tropical Research and Education Center, Homestead, Florida. Each leaf was then placed individually with its petiole immersed completely in tap water in a stik-

Table 1. Various insecticides and their rates used in the bioassay study.

Type	Common name	Range of rates (ppm)	Trade Name	Manufacturer	IRAC Code
Conventional	Imidacloprid	10.675 - 340	Admire® 2SC	Bayer Crop Protection	Group 4A
Conventional	Thiamethoxum	10.675 - 340	Platinum® 2SC	Syngenta Crop Protection	Group 4A
Conventional	Acetamiprid	3.125 – 100	Assail® 30SG	United Phosphorus, Inc.	Group 4A
Conventional	Endosulfan	5.760 – 168.5	Thiodan®	FMC Corp	2A
IGR	Buprofezin	3.125 = 100	Applaud® 70WP	AgrEvo	16
IGR	Pyriproxyfen	3.125 = 100	Knack® 11.23%	Valent USA	7C

(Note: endosulfan registration was voluntarily cancelled).

pic # 55-97 (SS Syndicate Sales Inc.). The leaves were then kept in a room at 25 ± 2˚C for 2 weeks to develop roots. These plantlets were used to conduct the bioassay.

Insect collection. Tomato Yellow Leaf Curl virus infected SLW adults were collected initially from an infected tomato field. These SLWs were then reared on TYLCV infected tomato plants in a greenhouse for three generations. Freshly emerged adults (0-24 h old) were collected for the study by placing infected tomato leaves with sufficient numbers of pupae into an insect cage.

Bean Golden Mosaic Virus infected SLW adults were initially collected from a bean field infested with BGMV. The rearing method and collection of SLW adults were as discussed in the previous paragraph. The adult whiteflies used in this experiment were fresh (0 – 24 h old).

Uninfected SLW adults were collected from a laboratory colony in the IPM laboratory at TREC. This colony had been maintained on cabbage and tomato for two years. Sufficient numbers of fresh adults (0-24 h old) were collected from the colony for use in the bioassay study.

Bioassay. Leaves (plantlets) prepared as discussed above were dipped in various concentrations of each insecticide and air-dried to remove excess moisture. Fifteen freshly collected adults were then placed on the adaxial surface of a treated leaf which was housed in a glass jar (20 x 20 20 cm) with adequate ventilation. This procedure was replicated five times for each concentration of a given insecticide. A total of 75 adults were used for each concentration. The treated leaves were checked at 24 h intervals for three days to record mortality of SLW adults. This method was used for TYLCV and BGMV infected and uninfected SLW adults.

The effect of insecticides on SLW eggs was studied by collecting large numbers of infested leaves with nymphs and pupae from a commercial tomato field. The insects were allowed to emerge in an insect cage in the laboratory. Twenty five SLW adults (0-24 h old) per group were placed on sweet potato leaves in a micro cage and allowed to lay eggs. Five leaves each containing 15 freshly laid eggs (0-24 h old) were used for each of the six concentrations of an insecticide. The leaves were dipped in the respective concentration of each insecticide and placed in the laboratory at 27˚±2.2˚C and a 12:12 h light-dark cycle for further study. The leaves were checked at 24-h intervals to record mortality of eggs. Mortality was confirmed by visually observing the color and shape of an egg. Nonviable eggs were recognized by their wrinkled outer surface and brown coloration.

The effects of insecticides on SLW crawlers were studied by collecting mature (8-12 h prior to hatching) eggs as discussed above and allowing them to develop into crawlers. The number of crawlers per leaf and methods of insecticide application were as described above in the egg study. Mortality of a crawler was confirmed by color, shape and attachment to the leaf. A dead or moribund crawler was loosely connected to the leaf and its body was desiccated.

All insecticides were mixed with Kinetic, a nonionic surfactant (Setre Chemical Co.) prior to dipping leaves used in the present study. All treated leaves were placed on a table in the laboratory at 27˚±2.2˚C and 12:12 h light-dark cycle for further study.

Field study. 'Solar Set' tomato seedlings were planted on 24 Nov. 2011 at TREC in Krome gravelly loam (loamy-skeletal, carbonatic hyperthermic lithic Udorthents), which consists of about 33% soil and 67% pebbles (>2mm). Experimental plots were randomly selected 30-ft-long segments of three adjacent raised beds 3 ft wide, 0.5 ft high, with 6 ft between bed centers. The beds were covered with 1.5-mil-thick black polyethylene mulch, fumigated 2 weeks prior to setting transplants with a mixture containing 67% methyl bromide and 33% chloropicrin at 220 lbs/acre. Seedlings were placed 18 inches apart within rows and drip irrigated and fertigated with 4-0-8. Plots were arranged in a randomized complete block design with four replications. A 5-ft-long nontreated planted area separated each replicate. Five treatments used in this study included (Treatments 1-3) imidacloprid (Admire® Pro 4.6SC at 10.50 oz/acre) followed by Cyazypyr (DPX-HGW86 10SE, DuPont) at 13.46, 16.82 and 20.50 oz/acre; (4) imidacloprid (Admire® Pro 4.6SC at 10.50 oz/acre) followed by dinotefuran (5.0 oz/acre, Venom®, Valent USA); (5) nontreated check. Admire® Pro was applied at plant as a soil drench using 100 gallons of water per acre. Cyazypyr and dinotefuran were sprayed on two dates (14 and 21 DAP) using a CO_2 backpack sprayer with two nozzles/row delivering 70 GPA. Treatments were evaluated on five dates by thoroughly checking a trifoliate on each of five randomly selected plants per treatment plot. In addition, 10 leaves, one leaf/plant, were collected and brought to the laboratory. These leaves were checked by using a microscope for SLW eggs and crawlers

Statistical analysis. Data from an entire replication in an insecticide efficacy study were discarded if percent mortality of adults and crawlers in the untreated control exceeded 15. Probit analyses were conducted on mortality responses of SLW adults and crawlers using POLO-PC (LeOra Software 1987). Failure of 95% CL to overlap was the criterion used to determine significant differences among the treatments.

Data collected from the field study were subjected to square root (x + 0.25) transformation. Transformed data were analyzed using SAS statistical package (SAS Institute 1990). The Duncan Muliple *K* ratio *t* test was used to separate treatment means where significant ($P < 0.05$) differences occurred (Waller & Duncan 1969).

RESULTS AND DISCUSSION

The susceptibility of TYLCV acquired SLW adults to various insecticides did not differ when LC_{50} values were considered (**Table 2**). The 95% CLs of these insecticides overlapped at the LC_{50} levels. At the LC_{90} level, the effectiveness of imidacloprid in controlling TYLCV infected SLW was significantly greater than endosulfan, but did not differ from acetamiprid and thiamethoxam.

Bean Golden Mosaic Virus infected SLW adults were found to be more susceptible to imidacloprid and acetamiprid than to endosulfan based on LC_{50} value (**Table 3**). This susceptibility of BGMV infected SLW adults did not differ from thiamethoxam. This was confirmed based on the failure of 95% CL to overlap at LC_{50} level for the insecticides tested. The LC_{50} for endosulfan was 5 and 2.7 times greater than those of imidacloprid and thiamethoxam. When LC_{90} was considered, BGMV acquired SLW adults did not differ in susceptibility to the insecticide treatments.

The LC_{50} values for nonviruliferous SLW adults did not differ among imidacloprid, thiamethoxam and acetamiprid (**Table 4**). The LC_{50} value was higher for endosulfan than any other insecticides. When LC_{90} was considered, nonviruliferous SLW adults were more susceptible to imidacloprid than thiamethoxam and endosulfan, but did not differ from acetamiprid.

Imidacloprid is a commonly used insecticide for controlling SLW in bean and tomato. Both BGMV and TYLCV acquired SLW adults were collected from commercial fields several weeks before the experiment where these populations had been repeatedly exposed to imidacloprid. This was reflected by the higher LC_{50} values of the viruliferous SLW adults (**Tables 2 & 3**) collected from the field than of the nonviruliferous control SLW adults (**Table 3**) collected from the laboratory. This increase in the LC_{50} values might indicate an initial state of development of resistance of SLW to imidacloprid. LC_{50} value for thiamethoxam was higher in BGMV acquired SLW adults than TYLCV and Control SLWs. This difference in the susceptibility between BGMV and TYLCV acquired SLWs for thiamethoxam is not clear. LC_{50} values for acetamiprid in BGMV and TYLCV acquired SLWs were higher than the control SLW. Susceptibility of TYLCV acquired and nonviruliferous SLW populations to endosulfan was similar and was comparatively less than BGMV acquired SLWs. An increase in the LC_{90} values in the instance of each insecticide, irrespective of population source, indicates that a widely variable gene pool prevailed in the three populations of SLW which might have attributed to the difference in susceptibility of SLW populations to various insecticides.

Pyriproxyfen inflicted almost 100% mortality of SLW eggs in all experimental rates (**Table 5**). The other insecticides did not stop embryonic development, where eggs hatched, but the resulting crawlers could not develop into the next stage except for buprofezin and endosulfan. The percentages mortality of eggs due to buprofezin and endosulfan ranged from 9-14 and 2-8, respectively.

Insecticide treatments performed poorly in causing significant mortality of SLW eggs (**Table 5**). Percentages mortality of crawlers were 92-98 when treated with imidacloprid, thiamethoxam and pyriproxyfen irrespective of concentration (**Table 5**). Among other insecticides, crawlers were more susceptible to acitamiprid and buprofezin than endosulfan (**Table 5**). Percentages mortality of crawlers were concentration dependent when treated with acetamiprid and buprofezin. Burprofezin and pyriproxyfen did not kill adults. On the other hand, percentages adult mortality caused by imidacloprid, thiamethoxam, acetamiprid and endosulfan were concentration dependent.

Field study. Cyazypyr at 13.46 and 16.82 oz/acre reduced Silverleaf whitefly inconsistently on different sampling dates (**Fig. 1**). The high rate of Cyazypyr (20.5 oz/acre) significantly reduced SLW when compared with the nontreated control ($F = 9.25$; $df = 4{,}74$; $P = 0.05$). This reduction in the number of SLW was consistent across the sampling dates. Dinotefuran significantly reduced SLW adults for the first 10 days after planting when compared with the nontreated control. After 10 days, mean numbers of SLW adults on dinotefuran treated tomato plants did not differ from nontreated control.

All insecticide treatments significantly reduced the number of TYLCV infected plants when compared with the nontreated control ($F = 7.01$; $df = 4{,}74$; $P = 0.05$) (**Fig. 2**). Cyazypyr provided highest reduction of TYLCV infected plants followed by dinotefuran and other Cyazypyr treatments.

In summary, acquiring TYLCV and BGMV did not change the response of SLW adults to neonicotinoid insecticides at LC_{50} and LC_{90} levels in the present study. Endosulfan effectiveness varied with the variation of populations. Susceptibility of TYLCV and BGMV infected adults did not differ from the laboratory reared fresh uninfected adults. Pyriproxyfen caused 100% mortality of eggs at all concentrations (3.13 – 100 ppm). The other insecticides did not cause substantial egg mortality (2 – 14%). Imidacloprid and thiamethoxam provided 92 – 98% crawler mortality at all concentrations. On the other hand, percentages of crawler mortality caused by acetamiprid were concentration dependent. In managing SLW and its virus transmission in tomato and bean, it is suggested to use neonicotinoid at planting followed by IGR. Other effective

Table 2. Dose – mortality response of TYLCV infected *Bemisia argentifolii* adults to various insecticides in a laboratory bioassay.

Insecticides	Slope ± SE	LC_{50} (CL 95%)	LC_{90} (CL 95%)
Imidacloprid	1.38 ± 0.18	11.25 (6.95-15.65)a[1]	94.93 (69.99 – 146.16)a
Thiamethoxam	1.06 ± 0.15	12.96 (7.02 – 19.42)a	207.77 (134.96 – 406.25)ab
Acetamiprid	1.15 ± 0.14	15.06 (10.81 – 20.19)a	196.31 (117.60 – 433.27)ab
Endosulfan	1.54 ± 0.15	33.60(13.99 – 68.08)a	433.70 (162.73 – 7509.02)b
Buprofezin[2]	-	-	-
Pyriproxyfen[2]	-	-	-

[1]LC50 and LC90 values within a column having same letter with overlapping confidence intervals at 95% level do not differ significantly (POLO-PC, LeOra Software. 1987).
[2]Adult mortality ranged from 2 – 8%.

Table 3. Dose – mortality response of BGMV infected *Bemisia argentifolii* adults to various insecticides in a laboratory bioassay.

Insecticides	Slope ± SE	LC_{50} (CL 95%)	LC_{90} (CL 95%)
Imidacloprid	1.17 ± 0.12	10.50 (3.52 – 18.26)a[1]	130.99 (77.88 – 352.45)a
Thiamethoxam	1.13 ± 0.14	20.04 (9.09 – 1231.27)ab	267.62 (151.42 – 763.54)a
Acetamiprid	0.93± 0.13	12.89 (8.96 – 17.67)a	310.22 (158.70 – 945.88)a
Endosulfan	1.24 ± 0.18	54.52 (29.83 – 92.99)b	589.03 (264.18 – 3711.49)a
Buprofezin[2]	-	-	-
Pyriproxyfen[2]	-	-	-

[1]LC_{50} and LC_{90} values within a column having same letter with overlapping confidence intervals at 95% level do not differ significantly (POLO-PC, LeOra Software. 1987).
[2]Adult mortality ranged from 2 – 8%.

Table 4. Dose – mortality response of BGMV infected *Bemisia argentifolii* adults to various insecticides in a laboratory bioassay.

Insecticides	Slope ± SE	LC_{50} (CL 95%)	LC_{90} (CL 95%)
Imidacloprid	1.42 ± 0.19	8.94 (5.24 – 12.70)a[1]	71.50 (53.64 – 106.82)a
Thiamethoxam	1.21 ± 0.19	14.24 (8.68 – 20.09)ab	161.94 (112.19 – 278.14)a
Acetamiprid	1.22± 0.15	11.55 (8.13 – 15.43)a	130.60 (83.39 – 256.54)ab
Endosulfan	1.31 ± 0.15	35.29 (26.43 – 46.27)b	333.89 (210.86 – 666.32)b
Buprofezin[2]	-	-	-
Pyriproxyfen[2]	-	-	-

[1]LC_{50} and LC_{90} values within a column having same letter with overlapping confidence intervals at 95% level do not differ significantly (POLO-PC, LeOra Software. 1987).
[2]Adult mortality ranged from 2 – 8%.

Table 5. Effectiveness of various insecticides on the percentages mortality of *Bemisia argentifolii* eggs and crawlers.

Insecticides	Rate (PPM) (ppm)	Egg	Crawler	Adult
		------------------(%)--------------		
Imidacloprid	10.675 - 340	2 – 8b[1]	93 -98a	75 – 100a
Thiamethoxam	10.675 - 340	2 – 6b	92 – 98a	47 – 81a
Acetamiprid	3.125 - 100	2 – 5b	47 – 100ab	33 – 76a
Endosulfan	5.760 – 168.5	2 – 8b	25 – 35b	41 – 48ab
Buprofezin[2]	3.125 - 100	9 – 14b	55 – 92a	1 – 4b
Pyriproxyfen[2]	3.125 - 100	99-98a	93 – 98a	0 – 1b

[1]Means within a column followed by a same letter do not differ significantly (P > 0.05; Waller and Duncan).
[2]Adult mortality ranged from 2 – 8%.

insecticides, not mentioned here, should be used as a foliar application after use of neonicotinoids at planting.

REFERENCES CITED

Byrne, D.N., T.S. Bellows, Jr. and M.P. Parella. 1990. Whiteflies in agricultural systems, pp. 227-261. In D. Gerling [ed.], Whiteflies: Their Bionomics, Pest Status and Management. Intercept, Andover, Hants, UK.

Chu, C.C., M.A. Boykin, C.G. Jackson and T.J. Henneberry. 1997. Dyne-Amic increased the efficacy of EXP 80667A against Silverleaf whiteflies on cotton Silverleaf Whitefly: 1997 Supplement to the 5-year National Research and Action Plan. P. 45.

Duffus, J.E. and R.A. Flock. 1982. Whitefly transmitted disease complex of the desert southwest. Calif. Agric. 36:4-6.

Ellsworth, P.C., I.W. Kirk, J.W. Diehl, D.L. Meade, C. Harris, H. Tom, T.J. Henneberry and J.R. Coppedge. 1997. Large scale evaluation of insect growth regulators for whitefly control. Silverleaf Whitefly: 1997 Supplement to the 5-year National Research and Action Plan. P. 46.

Gerling, D. 1990. Whiteflies: Their Bionomics, Pest Status and Management. Intercept, Andover, UK 348pp.

LeOra Software. 1987. POLO-PC. A user's guide to probit or logit analsis. LeOra Software, Berkeley, CA.

Peregrine, D.J. and R.W. Lemon. 1986. The value of Amitraz for control of Bemisia tabaci on cotton. Agric. Econ. Environ. 17: 129-136.

Perring, T.M., C.A. Farrar, T.S. Bellows, A.D. Cooper and R.J. Rodriguez. 1993. Evidence for a new species of whitefly: UCR findings and implications. California Agriculture 47(1):7-8.

Polston, J.E., R.J. McGovern and L.G. Brown. 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.

SAS Institute. 1990. SAS language and procedures, version 6.1 st edition.

Schuster, D. and J. Polston. 1999. Whitefly management guide: Tomato yellow leaf curl virus. Citrus and vegetable, July, A6 – A7.

Waller, R. A., and D. B. Duncan. 1969. A Bayes rule for the symmetric multiple comparisons problems. J. Am. Stat. Assoc. 64: 1484-503.

Figure 1. Control of silverleaf whitefly in tomato applying imidacloprid (soil drench) and three rates of cyazypyr (foliar) in a program, TREC, 2012. Dinotefuran (Venom, 5.0 oz/acre) was sprayed as a local standard.

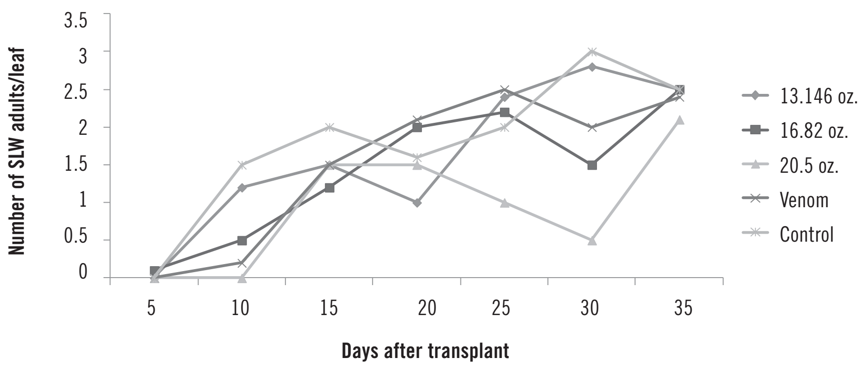
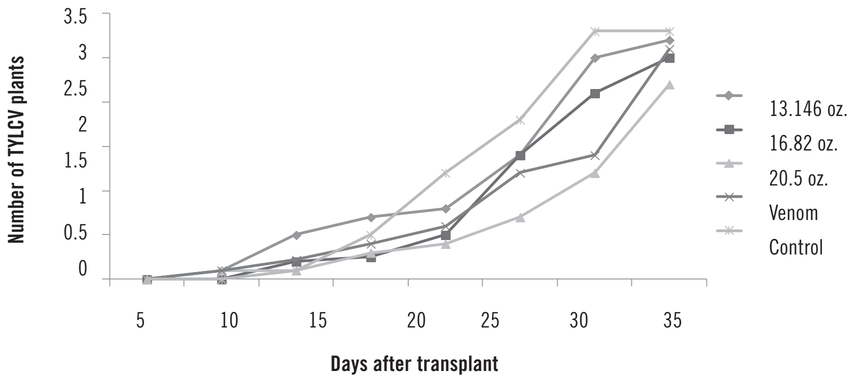


Figure 2. Control of TYLCV applying imidacioprid (soil drench) and three rates of cyazypyr (foliar) in a program, TREC, 2012. Dinotefuran (Venom, 5.0 oz/acre) was sprayed as a local standard.



The Continuing Challenge of Late Blight on Tomato

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The oomycete *Phytophthora infestans*, the causal agent of late blight on tomato and potato is the pathogen causing one of the most famous and enduring plant diseases. In the mid-1840s, late blight was responsible for the destruction of potato crops in Ireland resulting in the Potato Famine. More recently, in 2009 a widespread epidemic that also impacted tomato and potato growers from Florida to Canada caused huge losses of tomatoes in home gardens and organic farms. Losses were exacerbated by ideal weather conditions that continued during the summer along the northeastern states. This past season, Florida growers were challenged by persistence of late blight on tomato throughout the spring despite intensive control efforts. From 1993 to 2002, a continuous shifting in the population has occurred. US genotypes during this period were characterized as US-1, US-6, US-7, US-8, US-10, US-11 and US 17 in Florida (Weingartner and Tombolato, 2002). Since 2005, the detection and characterization of additional genotypes revealed novel genotypes of US-20, US-21, US-22, US-23, and US-24 in Florida and throughout the US (**Table 1**) (Schultz et al, 2010; Hu et al, 2012).

Environmental conditions in south Florida are generally favorable for late blight development with moderate temperatures and adequate nighttime durations of leaf wetness during the production season. Although potato seed pieces can be a source of inoculum for potato, the primary inoculum source infecting tomato remains elusive. Sporangia of *P. infestans* are readily airborne and dispersed by wind and rain. To date, there is no strong evidence for an endemic, sexually reproducing population although both mating types have occurred over time in Florida (Deahl et al., 1991; Weingartner and Tombolto, 2002; Tombolato, 2002).

Late blight management recommendations are similar for tomato and potato. However, one important difference is that late blight tolerant potato cultivars are available while commercial resistance in Florida adapted tomato cultivars is not. The pathogen is not considered seed-borne on tomato, but transplants may be infected while in the transplant house and carried to the field. Sources for potato seed piece should be disease-free to reduce the likelihood of contamination. Other practices that help manage the disease include cultural practices to remove sources of inoculum, such as destroying cull piles and destroying volunteer potato or tomato plants. Early detection through scouting fields for symptoms of late blight is critical to initiating a timely, effective fungicide spray program. Additionally, growers are usually advised to begin fungicide applications when weather conditions (cool temperatures and extended leaf moisture periods) are conducive to disease development.

Recently, new fungicides with different modes of action have become registered, increasing the number of products available for conventional growers. Fungicide spray trials evaluating many of the new products for control of late blight on tomato have been conducted at SWFREC. A partial list of products labeled for late blight on tomato is presented.

In 2011, USDA awarded a grant to fund researchers across the US, including University of Florida research and extension faculty, to 'research methods to better manage late blight disease in tomatoes and potatoes'. A national late blight reporting and alert system with an integrated decision support system to help growers make sound, science-based decisions via the Internet has been introduced. The website http://usablight.org/ and Blightcast should prove useful to Florida Tomato Growers.

Table 1. Date and host of first detection of *Phytophthora infestans* since 1998 in Florida

Florida Growing Season (Aug-May)	Date of first recorded detection*	First Host Reported
1998-99	Dec 22, 1998	Potato
1999-00	Jan 29, 2000	Potato
2000-01	Feb 9, 2001	Potato
2001-02	Feb 15, 2002	Tomato
2002-03	None	None
2003-04	Jan 23, 2004	Potato
2004-05	Jan 7, 2005	Potato
2005-06	Jan 10, 2006	Tomato
2006-07	Nov 17, 2006	Tomato
2006-07	Nov 20, 2006	Potato
2007-08	Feb 7, 2008	Tomato
2008-09	Dec 9, 2008	Tomato
2009-10	Dec 23, 2009	Tomato
2010-11	Apr 7, 2011	Tomato**
2011-12	Dec 14, 2011	Tomato**

*Source: Florida Extension Plant Disease Diagnostic Clinic, Immokalee, FL and South Florida Vegetable Pest and Disease Hotline.
**First detection by Glades Crop Care scouts

SELECTED REFERENCES

Deahl, K.L., Goth, R.W., Young., R., Sinden, S.L., and Gallegley, M.E. 1991. Occurrence of the A2 mating type of Phytophthora infestans in the United States and Canada. Am. Potato J. 68:717-725.

Hu, C.H., Perez, F., Donahoo, R., McLeod, A., Myers, K., Ivors, K., Secor, G., Roberts, P. Deahl, K., Fry, W.E., and Ristaino, J.B. 2012. Recent genotypes of Phytophthora infestans in eastern USA reveal clonal populations and reappearance of mefenoxam sensitivity. Plant Dis. (Accepted) In press.

Schultz, D., Donahoo, R.S., Perez, F.G.M, Tejeda, S., Roberts, P.D., and Deahl, K.L. 2010. A survey of tomato and potato field in Florida reveals unique genotypes of Phytophthora infestans between 2005 and 2007. HortScience 45:1064-1068.

Tombolato, D. 2002. Characterization of isolates of Phytophthora infestans collected in Florida in 199 and 2001. PhD dissertation. University of Florida. 113 pages.

Weingartner, P. and Tombololato, D. 2002. Perspectives on a decade of late blight in Florida tomatoes (and potatoes). in 2002 Florida Tomato Institute Proceedings. Eds. P. Gilreath and C.S. Vavrina, University of Florida. PRO 519:42-50.

Groundnut Ringspot Virus and *Tomato Spotted Wilt Virus* – Tospoviruses in Florida

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INTRODUCTION

In late 2009 and early 2010, *Groundnut ringspot virus* (GRSV) emerged in solanaceous vegetables in the Homestead area of Miami-Dade County in South Florida, extending the known distribution of this tospovirus beyond South America and South Africa. GRSV can infect tomato and other solanaceous vegetable crops at all stages of plant growth, and can lead to non-marketable fruits or plant death. *Groundnut ringspot virus* is a relative of *Tomato spotted wilt virus* (TSWV), the original member of the tospovirus group of plant viruses. Tomato spotted wilt virus remains a serious economic limitation to the production of tomatoes, peppers and peanuts in the southeastern U.S. more than 20 years after its appearance. Although TSWV is well-known to Florida tomato producers, scouts, extension personnel and scientists, GRSV had been relatively unknown until it first appeared in the U.S. in 2009-2010.

TOSPOVIRUSES IN FLORIDA TOMATOES

Tospoviruses cause characteristic symptoms in tomato and other crops, although initial symptoms are often difficult to visually diagnose. Specific molecular tests are required to discriminate between GRSV and TSWV. Inward rolling of leaves, bronze casts to leaves, and dark brown spots or flecks on leaves are common symptoms caused by both GRSV and TSWV in tomato plants infected at an early age. Tomato fruits are often deformed with raised rings, ring patterns or bumps on the surface, and may ripen unevenly on plants infected with GRSV or TSWV at later growth stages. To date, GRSV appears to uniquely cause brown streaks on the epidermis (skin) of stems and petioles, and wilting (or death) of the growing points (top portion) of tomato plants.

Groundnut ringspot virus has a relatively narrow known host range. Beyond tomato, GRSV has been detected in pepper, eggplant, tomatillo and several solanaceous weeds in Florida. Symptoms in hosts other than tomato are virtually indistinguishable from those caused by TSWV. Experimental host range testing and field surveys are ongoing to define a more complete host range for GRSV in Florida.

Tospoviruses are transmitted by several species of thrips. Western flower thrips (*Frankliniella occidentalis*) is well-described for TSWV transmission and has been recently shown to transmit GRSV in Florida. Other locally important thrips species are currently being tested to determine their ability to acquire and transmit GRSV.

To date, GRSV has been detected in commercial tomato and/or pepper fields in Charlotte, Collier, Hendry, Lee, Manatee, Martin, Miami-Dade, Palm Beach and St. Lucie Counties. Broader geographic surveys for GRSV are ongoing.

WORKING TOWARD A SOLUTION

Our multidisciplinary and multi-institutional team is addressing the most pressing practical issues resulting from the detection of GRSV in Florida. Strong grower and industry support has bolstered these efforts to develop effective GRSV management strategies.

Management of GRSV, TSWV and the thrips vectors is difficult. Once a plant becomes infected with either virus, it cannot be cured. Roguing should be used to prevent further spread of GRSV or TSWV to adjacent plants. This is particularly important in transplant production, and also with GRSV in field production,where incidence generally remains low (less than 2%). Management of western flower thrips and other potential thrips species (yet to be identified) capable of transmitting GRSV in Florida is important to reduce virus spread. Since GRSV and TSWV are closely related, it is likely that the integrated TSWV management strategies developed and currently used in North Florida can be adapted for effective GRSV management elsewhere in the state. The usefulness of TSWV-resistant tomato cultivars for GRSV management is being evaluated as part of these strategies because initial tests indicate that some commercial TSWV resistance is effective against both viruses.

Ongoing surveys for GRSV and thrips vectors in Florida and beyond are benefiting from the development and current testing of a smartphone-based system to collect and upload GPS-labeled scouting data (virus, thrips and production information) to a central server where it can be processed and analyzed. This all-inclusive scouting smartphone application was introduced at last year's Florida Tomato Institute. When fully implemented, this system will deliver real-time reports and management recommendations to growers and/or their scouts making possible"area-wide" management of diseases and pests, including GRSV.

CONCLUSION

A growing number of solanaceous crop and weed species infected with GRSV has been identified in Florida. Continuing geographic spread of GRSV into additional vegetable production areas of Florida has also been documented. Much has been learned about GRSV in Florida although many questions remain.

FOR FURTHER INFORMATION

McAvoy, E., Adkins, S., Webster, C., Mellinger, C., Horsman, L., Frantz, G., Reitz, S., and Zhang, S. 2011. Groundnut Ringspot Virus in Florida. University of Florida, Extension Digital Information Source PP282.

Webster, C.G., Turechek, W.W., Mellinger, H.C., Frantz, G., Roe, N., Yonce, H., Vallad, G.E., and Adkins. S. 2011.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.

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.

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A New Virus for Florida Tomatoes

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The tospovirus, *Tomato chlorotic spot virus* (TCSV) was found for the first time this past spring in field tomato plants in Miami-Dade and Hendry Counties. This identification was based on the necrotic symptoms, ELISA, reverse-transcription PCR with 6 different pairs of primers and sequence comparisons of the PCR products with sequences of known viruses. *Tomato chlorotic spot virus* causes necrosis in tomato leaves and stems, and causes ringspots and other deformations of the fruit. This virus was found in necrotic plants which later died this past spring in Homestead. *Tomato chlorotic spot virus* is similar but distinct from other tospoviruses, such as *Tomato spotted wilt virus* (TSWV) and *Groundnut ringspot virus* (GRSV), viruses with which some Florida tomato growers may be familiar. Following is a brief summary of TCSV and tospoviruses, for growers who may encounter these viruses in their fields.

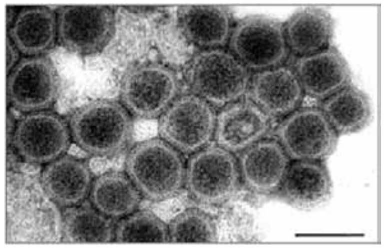
TOSPOVIRUSES

Tospoviruses are one of the important groups of emerging plant viruses. There are only eight recognized species of tospoviruses, although an additional 15 species await more information before they can be approved as new species (**Table 1**). Some of them are found in many locations throughout the world; such as TSWV and INSV (*Impatiens necrotic spot virus*) while others have a more narrow distribution. Some of these viruses have very extensive host ranges, such as TSWV with over 800 known hosts. Others have more limited host ranges, which may be due to the virus or maybe due to a lack of research on their host ranges. Tospoviruses can be challenging to study and to manage; they are not typical plant viruses in many ways.

Unusual Virus and Genome Structure: Tospoviruses have an RNA genome that is divided into three separate segments. They do not have a coat protein or particle shape like most other plant viruses. Each of their RNA segments is protected by a layer of N protein and enclosed in a membrane. So their shape is irregular and flexible (pleomorphic) (**Figure 1**) and not as stable as many viruses. It has been shown recently that tospoviruses can exchange their genome segments, thus creating new isolates. This is one way that tospoviruses can ensure diversity and improve their chances of adapting to new situations.

Unusual Transmission: Tospoviruses are transmitted by a range of thrips species in a persistent and propagative manner. This means that they replicate in cells of their thrips vectors as well as in cells of their plant hosts. They are acquired by the immature thrips as it feeds on an infected plant host.

Figure 1. Electron micrograph[1] of *Tomato spotted wilt virus* showing the variable shape of the virus particles.



[1]From: King et al (2012)

The thrips then pupates (often in the soil), and when it emerges as an adult it is then capable of transmission as well as flight to healthy plants.

They can be transmitted mechanically under experimental conditions using a specific buffer and carborundum. However, they are not likely to be transmitted mechanically in the field. The virus is not very stable so samples must be stored at – 80^{o}C to retain infectivity.

Tospoviruses are not seed transmitted but can be moved long distances in infected vegetative plant parts and transplants.

Unusual Symptoms: Unlike many plant viruses, tospoviruses can cause necrosis and even death of their host plants. These necrotic symptoms can look more like those caused by bacteria and fungi rather than a virus. Symptoms of different tospoviruses often look similar in the same hosts. Typical symptoms can be necrotic lesions and ringspots on leaves, stems, petioles, flowers, and fruit. Necrotic lesions can be small or large. Symptoms of chlorotic spots and ringspots can be produced as well as wilting and bronzing. Sometimes plants can die as a result of infection. Infected plants and fruits are often unmarketable due to these severe types of symptoms. For this reason tospoviruses can cause tremendous economic losses.

TOSPOVIRUSES IN THE U.S. AND FLORIDA

There are now five tospoviruses reported in the U.S.: TCSV, TSWV, GRSV, INSV, and *Iris yellow spot virus* (IYSV) (Webster et al. 2010, Pappu et al. 2009). All of them except for IYSV have been reported from Florida. None of these viruses are native to North America and all were probably introduced at various times (Pappu et al. 2009). Recently, an isolate of GRSV (GRSV-LG-MTSG) was reported from Florida that has 2/3 of its genome from GRSV and 1/3 from TCSV (Webster et al. 2011). It is likely that both TCSV and GRSV were introduced within the last few years into Florida.

Three of the four tospoviruses reported from Florida have been found infecting tomatoes in the field: TCSV, TSWV, and GRSV. There are many isolates of TSWV

Table 1. Approved and proposed species of tospoviruses[1].

Approved Species	Distribution	Proposed Species
Tomato spotted wilt virus	Worldwide	Alstromeria necrotic streak virus
Tomato chlorotic spot virus	South America	Calla lily chlorotic spot virus
Groundnut ringspot virus	North and South America, Africa,	Capsicum chlorosis virus
Impatiens necrotic spot virus	Worldwide	Chrysanthemum stem necrosis virus
Groundnut bud necrosis virus	Asia	Groundnut chlorotic fan-spot virus
Groundnut yellow spot virus	Asia	Iris yellow spot virus
Watermelon silver mottle virus	Asia	Melon severe mosaic virus
Zucchini lethal chlorosis virus	South America	Melon yellow spot virus
		Physalis severe mottle virus
		Polygonum ringspot virus
		Tomato necrosis virus
		Tomato necrotic ringspot virus
		Tomato yellow ring virus
		Tomato zonate spot virus
		Watermelon bud necrosis virus

[1]Data obtained from King et al (2012) and Pappu et al (2009)

Table 2. Known vectors of *Tomato chlorotic spot virus*[1].

Efficiency of Transmission	Genus and species	Common name	Presence in Florida
Good (11-40%)	*Frankliniella occidentalis*	Western flower thrips	Yes
	Frankliniella schultzei (dark form)	Common blossom thrips	Yes
Poor (<10%)	*Frankliniella intonsa*	European flower thrips	Not reported
	Frankliniella schultzei (light form)	Common blossom thrips	Not reported
None (0%)	*Thrips tabaci*	Tobacco thrips	Yes

[1]Data obtained from Wijkamp et al (1995)

Table 3. Known host range of Tomato chlorotic spot virus[1].

Family	Genus and Species	Common Name	Symptoms
Asteraceae	*Lactuca sativa*	Lettuce	Dwarfing, mosaic, chlorotic and necrotic ringspots
	Cichorium endivia	Escarole	Mosaic, chlorotic and necrotic ringspots
	Emilia sonchifloria	lilac tasselflower	Mosaic
Balsaminaceae	*Impatiens sp.*	Impatiens	Yellowing and vein clearing
Fabaceae	*Arachis hypogeae*	Peanut	Mosaic
	Phaseolus vulgaris	common bean	Vein clearing
	Pisum sativum	Pea	Mosaic, bronzing, wilting
	Vigna unguiculata	Cowpea	Mosaic, leaf distortion
Gentianaceae	*Eustoma russellianum*	Lisianthus	Ringspots, necrosis, leaf deformation, dwarfing
Solanaceae	*Capsicum annuum*	Pepper	Mottling, leaf distortion, dwarfing, apical necrosis, callousing on the stem
	Datura stramonium	Datura	Mottling, leaf distortion, dwarfing, apical necrosis, plant death
	Nicotiana tabacum	Tobacco	Vein clearing, mosaic, leaf distortion
	Solanum lycopersicum	Tomato	Mottling, bronzing, necrotic spots, necrosis on stems and petioles
	Physalis floridana	husk tomato	Mottling, veinal necrosis

[1]Data collected from Dal Bo et al (1999), de Avila et al (1993), Colariccio et al (2001a), Colariccio et al (2001b), and Londoño et al (Submitted).

known which can vary in their symptoms from a light bronzing to a necrosis of stems and leaves and wilting of the plant. Less is known of the variation in symptoms caused by either TCSV or GRSV. Both of these viruses are associated with necrotic spots, necrosis of leaves and stems, and necrosis and deformation of fruit.

TOMATO CHLOROTIC SPOT VIRUS

TCSV was first described from Brazil as a variant of Tomato spotted wilt virus but was later determined to be a unique virus. Relatively few studies have been conducted on TCSV compared to other tospoviruses. We do know from studies in Brazil, that TCSV can be transmitted by a number of species of thrips and that some thrips are more efficient vectors than others (**Table 2**). Like other tospoviruses, TCSV replicates in its vector as well as in the plant. While we know the vector status of many thrips species with regard to transmission of TSWV, only five thrips species have not been tested for their ability to transmit TCSV.

The host range of TCSV has also not been studied very extensively. What is known is presented in **Table 3**. The virus has been found to cause diseases in the field in lettuce, escarole and tomato. The other hosts are a result of artificial inoculations in greenhouse studies but demonstrate the ability of the plant to be a host. No plants have been reported to be immune. This is most likely the result of limited host range studies on this virus.

DETECTION OF TCSV AND OTHER TOSPOVIRUSES

While symptoms of tospoviruses are different from other viruses, they are not that different from each other so cannot be used as a means of identification. Symptoms, especially the necroses, often resemble those caused by fungi and bacteria so they can be misdiagnosed very easily. The fastest means to identify tospoviruses is through the use of rapid assays such as “dipsticks” or “immunostrips”. These are available for some tospoviruses. An ELISA is available for TCSV and GRSV. The assay can distinguish these viruses from TSWV and INSV as well, but cannot distinguish between TCSV and GRSV. Reverse-transcription PCR is a method that can rapidly detect and distinguish individual tospoviruses from other viruses as well as from each other. Currently we only have a few primer pairs that are specific to a single tospovirus so we rely on broader spectrum primer pairs and sequence the RT-PCR products to be sure of our identification.

MANAGEMENT OF TOSPOVIRUSES IN TOMATO

Without knowing the specifics of which thrips are the vector (there are more than 140 thrips species in Florida) and the identity of alternative hosts it is not possible to make specific recommendations for the management of TCSV or GRSV. There are some strategies developed for TSWV in tomato which are likely to be helpful in the management of other tospoviruses in tomato. The use of virus-free transplants, insecticides, SAR elicitors such as Actigard, and UV-reflective mulch will likely be effective for TCSV and GRSV. More detailed information on the management of TSWV and tospoviruses can be found at: http://nfrec.ifas.ufl.edu/programs/tomato_spotted_wilt_management.shtml and http://edis.ifas.ufl.edu/pp134 .

REFERENCES

Colariccio A, Chaves ALR, Eiras M and Chagas CM (2001a) Identification of the tomato chlorotic spot virus in endive (Cichoriumendiva L.). Summa Phytopathologica 27: 325–327.

Colariccio A, Eiras M, Alexandre LR, Chaves RH and Chagas CM (2001b) Characterization of Tomato chlorotic spot virus from hydroponic grown lettuce in Brazil. In: Marullo R and Mound L, (eds) Thrips and Tospoviruses: Proceedings of the 7th International Symposium on Thysanoptera,Reggio Calabria, Italy, 1–8 July 2001. ANIC, Reggio, Calabria, Italy 99–104.

DalBó E, Chiarrone G, Rolleri J, Ronco L. (1999) Tospovirus en los cultivos ornamentales de La Plata. Revista de la Facultad de Agronomía (La Plata) 104 (1): 35-40.

deAvila AC, de Haan P, Kormelink R, ResendeRde O, Goldbach RW, Peters D (1993) Classification of tospovirusesbasedonphylogeny of nucleoprotein gene sequences. J Gen Virol 74:153-159.

King AMQ, Adams MJ, Carstens EB, Lefkowitz EJ (2012) Ninth Report of the International Committee on Taxonomy of Viruses. Elsevier, San Diego, CA.

Londono, A, Capobianco H, Zhang S, Polston JE. 20-- First record of Tomato chlorotic spot virus in the U.S. (Submitted).

Pappu HR, Jones RAC, Jain RK (2009) Global status of tospovirus epidemics in diverse cropping systems: Successes achieved and challenges ahead. Virus Res 141:219–236.

Webster CG, Perry K, Lu X, Horsman L, Frantz G, Mellinger C, Adkins ST (2010) First report of Groundnut ring spot virus infecting tomato in south Florida. Plant Health Progress.doi:10.1094/PHP-2010-0707-01-BR.

Webster CG, Reitz SR, Perry KL, Adkins S (2011) 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.

Wijkamp, I, Almarza, N, Goldbach, R, Peters, D. (1995) Distinct leves of specificity in thrips transmission of tospoviruses. Phytopathology 85: 1069-1074.

Sustainability of Methyl Bromide Alternative Fumigants and New Labels from Phase II Reregistration of these Soil Fumigants

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At some point in the near future we will stop talking and thinking about methyl bromide. It is not as if we didn’t have sufficient opportunity and a long enough time to prepare the user community for its ultimate phase-out. The detection of methyl bromide in the atmosphere in late 1992, the cause of its ultimate cancellation, will for all intents and purposes, causes elimination of methyl bromide from even limited soil fumigation uses within the next year, possibly two. Currently the approved CUE levels for new production and consumption for 2012 are projected at 3.0% of the 1991 baseline level, a level sufficient to treat about 500 acres. Next year, (2013), methyl bromide will not even be available for use in Florida strawberry, and quantities for tomato may only be sufficient to treat as few as 250 acres. For the past 19 years we have discussed this phase-out process, critical use exemptions, and reported the results of ongoing alternatives research in Florida. This year being no different, we would like to discuss performance and sustainability of repeated use of these alternative fumigants in long-term studies, and conclude with a discussion of their changing regulatory status and grower compliance with new label requirements.

Methyl bromide is an effective pre-plant soil fumigant used to control a variety of soilborne pests and pathogens in a variety of Florida fruit and vegetable crops. Because methyl bromide has provided such a consistent and reliable return on investment as a pest management input, the use of soil fumigation has become a more or less standardized production practice in Florida agriculture. We have had many different soil fumigants come and go, and continue to recognize and declare the need for other, more sustainable approaches. We continue to study new sustainable approaches but none have risen to the benchmark cost and production requirement needed to replace dependence on soil fumigants. These alternative control measures are usually defined or based on other chemicals, host plant genetic resistance, and cultural practices that require a greater knowledge of pest biology, cultural practice,and environmental interactions to achieve satisfactory results. Today, we still want to talk about sustainability, but more specifically to provide a preliminary assessment of the sustainability of methyl bromide alternative fumigants in an era after methyl bromide.

A considerable portion of the current field research being conducted in Florida by the University of Florida and by USDA ARS scientists has focused on short-term evaluations of a variety of cocktailed fumigants. Chloropicrin, the foundation of any alternative fumigant system, is co-applied with a variety of other fumigants such as 1,3-D (Telone), DMDS (Paladin), metam sodium (Vapam), or metam potassium (KPam). For the most part, these experiments have not been designed to look at the long term, repeated use of the strategy on the same crop, and on the same land year after year. From a grower standpoint, a long-term experiment is necessary with a research objective to evaluate the practical and economic sustainability of the alternative fumigant system after repeated use in a grower field. Not many research projects have been fortunate enough to have had research dollars to study crop yields and pest control efficacy in the same crops and on the same lands over a 3- to 4-year period. Beginning in 1998 Dr. Jim Gilreath conducted a three-year study at the Gulf Coast Research and Education Center in Bradenton, FL during the fall of 1998, 1999 and 2000 and the spring of 1999, 2000 and 2001. This study compared standard methyl bromide soil fumigation to the best chemical alternative, a mixture of 1,3-D and chloropicrin as Telone C17™ used in combination with the nutsedge herbicide Tillam™ (pebulate), and the best nonchemical alternative, soil solarization, for soilborne pest control and crop response in both fall tomatoes and spring double-cropped cucumbers over multiple years on the same site. Tillam was applied broadcast, preplant incorporated at 4 lb.a.i./acre, then 35gal/acre of a mixture of 1,3-D + chloropicrin (Telone C17) was applied through three chisels to the soil in 8 inch tall raised beds during the summer of 1998,1999 and 2000. Methyl bromide + chloropicrin (350 lbs/acre of 67/33%) was applied at the same time and in a similar fashion. In this long-term study, the number of nutsedge plants increased greatly from 1999 to 2000 but declined in 2001. In the spring of 2000, there was more nutsedge in 1,3-D + chloropicrin + pebulate plots than was present in methyl bromide plots and there was a trend for this again in spring 2001, although this difference was not significant in 2001. In general, the sustainability of the approach was challenged by the inability to manage nutsedge with repeated applications of an alternative fumigant, even when a supplemental nutsedge herbicide was included as a component of the alternative system.

This was not the last long-term experiment to have been conducted. A three-year trial was initiated by Dr. Andrew MacRae in August of 2008 at the Gulf Coast Research and Educational Center in Balm, FL. The objective of this study was to determine the long-term sustainability of four methyl bromide alternative programs compared with a non-treated control and a methyl bromide plus chloropicrin standard in both a Florida tomato and bell pepper production system. The methyl bromide alternatives were methyl iodide in combination with chloropicrin, dimethyl disulfide in combination with chloropicrin, 1,3-dichloropropene in combination with chloropicrin followed by a 3 way system approach, including metam potassium, and 1,3-dichloropropene in combination with chloropicrin. Each of the different fumigant treatments were applied with and without a pre-emergence herbicide program. In this long term trial, a separate application of one or more herbicides under polyethylene mulch was added because it has been deemed a requirement for effective weed control with any alternative system. The herbicides included imazosulfuron (League®) or fomesafen (Reflex®), in combination with napropamide (Devrinol 2EC®). All are currently or soon to be registered for pre-emergence application in tomato in Florida. All are also currently or soon to be registered as pre-emergent products for bell pepper except for League® which will be registered as a post-directed application. S-metolachlor has a full registration for tomato and a third party registration for bell pepper, but was not included in these studies. This study also did not include a post-emergence application of halosulfuron which is a common practice in tomato.

In general, all fumigant systems showed an increase in weed populations over a three year period. The addition of an herbicide to the fumigant system provided better control of yellow and purple nutsedge and reduced the rate of population increase for all weeds. However, the fumigant systems in combination with herbicides showed a better potential for sustainability in tomato than bell pepper. The bottom line is that the sustainability of all the different fumigant systems evaluated in this long term study were benefitted by the addition of a herbicide that growers must use to avoid the buildup of different weeds from one season to the next. Given the general lack of herbicidal activity associated with the alternative fumigants, weed control, regardless of crop, will require a separate application of one or more herbicides as a requirement for effective weed control with any methyl bromide chemical alternative system.

PHASE II FUMIGANT REREGISTRATION - A NEW SET OF PRODUCT LABELS ARE COMING

EPA has completed review and approval of all soil fumigant product labels incorporating the second phase of mitigation measures required by EPA (based on the 2009 Reregistration Eligibility Decisions- REDs) for the soil fumigants methyl bromide, chloropicrin, metam sodium/metam potassium, and dazomet. With these latest changes to the fumigant labels, new risk reduction measures which will be implemented this year will include buffer zones, site specific maps of treated areas, posting requirements, difficult to evacuate sites, emergency preparedness and response measures, fumigant site monitoring, and or notification of neighbors to name but a few. These are additional to the other measures which were added to fumigant product labels in the first phase of implementation and reregistration including Fumigant Management Plans (FMPs), mandatory good agricultural practice (GAP) requirements, and new worker protection measures that required certified applicators to provide certification that handlers in the field had received new safety information for handlers working with soil fumigants. This initial Phase 1 labels were approved in 2010, and certified applicators were required to comply with them after Jan 1, 2011. When the new Phase 2 fumigant labels appear in the market place by the end of year (2012), fumigant users will need to comply with these new requirements as well.

Applicator compliance with the new labels will in many cases be determined by the time of delivery of the fumigant products into their fields. For example, existing stocks of products bearing Phase 1 labels may be sold and distributed by registrants until December 1, 2012. After that date, only products bearing the newly approved labels may be sold or distributed by registrants. Distributors and retailers who are not registrants may sell and distribute products until their supplies are exhausted. Likewise, growers and applicators may apply products bearing old labels until those supplies have been exhausted. Land owners and certified applicators should know that the newly approved labels will be available from registrants, distributors, and through EPA's Pesticide Product Label System (PPLS) (www.epa.gov/pesticides/ppls). Applicators are also encouraged to visit the EPA Soil Fumigant Toolbox website www.epa.gov/pesticides/reregistration/soil_fumigants/ for more information about soil fumigants and new label requirements for their use.

Other product labels which did not undergo reregistration have some new stipulations which we would like to bring to your attention. For example, to avoid the requirement for use of half face respirators, Telone II can only be injected to flat soil prior to any soil mounding or bed forming operation (PreBed) to a depth of at least 12 inches below the final bed top. Any other application method will require handlers in the field to wear a minimum of a half face respirator. It is important to note that any fumigant application that is to take place with a product using the Phase II labels will require the applicator to be trained by the registrant or a state delivered and approved training program. This training should be taken into account for those growers planning on application of fumigant during the end of 2012 and from that point forward. The University of Florida has almost completed their training program that will take the place of the registrant's training program, after the EPA has given final approval. This training program will consist of either an on-site and on-line program consisting of 12 modules. Further information on training will be forth coming as the fall season approaches.

Regulatory Issues of Transporting Migrant and Seasonal Farm Workers

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Agricultural producers enjoy many exemptions from state and federal transportation regulations. These exemptions, however, pertain primarily to produce trucks carrying agricultural crops to their first point of processing or distribution. When it comes to vehicles that transport workers, agricultural employers are obliged to follow many of the same regulations enforced on non-farm motor carriers. The purpose of this paper is to outline the various regulations and regulatory authorities charged with protecting agricultural workers as they are transported to and from their field work sites.

Transportation is regulated by U.S. Departments of Transportation, Federal Motor Carrier Safety Association (FMCSA). Transportation specifically of farm workers is a major focus of the Migrant & Seasonal Agricultural Worker Protection Act (MSPA), which is enforced by the federal Department of Labor (DOL) and the Florida Department of Business & Professional Regulations (DBPR). Florida Department of Business & Professional Regulations also enforces the Florida Farm Labor Registration Law, Chapter 450 of the Florida Statutes, which has transportation-related provisions.

DEPARTMENT OF TRANSPORTATION (DOT)

Prior to 2011, Florida Department of Transportation (FDOT) was charged with enforcing motor carrier laws. The State of Florida had previously adopted most of the U.S. DOT regulations, and about 200 officers enforced those regulations, plus a few specially trained officers in the Florida Highway Patrol and within several local Sheriff's Departments. In 2011, the FDOT merged with the Florida Highway Patrol (FHP). During the early transition years the original DOT officers will continue to carry out their previous responsibilities. It is expected, however, that many of the 2,000 FHP officers will be cross-trained to carry out vehicle inspections and enforce motor carrier regulations.

Department of Transportation regulations cover the following: DOT numbers; vehicle inspections; proper licensing; driver qualification files;hours of service; and drug & alcohol testing.

DOT NUMBERS

DOT numbers are required to be displayed on all buses carrying farm workers, in addition to the name of the bus individual or corporate owner. One DOT number per company is all that is needed for multiple vehicles. The name on the bus must match the name on the DOT database, e.g. Jones' Harvesting Company would be the same name and number on Jones' buses as well as trucks. DOT numbers are provided online and at no charge.

The assigned number will be available immediately. It must be painted or otherwise affixed to both sides of buses in a way that it is visible from 50 feet, or with letters and numbers that are at least 3 inches tall, in a contrasting color to the bus. As of this date, the fine for not displaying a DOT number is \$50. The fine for not having a DOT number is \$500. An agricultural bus missing a DOT number becomes an easily-visible reason for officers to stop a vehicle and then perform a more comprehensive inspection.

VEHICLE INSPECTION

Vehicles must be inspected daily before and after driving, and periodically (at least once every 12 months) with a complete, comprehensive inspection by a qualified mechanic. Required information must be completed and filed where the vehicle is kept. Forms for inspections are commercially available.

Daily Inspections: Completed information must be kept for 12 months that include:
- Identification of the vehicle
- Nature and due date of inspection / maintenance
- Records of inspection, repair and maintenance

Periodic Inspections: Vehicles must be inspected by a qualified mechanic at least once every 12 months. The report must be kept for 14 months and include:
- Individual performing the inspection
- Qualifications of that person
- Company operating the vehicle
- Date of the inspection
- Vehicle inspected
- Components inspected and the results

COMMERCIAL DRIVER'S LICENSE (CDL)

Two types of agricultural vehicles require a Commercial Drivers' License (CDL). First, are vehicles with a GVWR (Gross Vehicle Weight Rating) of 26,000 or more pounds. Second, are vehicles designed to transport 16 or more passengers, including the driver. The CDL must be of the appropriate Class (A, B, or C), depending on the weight of the vehicle. In addition, if the vehicle is designed to transport people, the CDL must carry a "P" endorsement. The license must list any restrictions including corrective lenses and hearing aids. If corrective lenses are required, the driver must be wearing them if stopped. If the driver requires a hearing aid, it must be worn, and a spare battery must be carried by the driver. If the vehicle is equipped with air brakes, the CDL license must show that endorsement as well.

Agricultural operations use several vehicles that have been modified from their original design. School busses converted into watermelon haulers are a good example. Another example is when several rows of seats are removed from a bus to accommodate cargo, resulting in seating for fewer than 15 people. A CDL is still required for such a vehicle, based on the reasoning that the seats could be restored at some point. The vehicle owner may request a new VIN Number with a new vehicle designation and plate from the Department of Motor Vehicles, to avoid any issues related to its original designed use.

DRIVER QUALIFICATION FILES

Two types of commercial vehicles need to maintain driver qualification files: 1) any CDL required vehicle (see previous discussion on CDLs); 2) any passenger vehicle with a GVWR of more than 10,000 pounds. A file must be maintained for each driver employed by a grower or a contractor. If an employee works for another grower at any time during the year, for example, up north in the summer, the information in the forms must all be re-verified when they return, just as if the driver were a new employee. Required forms are:

- Application for Employment
- Inquiries to Previous Employers
- Inquiries to State Agencies
- Annual Review of Driving Record
- Annual Driver's Certification of Violations
- Driver's Road Test or Equivalent
- DOT Medical Examiner's Certificate

Note: The Department of Transportation medical examination form is more complex and stringent than the Department of Labor form. The DOT certificate is accepted by the DOL and DBPR, but the DOL certificate is not accepted by DOT. The DOT Medical form expires every 2 years unless the doctor indicates a shorter period for certain conditions, e.g. high blood pressure. The DOT Medical certificate may be completed by a non-MD health-care professional, including doctor of osteopathic medicine, physician's assistant, a nurse practitioner, or a chiropractic physician.

HOURS OF SERVICE

To ensure that drivers get adequate rest between driving, the DOT has established rules for the "hours of service" a driver may work. Two types of commercial vehicles need to observe "hours of service" constraints: 1) any CDL-required vehicle (see previous discussion on CDLs); and 2) any passenger vehicle with a GVWR of more than 10,000 pounds. The logbooks or time records described below must be kept for a minimum of 6 months. Important to take note that every line on log books must be filled out correctly, or face fines that can be as much as $100 per line item.

- The 10/15 Hour Rule – No more than 10 hours driving and no more than 15 hours "on duty," which includes time behind the wheel and other time spent working, inspecting the bus, or even resting, if the rest time is less than 8 consecutive hours. A complete 8 hour rest period ("off duty") is required before driving again. Drivers must keep a daily logbook of Off Duty, Driving, and On Duty time.
- 60/70 Hour Rule – No more than 60 hours in any 7 consecutive days, OR 70 hours in any 8 consecutive days. This time must be logged in a monthly log-sheet and is a "rolling" total. You must stick to one or the other. Once the maximum number of hours is reached, a 24-hour rest period is required.
- 12 Hour Rule – This rule is a "short haul provision" for drivers who do not drive farther than a 100 air mile radius. No more than 10 hours driving and 12 hours on duty, including driving. If this rule is used, a log book is not required, but some form of time record must be kept.

DRUG & ALCOHOL PROGRAM

A formal drug and alcohol testing program is required only for CDL required vehicles, those commercial vehicles with GVWR of more than 26,000 pounds or commercial passenger vehicles designed to carry 16 or more people including the driver. A "Drug Free Workplace" does not meet the criteria of a DOT-approved drug and alcohol program. The DOT drug and alcohol program is specific to drivers and ensures that every driver is tested:

- Before they are hired
- After an accident if someone dies and/or if the driver gets a ticket and/or if the vehicle has to be towed.
- Upon "reasonable suspicion" (Note: Two-hour reasonable suspicion training must be completed before anyone is qualified to suspect drug or alcohol use.)
- Throughout the year, if selected via a statistically random process.

Fines associated with drug and alcohol program violations can be significant. It is highly recommended that companies thoroughly research the drug and alcohol program requirements and even hire a knowledgeable consultant when designing and implementing their program. Small companies can enlist the services of a DOT-approved outside company that puts drivers in a consortium with other small companies. The program must ensure that at least 50% of drivers in the company's own pool, or the consortium, are tested for controlled substances and 10% are tested for alcohol every year (as of the date of this paper).

If a new driver has not yet had, or if an existing driver has failed, a drug or alcohol test, they may not perform any "safety sensitive functions," meaning anything that touches vehicles. Safety sensitive functions include maintenance, loading, painting, or washing. Even riding with someone else to learn the route, prior to a positive drug test, is not permitted.

DOT-REQUIRED DOCUMENTS

Drivers should carry with them and in their vehicle, the following documents:

1. CDL with "P" endorsement or regular driver's license if vehicle is designed to hold fewer than 15 passengers plus the driver.
2. DOT medical certificate
3. Vehicle Registration
4. Certificate of Liability Insurance

DOT-REQUIRED MARKINGS AND POSTINGS ON VEHICLE

1. Name of company and DOT#
2. Railroad Crossing Sign

DEPARTMENT OF LABOR (DOL) DEPARTMENT OF BUSINESS AND PROFESSIONAL REGULATIONS (DBPR)

The Federal Department of Labor (DOL) and Florida State Department of Business and Professional Regulations (DBPR) both inspect and enforce the Migrant and Seasonal Agricultural Worker Protection Act (MSPA), which includes regulations for transporting workers. In addition, DBPR enforces Florida Statutes for transportation. In particular, Florida requires that all labor buses must be painted a color different from the orange or yellow color known as "school bus chrome," or any color resembling the color of a school bus. All signs and insignia that mark the vehicle as a school bus must be removed.

Car-Pooling. To be exempt from MSPA regulations, a "car-pool" must only be a group of workers who voluntarily ride together to a farm work site. They may chip in for gas for a ride in a vehicle owned by the driver or someone else riding in the car. It is not a car-pool if:

- The driver is paid, either by the riders or the employer, more than the gas plus a small amount more for wear and tear on the vehicle;
- The grower or contractor pays for the gas;
- The driver's job is dependent on driving;
- The driver earns more than the other workers because he or she transport workers;
- The owner of the vehicle is not part of the car-pool;
- The grower or contractor instructs the driver to transport the workers. (Instructing the driver includes moving from one place on a farm to another.)
- Recreational vehicles or buses are used.

If any of these conditions exist, then the situation is not a car-pool and the driver could be considered a farm labor contractor with all the attending legal obligations. These include having Workers' Comp coverage for the workers transported in the vehicle; $50,000 property damage liability; and an annual safety inspection.

VEHICLE INSPECTIONS

Vehicles must be in safe condition. All DOT inspection items are considered part of keeping the vehicles in safe condition. In addition, the DOL and DBPR inspectors look for the following in their objective to enforce MSPA regulations:

- No re-grooved, re-capped, or re-treaded tires on front wheels.
- Vehicles must be clean.
- A seat for each rider, firmly secured to the floor.
- Windows operational to allow fresh air.
- Vehicle must protect passengers from inclement weather such as rain.
- Door handles and latches must work.
- Side walls and ends above the floor must be at least 60 inches high.
- Floor and sides must be free of holes, rusted areas, or other defects.
- No protruding obstructions more than two inches high, and no nails, screws, or splinters.
- No objects obscuring the driver's view or motions, ahead or to rear, and to the right and left.
- Adequate means of ingress and egress, at least 18 inches wide and 60 inches high.
- Gates or doors must be provided and equipped with a fastening device, readily operable without the use of tools, and hand holds to permit safe entry and exit.
- At least one emergency exit with a gate or door, on a side or rear where other exits do not exist.
- Safe protection from cold, not including exhaust heaters or other potentially dangerous heaters, and must be securely fastened to the vehicle.

DRIVERS

- Must be at least 21 years old
- One-year driving experience
- Knowledge of regulations
- Knowledge of English

DOL AND DBPR REQUIRED DOCUMENTS

Drivers should have on their person or in the vehicle, the following documents:

- CDL of proper classification, with "P" endorsement, or regular driver's license if vehicle is designed to hold fewer than 15 passengers plus the driver.
- DOT or DOL medical form signed by a Medical Doctor with the initials "MD."
- Vehicle Registration
- Current safety inspection certificate.
- Proof of Workers' Compensation coverage plus a minimum $50,000 property damage liability insurance policy.
- Federal Farm Labor Contractor registration certificate with "DA" authorization
- Florida State FLC registration certificate with "DA" (driving authorized)
- Copy of owner's FLC registration certificate with "TA" (transportation authorized)

DOL/DBPR-REQUIRED MARKINGS AND POSTINGS ON/OR IN VEHICLES

- Railroad Crossing Sign
- "Labor Bus" sign on rear door
- Posters – DBPR requires required posters visible to all workers
- Statement of Working Conditions
- Vans must have Buckle Your Seatbelt sign

The information in this paper is from a Farm Labor Supervisor Training Program launched in fall 2010. The program is designed to enhance the professionalism and regulatory knowledge of Farm Labor Supervisors, including Farm Labor Contractors, also known as Crew Leaders.

ADDITIONAL RESOURCES:

DOT. Federal Motor Carrier Safety Association: www.fmcsa.dot.gov

Apply for a DOT #: www.fmcsa.dot.gov/registration-licensing

DOL. http://www.dol.gov/whd/msp/index,htm

DBPR.http://www.myfloridalicense.com/dbpr/reg/farmlabor.html

Tomato Varieties for Florida

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

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

1. 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.

2. 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.

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

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

5. 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

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 (race 1,2,3), root-knot nematode , Gray leaf spot and Tomato spotted wilt.

Bella Rosa. Midseason maturity. Determinate salad variety with very good heat setting ability and good flavor. Medium to large vine. Produces large to extra-large, firm, uniformly green and globe shaped fruit. Variety is well suited for mature green or vine-ripe production. Resistance: Verticillium wilt (race 1), Fusarium wilt (race 1,2), Tomato spotted wilt and intermediate resistance to Gray leaf spot.

BHN 585. Midseason maturity. Determinate, medium to tall vine. Large to extra-large, deep globe shaped fruit. Firm uniform green fruits are well suited for mature green or vine-ripe production. Resistance: Verticillium wilt (race 1), Fusarium wilt (race 1,2), Fusarium crown rot and root-knot nematode.

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

BHN 730. Determinate, Mid-season variety. Medium to large bush with good vine cover. Performs well on weak ground. Large fruit with good color and uniform green shoulders borne on jointed pedicels. Resistant to Verticillium wilt (race 1), Fusarium wilt (race 1, 2), Fusarium Crown Rot and Bacterial Speck (race 0).

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

BHN 1064. Strong determinate bush with good set. Smooth, very firm fruit. Resistance: Tomato spotted wilt and fusarium wilt (race 1-2-3.

Caddo. Vigorous determinate main season variety earlier than FL 47. Firm, mostly large and extra-large deep red, globe-shaped fruit. Good for vine ripe and mature green. Resistant to Verticillium wilt (race 1), Fusarium wilt (race 1, 2), Fusarium Crown Rot, intermediate resistance to Tomato yellow leaf curl.

Charger. Early maturity. Transition variety is a strong performer growing from hot to cold. High yielding with extra-large fruit. The fruit are very firm, smooth shouldered with excellent color for mature green and vine ripe markets. Resistant to Alternaria stem canker, Fusarium wilt (race 1- 3), Verticillium wilt (race 1) and intermediate resistance to Gray leaf spot and Tomato yellow leaf curl.

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

Crown Jewel. 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 (race 1,2) Fusarium crown rot, Alternaria stem canker and Gray leaf spot.

Fletcher. Midseason maturity. Large, globe to deep oblate 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. Replacement for Mountain Spring where Tomato spotted wilt is a problem. Resistance: Verticillium wilt (race 1), Fusarium wilt (race 1,2,3), Tomato spotted wilt and root-knot nematode.

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

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

HA 3073. A midseason, determinate, jointed hybrid. Fruit are large, firm, slightly oblate and are uniformly green. Resistant: Resistance: Verticillium wilt (race 1), Fusarium wilt (race 1,2), Gray leaf spot, Tomato yellow leaf Curl and Tomato mosaic.

Linda. Main season determinate. Well adapted for mature green and vine ripe harvesting. Plants have good vigor and are tall with excellent fruit cover. Fruit quality is very good, extra-large with uniform green shoulders, smooth, have excellent firmness and have a deep oblate shape with a small blossom end. Resistance: Alternaria stem canker, Fusarium wilt (race 1,2),

Pawnee. Medium vigorous determinate warm season variety suited for fall production. 71 days to maturity. . Firm, mostly extra-large to jumbo, glossy red, round fruit. Good for vine ripe and mature green. Resistant to Verticillium wilt (race 1), Fusarium wilt (race 1, 2), Fusarium crown rot, intermediate resistance to Tomato yellow leaf curl.

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 (race 1,2), Alternaria stem canker and Gray leaf spot.

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

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

Red Bounty. Medium maturity with good heat set, vigorous bush with good foliage cover, high yielding with extra-large, uniform fruit. Resistance: Verticillium wilt (race 1), Fusarium wilt (race 1, 2), Gray leaf spot, root-knot nematode and Tomato spotted wilt.

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 (race 1,2,3) and Grey leaf spot.

RPT 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 (race 1,2) 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 (race 1,2), root-knot nematodes, Alternaria stem canker and Gray leaf spot.

Sebring. A late midseason determinate, jointed hybrid with a smooth, deep oblate, firm, thick walled fruit. Resistance: Verticillium wilt (race 1), Fusarium wilt (race 1,2,3), Fusarium crown rot and 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, round and firm fruit. Resistance: Alternaria stem canker, Fusarium wilt (race 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, firm, light green shoulder and blossom scars are smooth. Resistance: Verticillium wilt (race 1), Fusarium wilt (race 1, 2 and 3) and Gray leaf spot.

Solimar. A midseason hybrid producing globe-shaped, green shouldered fruit. Resistance: Verticillium wilt (race 1), Fusarium wilt (race 1 and 2), Alternaria stem canker, 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 (race 1,2,3), Fusarium crown rot and Gray leaf spot.

Sunkeeper. Medium to tall vine. Not a true hot set variety, but a transition variety for September plantings in South Florida which goes well from hot to cold and is also a strong season finisher for late spring plantings. Extra-large fruit. Sets and holds large volumes. Resistance: Verticillium wilt (race 1), Fusarium wilt (race 1, 2) and Fusarium crown rot

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 (race 1,2), Tomato spotted wilt and Gray leaf spot.

Tasti-Lee. It is a limited released for 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 (race 1,2,3), Verticillium wilt (race 1), and Gray leaf spot.

Tribeca. Vigorous determinate plant. Fruit are large to extra-large, firm and dark red. Has some heat tolerance. Resistance: Verticillium wilt (race 1), Fusarium wilt (race 1,2) and Tomato spotted wilt.

Tribute. Main season with good heat setting ability. Large, firm, uniform green shouldered, smooth shouldered and globe shaped fruit. Plants are medium tall and benefit from light to no pruning. Resistant to Alternaria stem canker, Fusarium wilt (race 1 and 2), Tomato spotted wilt and Verticillium wilt (race 1) and intermediate resistance to Gray leaf spot and Tomato yellow leaf curl.

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

PLUM TYPE VARIETIES

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

BHN 1051. Midseason Roma type. Vigorous vine with good fruit cover. Large high quality fruit. Resistance: Verticillium wilt (race 1), Fusarium wilt (race 1, 2), Bacterial Speck (race 0) and Tomato Spotted Wilt.

Mariana. 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 (race 1,2), root-knot nematode, Alternaria stem canker and tolerant to Gray leaf spot.

Monticello. Roma type with high yields of large, quality fruit. Featuring excellent smoothness, great firmness, and superior quality. An extremely vigorous plant. Resistance: Fusarium wilt (race 1,2) Tomato spotted wilt, Bacterial speck, and root-knot nematode.

Picus. Main season. Determinate, medium to large vigorous plant that provides good fruit cover and sets well in hot temperatures. Fruits are large, uniform and blocky maturing to a deep red color with good firmness. Resistance: Verticillium wilt (race 1), Fusarium wilt (race 1,2), Alternaria stem canker, Cladosporium leaf mold and Tomato spotted wilt.

Plum Dandy. Medium to large determinate plants. Rectangular, blocky, defect-free fruit for fresh-market production. When grown in hot, wet conditions, it does not set fruit well and is susceptible to bacterial spot. For winter and spring production in Florida. Resistance: Verticillium wilt, Fusarium wilt (race 1), Early blight, and rain checking.

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

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 (race 1,2), Bacterial speck (race 0), root-knot nematodes, Tomato mosaic and Gray leaf spot.

Tachi. Midseason Roma type. Produces extra-large and large uniform fruit. Very similar to Mariana but with the added resistance of Tomato spotted wilt. Resistance: Verticillium wilt (race 1), Fusarium wilt (race 1,2), root-knot nematode, Alternaria stem canker and tolerant to Gray leaf spot.

CHERRY TYPE VARIETIES

BHN 268. Early. An extra firm cherry tomato that holds, packs and ships well. Determinate, small to medium bush with high yields. Resistance: Verticillium wilt (race 1) and 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.

Mountain Belle. Vigorous, determinate type plants. Fruit are round to slightly ovate with uniform green shoulders borne on jointless pedicels. Resistance: Fusarium wilt (race 2) and Verticillium wilt (race 1).

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

Super Sweet 100 VF. Produces large clusters of round uniform fruit with high sugar levels. Fruit somewhat small and may crack during rainy weather. Indeterminate vine with high yield potential. Resistance: Verticillium wilt (race 1) and Fusarium wilt (race 1).

Sweet Million. Very early maturing indeterminate round cherry tomato. Fruits are uniform with an average shelf life. Excellent home garden/roadside variety offering superb flavor. Resistance: Fusarium wilt (race1) and Tomato mosaic.

Sweet Treats. A unique early maturing indeterminate large pink cherry tomato with superb flavor. Resistance: Gray leaf mold, Tomato mosaic, Fusarium wilt (race 1, 2), and intermediate resistance to Fusarium crown rot and Gray leaf spot.

GRAPE TOMATOES

Amai. Indeterminate grape with deep red color, and good flavor and yield potential. . Maintains size and shape uniformity through the production cycle. Resistance: Gray leaf mold, Fusarium wilt (race1), Tomato mosaic and intermediate resistance to root-knot nematode and Gray leaf spot.

BHN 785. Mid-season. Determinate grape hybrid with a strong set of very uniform size and shaped fruit on a vigorous bush with good cover. Resistance: Fusarium wilt (race 1).

Brixmore. Very early. Indeterminate. 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), root-knot nematodes and Tomato mosaic.

Cupid. Early. Vigorous, indeterminate bush. Oval-shaped fruit have an excellent red color and a sweet flavor. Resistance: Fusarium wilt (race 1,2), Bacterial speck (intermediate resistance race 0) 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.

Jolly Elf HOV 100+. Determinate early grape with bright red, firm smooth fruit with the right size and shape. Greater yield potential and higher tolerance to field diseases over the original Jolly Elf. Resistant: Verticillium wilt (race 1), Fusarium wilt (race 2) and cracking.

Montesino. A Santa type tomato that is highly productive in the open field or unheated greenhouse. Sweet, tasty grape shaped fruits that weigh on average 0.35-0.5 oz. (10-14 gr) with medium to early maturity. Resistance: Tomato mosaic, Fusarium wilt (race 0),

Red Grape. 68 days. Vigorous indeterminate bush. Firm excellent shaped fruit weighing 8-15 gms.

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 (race 1), 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. Resistance: Verticillium wilt (race 1) and Fusarium wilt (race 1)

Sweet Hearts. Early to mid-season. Brilliant red elongated grape has excellent flavor, shelf life and resistance to cracking. Indeterminate plants are well suited for single fruit harvest. Resistant to leaf mold, Fusarium wilt (race1), Tomato mosaic and intermediate resistance to Gray leaf spot.

Sweet Zen. Early maturing, determinate grape. Bright red fruits weigh around 13-14 grams and good Brix. Tolerant to heat. Firm fruits handle shipping well. Extended harvest type.

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

Fertilizer and Nutrient Management for Tomato

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

CALIBRATED SOIL TEST: TAKING THE GUESSWORK OUT OF FERTILIZATION

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

The crop nutrient requirements of nitrogen, phosphorus, and potassium (designated in fertilizers as N, P_2O_5, and K_2O, respectively) represent the optimum amounts of these nutrients needed for maximum tomato production (**Table 1**). Fertilizer rates are provided on a per-acre basis for tomato grown on 6-ft centers. Under these conditions, there are 7,260 linear feet of tomato row in a planted acre. When different row spacings are used, it is necessary to adjust fertilizer application accordingly. For example, a 200 lbs/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 lbf is accomplished by injecting 7.46 lbs of N to 5,333 lbf.

LIMING

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	220	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	220	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 pre-plant. Rate may be reduced when a controlled-release fertilizer source is used.
[u] Plant nutritional status may be determined with tissue analysis or fresh petiole-sap testing, or any other calibrated method. The "low" diagnosis needs to be based on UF/IFAS interpretative thresholds.
[t] Plant nutritional status must be diagnosed every week to repeat supplemental application.
[s] Supplemental fertilizer applications are allowed when irrigation is scheduled following a recommended method. Supplemental fertilization is to be applied in addition to base fertilization when appropriate. Supplemental fertilization is not to be applied >in advance= with the pre-plant fertilizer.
[r] A leaching rain is defined as a rainfall amount of 3 inches in 3 days or 4 inches in 7 days.
[q] Supplemental amount for each leaching rain
[p] Plant nutritional status must be diagnosed after each harvest before repeating supplemental fertilizer application.

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

Calcium (Ca) and magnesium (Mg) levels should be also corrected according to the soil test. If both elements are "low", and lime is needed, then broadcast and incorporate dolomitic limestone ($CaCO_3$, $MgCO_3$). Where calcium alone is deficient, "hi-cal" ($CaCO_3$) limestone should be used. Adequate Ca is important for reducing the severity of blossom-end rot. Research shows that a Mehlich-I (double-acid) index of 300 to 350 ppm Ca would be indicative of adequate soil-Ca. On limestone soils, add 30-40 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 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 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).

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

				N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu	Mo
				%						ppm					
Tomato	MRM[z] leaf	5-leaf stage	Deficient	<3.0	0.3	3.0	1.0	0.3	0.3	40	30	25	20	5	0.2
			Adequate	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

[z]MRM=Most recently matured leaf.

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), isobutylidenediurea (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.

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

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**).

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

Nutrient Management Level	Rating	Description
0	None	Guessing
1	Very low	Soil testing and still guessing
2	Low	Soil testing and implementing >a= recommendation
3	Intermediate	Soil testing, understanding IFAS recommendations, and correctly implementing them
4	Advanced	Soil testing, understanding IFAS recommendations, 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 scheduling methods.)

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

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/HS367Hochmuth, 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

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

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

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

TOMATO WATER REQUIREMENT

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

By definition, ETo represents the water use from a uniform green cover surface, ac-

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

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

Table 2. Summary of irrigation management guidelines for tomato.

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

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

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

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

TOMATO IRRIGATION REQUIREMENT

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

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

IR = ETc/Ea

IRRIGATION SCHEDULING FOR TOMATO

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

Irrigation scheduling for drip irrigated tomato typically consists in daily applications of ETc, estimated from Eq. [1] or [2] above. In areas where real-time weather information is not available, growers use the "1,000 gal/

acre/day/string" rule for drip-irrigated tomato production. As the tomato plants grow from 1 to 4 strings, the daily irrigation volumes increase from 1,000 gal/acre/day to 4,000 gal/acre/day. On 6-ft centers, this corresponds to 15 gal/100lbf/day and 60 gal/100lbf/day for 1 and 4 strings, respectively.

SOILS MOISTURE MEASUREMENT

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

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

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

A SWT at the 6-inch depth remaining with the 4-8 cb range, but the 12-inch-depth reading showing a SWT of 20-25cb suggest that deficit irrigation has been made: irrigation has been applied to re-wet the upper part of the profile only. The amount of water applied was not enough to wet the entire profile. If SWT at the 12-inch depth continues to increase, then water stress will become more severe and it will become increasingly difficult to re-wet the soil profile. The sandy soils of Florida have a low water holding capacity. Therefore, SWT should be monitored daily and irrigation applied at least once daily. Scheduling irrigation with SWT only can be difficult at times. Therefore, SWT data should be used together with an estimate of tomato water requirement.

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

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

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

GUIDELINES FOR SPLITTING IRRIGATION

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

UNITS FOR MEASURING IRRIGATION WATER

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

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

EXAMPLE

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

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

ters are spaced 1 foot apart.

1. In the 2-acre field, there are 14,520 feet of bed (2 x 43,560/6). Because of the alleys, only 6/8 of the field is actually planted. So, the field actually contains 10,890 feet of bed (14,520x 6/8).

2. A 0.20 acre-inch irrigation corresponds to 5,430 gallons applied to 7,260 feet of row, which is equivalent to 75gallons/100feet (5,430/72.6).

3. The drip tape flow rate is 0.30 gallons/hr/emitter which is equivalent to 30 gallons/hr/100feet. It will take 1 hour to apply 30 gallons/100ft, 2 hours to apply 60gallons/100ft, and 2 2 hours to apply 75 gallons. The total volume applied will be 8,168 gallons/2-acre (75 x 108.9).

IRRIGATION AND BEST MANAGEMENT PRACTICES

As an effort to clean impaired water bodies, federal legislation in the '70s, followed by state legislation in the '90s 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

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Active Ingredient lb. a.i./A	Trade name Formulation/A	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 preplant burndown 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.
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.
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 3 – 10%	(Scythe) 4.2 EC	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 H2O) 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.
	POSTEMERGENCE	
Trifluralin 0.5	(Treflan HFP, Trifluralin, Trifluralin HF) 4EC 1 pt. (Treflan TR-10) 5 lbs.	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.
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.
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	(GramaxoneInteon) 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.
	POSTHARVEST	
Paraquat 0.62 -0.94	(GramaxoneInteon) 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 tomato plants after the final harvest. Use a nonionic surfactant. Thorough coverage of tomato vines is required to insure maximum burndown.

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).

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

Disease or Pathogen	Chemical (active ingredient)	Fungicide Group[1]			Min. Days to Harvest	Remarks[2]
Anthracnose	(copper compounds) Many brands available.	M1			0	Mancozeb or maneb enhances bactericidal effect of fix copper compounds. See label for details. **Be aware that reentry intervals have changed for many copper compounds.
	(maneb) Many brands available.	M3	SEE INDIVIDUAL LABELS		5	*Bacterial spot control only when tank mixed with a copper fungicide. See label for details.
	(mancozeb) Many brands available.	M3			5	
	Ziram 76DF (ziram)	M3	4 lbs	23.7 lbs	7	Do not use on cherry tomatoes. See label for details.
	Cuprofix MZ Disperss (mancozeb + copper sulfate)	M3 / M1	7.25 lbs	55.2 lbs	5	See label
	ManKocide (mancozeb + copper hydroxide)	M3 / M1	5 lbs.	112 lbs.	5	See label
	(chlorothalonil) Many brands available.	M5	SEE INDIVIDUAL LABELS		0	Use higher rates at fruit set and lower rates before fruit set, see label
	Inspire Super (difenoconazole + cyprodinil)	3 / 9	20 fl oz	47 fl oz	0	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 ; see label.
	Fontelis (penthiopyrad)	7	24 fl oz	72 fl oz	0	For disease suppression only. Begin application on a 7- to 14-day interval prior to disease development. Alternate with non-FRAC code 7 fungicides, see label. Labeled for greenhouse production.
	Amistar 80 DF (azoxystrobin)	11	2 oz	12 oz	0	Must alternate or tank mix with a fungicide from a different FRAC group; use of an adjuvant 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; see label.
	Heritage (azoxystrobin)	11	3.2 oz	1.6 lbs	0	
	Quadris FL (azoxystrobin)	11	6.2 fl.oz	37 fl.oz	0	
	Cabrio 2.09 F (pyraclostrobin)	11	12 fl oz	96 fl oz	0	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.
	Flint (trifloxystro-bin)	11	4 oz	16 oz	3	Only suppresses anthracnose. Limit is 5 appl/crop. Must alternate or tank mix with a fungicide from a different FRAC group, see label.
	Quadris Opti (azoxystrobin + chlorothalonil)	11 / M5	1.6 pts	8 pts	0	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.
	Quadris Top (azoxystrobin + difenoconazole)	11 / 3	8 fl.oz	47 fl.oz.	0	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.
	Tanos (famoxadone + cymoxanil)	11 / 27	8 oz	72 oz	3	Do not alternate or tank mix with other FRAC group 11 fungicides. See label for details
	Ph-D WDG (Polyoxin D zinc salt)	19	6.2 oz	31 oz	0	Limit is 5 apps. on 10-14 day interval. Alternate with a non-FRAC code 19 fungicide. See label.
	Revus Top (mandipropamid + difenoconazole)	40 / 3	7 fl.oz.	28 fl.oz.	1	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
Bacterial Spot and Bacterial Speck	Actigard (acibenzolar-S-methyl)	P	0.75 oz.	4.75 oz.	14	See label for details.
	(copper compounds) Many brands available.	MI			0	Mancozeb or maneb enhances bactericidal effect of fix copper compounds. See label for details. ** Be aware that reentry intervals have changed for many copper compounds.
	(maneb) Many brands available.	M3	SEE INDIVIDUAL LABELS		5	*Bacterial spot control only when tank mixed with a copper fungicide. See label for details.
	(mancozeb) Many brands available.	M3			5	
	Cuprofix MZ Disperss (mancozeb + copper sulfate)	M3 / M1	7.25 lbs	55.2 lbs	5	
	ManKocide (mancozeb + copper hydroxide)	M3 / M1	5 lbs	112 lbs	5	

	Gavel 75DF (zoaximide + mancozeb)	22 / M3	2.0 lbs	16 lbs	5	*Bacterial spot control only when tank mixed with a copper fungi-cide. See label for details.
	Agri-mycin 17 Ag Streptomycin Bac-Master Fire Wall (streptomycin sulfate)	25	200 ppm			See label for details. For transplant production only. Many isolates are resistant to streptomycin.
	Tanos (famoxadone + cymoxanil)	11 / 27	8 oz	72 oz	3	Bacterial spot suppression only. Do not alternate or tank mix with other FRAC group 11 fungicides. See label for details
Black Mold (Alternaria spp.)	(chlorothalonil) Many brands available.	MS	SEE INDIVIDUAL LABELS		0	Use higher rates at fruit set and lower rates before fruit set, see label
	Endura (boscalid)	7	5 oz	25 oz	0	Limit is 5 apps per season. Alternate with non-FRAC code 7 fungicides, see label
	Inspire Super (difenoconazole + cyprodinil)	3 / 9	20 fl oz	47 fl oz	0	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 ; see label.
	Amistar 80 DF (azoxystrobin)	11	2 oz	12 oz	0	Must alternate or tank mix with a fungicide from a different FRAC group; use of an adjuvant 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; see label.
	Heritage (azoxystrobin)	11	3.2 oz	1.6 lbs	0	
	Quadris FL (azoxystrobin)	11	6.2 fl oz	37 fl oz	0	
	Cabrio 2.09 F (pyraclostrobin)	11	12 fl oz	96 fl oz	0	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.
	Quadris Opti (azoxystrobin + chlorothalonil)	11 / MS	1.6 pts	8 pts	0	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.
	Quadris Top (azoxystrobin + difenoconazole)	11 /3	8 fl oz	47 fl oz	0	Do not apply until 21 days after transplant or 35 days after seed-ing. 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.
	Revus Top (mandipropamid + difenoconazole)	40 / 3	7 fl oz	28 fl oz	1	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
Botrytis or Gray Mold	(chlorothalonil) Many brands available.	MS	SEE INDIVIDUAL LABELS		0	Use higher rates at fruit set and lower rates before fruit set, see label
	Endura (boscalid)	7	12.5 oz	25 oz	0	For disease suppression only. Limit is 2 apps per season at rates greater than 9 oz/A. Alternate with non-FRAC code 7 fungicides, see label
	Fontelis (penthiopyrad)	7	24 fl oz	72 fl oz	0	Begin application on a 7- to 14-day interval prior to disease de-velopment. Alternate with non-FRAC code 7 fungicides, see label. Labeled for greenhouse production.
	Scala SC (pyrimethanil)	9	7 fl oz	35 fl oz	1	Use only in a tank mix with another effective non-FRAC code 9 fungicide; Has a 30 day plant back with off label crops; see label.
	Switch 62.5WG (cyprodinil + fludioxonil)	9 / 12	14 oz	56 oz per year	0	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; see label
	Cabrio 2.09 F (pyraclostrobin)	11	16 fl oz	96 fl oz	0	Disease suppression only. Only 1 sequential appl. allowed. Limit is 6 appl/crop. Must tank mix with a fungicide from a different FRAC group, see label.
	Botran 75 W (dichloran)	14	1 lb per 43,680 sq ft	4 lbs	10	Greenhouse use only. Limit is 4 applications. Seedlings or newly set transplants may be injured, see label
	Ph-D WDG (Polyoxin D zinc salt)	19	6.2 oz	31 oz	0	Limit is 5 apps. on 10-14 day interval. Alternate with a non-FRAC code 19 fungicide. See label
Early Blight	(copper compounds) Many brands available.	M1			0	Mancozeb or maneb enhances bactericidal effect of fix copper compounds. See label for details. **Be aware that reentry inter-vals have changed for many copper compounds.
	(maneb) Many brands available.	M3	SEE INDIVIDUAL LABELS		5	*Bacterial spot control only when tank mixed with a copper fungicide. See label for details.
	(mancozeb) Many brands available.	M3			5	
	Ziram 76DF (ziram)	M3	4 lbs	23.7 lbs	7	Do not use on cherry tomatoes. See label for details.
	Cuprofix MZ Disperss (mancozeb + copper sulfate)	M3 / M1	7.25 lbs	55.2 lbs	5	See label
	ManKocide (mancozeb + copper hydroxide)	M3 / M1	5 lbs	112 lbs	5	See label
	(chlorothalonil) Many brands available.	M5	SEE INDIVIDUAL LABELS		0	Use higher rates at fruit set and lower rates before fruit set, see label

	Ridomil Gold Bravo 76.4 W (chlorothalonil + mefenoxam)	4 / M5	3 lbs.	12 lbs	14	Limit is 4 appl./crop, see label
	Endura (boscalid)	7	3.5 oz	21	0	Limit is 6 apps per season at rates less than 3.5 oz/A. Alternate with non-FRAC code 7 fungicides, see label
	Fontelis (penthiopyrad)	7	24 fl oz	72 fl oz	0	Begin application on a 7- to 14-day interval prior to disease development. Alternate with non-FRAC code 7 fungicides, see label. Labeled for greenhouse production.
	Scala SC (pyrimethanil)	9	7 fl oz	35 fl oz	1	Use only in a tank mix with another effective non-FRAC code 9 fungicide ; Has a 30 day plant back with off label crops ; see label
	Inspire Super (cyprodinil + difenoconazole)	9 / 3	20 fl oz	47 fl oz	0	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 ; see label.
	Switch 62.5WG (cyprodinil + fludioxonil)	9 / 12	14 oz	56 oz per year	0	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; see label
	Amistar 80 DF (azoxystrobin)	11	2 oz	12 oz	0	Must alternate or tank mix with a fungicide from a different FRAC group; use of an adjuvant 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; see label.
	Heritage (azoxystrobin)	11	3.2 oz	1.6 lbs	0	
	Quadris FL (azoxystrobin)	11	6.2 fl oz	37 fl oz	0	
	Cabrio 2.09 F (pyraclostro-bin)	11	12 fl oz	96 fl oz	0	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.
	Flint (trifloxystro-bin)	11	3 oz	16 oz	3	Limit is 5 appl/crop. Must alternate or tank mix with a fungicide from a different FRAC group, see label.
	Aftershock Evito (fluoxastrobin)	11	5.7 fl oz	22.8 fl oz	3	Limit is 4 appl/crop. Must alternate or tank mix with a fungicide from a different FRAC group, see label.
	Reason 500 SC (fenamidone)	11	8.2 oz	24.6 lb	14	Must alternate with a fungicide from a different FRAC group. See supplemental label for restrictions and details.
	Quadris Opti (azoxystrobin + chlorothalonil)	11 / M5	1.6 pts	8 pts	0	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.
	Quadris Top (azoxystrobin + difenoconazole)	11 /3	8 fl oz	47 fl oz	0	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.
	Tanos (famoxadone + cymoxanil)	11 / 27	8 zo	72 oz	3	Do not alternate or tank mix with other FRAC group 11 fungicides. See label for details
	Ph-D WDG (Polyoxin D zinc salt)	19	6.2 oz	31 oz	0	Limit is 5 apps. on 10-14 day interval. Alternate with a non-FRAC code 19 fungicide. See label.
	Gavel 75DF (zoaximide + mancozeb)	22 / M3	2 lbs	16 lbs	5	See label
	Promess (propamocarb hydrochloride)	28	1.5 pts	7.5 pts	5	Must tank mix with Chlorothalonil, maneb or mancozeb; see label.
	Revus Top (mandipropamid + difenoconazole)	40 / 3	7 fl oz	28 fl oz	1	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
Gray Leaf Spot	(copper compounds) Many brands available.	M1	SEE INDIVIDUAL LABELS		0	Mancozeb or maneb enhances bactericidal effect of fix copper compounds. See label for details. **Be aware that reentry intervals have changed for many copper compounds.
	(maneb) Many brands available.	M3			5	*Bacterial spot control only when tank mixed with a copper fungicide. See label for details.
	(mancozeb) Many brands available.	M3			5	
	Cuprofix MZ Disperss (mancozeb + copper sulfate)	M3 / M1	7.25 lbs	55.2 lbs	5	See label
	ManKocide (mancozeb + copper hydroxide)	M3 / M1	5 bls	112 lbs	5	See label
	(chlorothalonil) Many brands available.	M5	SEE INDIVIDUAL LABELS		0	Use higher rates at fruit set and lower rates before fruit set, see label
	Ridomil Gold Bravo 76.4 W (chlorothalonil + mefenoxam)	4 / M5	3 lbs.	12 lbs	14	Limit is 4 appl./crop, see label
	Inspire Super (difenoconazole + cyprodinil)	3 / 9	20 fl oz	47 fl oz	0	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 ; see label.
	Ridomil Gold Bravo 76.4 W (chlorothalonil + mefenoxam)	4 / M5	3 lbs	12 lbs	14	Limit is 4 appl./crop, see label.

	Flint (trifloxystrobin)	11	4 oz	16 oz	3	Limit is 5 appl/crop. Must alternate or tank mix with a fungicide from a different FRAC group, see label.
	Quadris Top (azoxystrobin + difenoconazole)	11 / 3	8 fl oz	47 fl oz	0	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.
	Gavel 75DF (zoaximide + mancozeb)	22 / M3	2 lbs	16 lbs	5	See label
	Revus Top (mandipropamid + difenoconazole)	40 / 3	7 fl oz	28 fl oz	1	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
Late Blight	(copper compounds) Many brands available.	M1			1	Mancozeb or maneb enhances bactericidal effect of fix copper compounds. See label for details. **Be aware that reentry intervals have changed for many copper compounds.
	(maneb) Many brands available.	M3	SEE INDIVIDUAL LABELS		5	*Bacterial spot control only when tank mixed with a copper fungicide. See label for details.
	(mancozeb) Many brands available.	M3			5	
	Cuprofix MZ Disperss (mancozeb + copper sulfate)	M3 / M1	7. 25 lbs	55.2 lbs	5	See label
	ManKocide (mancozeb + copper hydroxide)	M3 / M1	5 lbs.	112 lbs.	5	
	(chlorothalonil) Many brands available.	M5	SEE INDIVIDUAL LABELS		0	Use higher rates at fruit set and lower rates before fruit set, see label
	Ridomil MZ 68 WP (mefenoxam + mancozeb)	4 / M3	2.5 lbs	7.5 lbs	5	Limit is 3 appl./crop, see label
	Ridomil Gold Copper 64.8 W (mefenoxam + copper hydroxide)	4 / M1	2 lbs.		14	Limit is 3 appl. /crop. Tank mix with maneb or mancozeb fungicide, see label
	Ridomil Gold Bravo 76.4 W (chlorothalonil + mefenoxam)	4 / M5	3 lbs.	12 lbs	14	Limit is 4 appl./crop, see label
	Amistar 80 DF (azoxystrobin)	11	2 oz	12 oz.	0	Must alternate or tank mix with a fungicide from a different FRAC group; use of an adjuvant 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; see label.
	Heritage (azoxystrobin)	11	3.2 oz	1.6 lbs	0	
	Quadris FL (azoxystrobin)	11	6.2 fl oz	37 fl oz	0	
	Cabrio 2.09 F (pyraclostrobin)	11	16 fl oz	96 fl oz	0	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.
	Flint (trifloxystrobin)	11	4 oz	16 oz	3	Limit is 5 appl/crop. Must tank mix with another labeled fungicide from a different FRAC group at 75% of its labeled rate, see label.
	Aftershock Evito (fluoxastrobin)	11	5.7 fl oz	22.8 fl oz	3	Limit is 4 appl/crop. Must alternate or tank mix with a fungicide from a different FRAC group, see label.
	Reason 500 SC (fenamidone)	11	8.2 oz	24.6 lbs	14	Must alternate with a fungicide from a different FRAC group. See supplemental label for restrictions and details.
	Quadris Opti (azoxystrobin + chlorothalonil)	11 / M5	1.6 pts	8 pts	0	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.
	Tanos (famoxadone + cymoxanil)	11 / 27	8 oz	72 oz	3	Do not alternate or tank mix with other FRAC group 11 fungicides. See label for details
	Ranman (cyazofamid)	21	2.75 fl oz	16 fl oz	0	Limit is 6 appl./crop, see label
	Gavel 75DF (zoaximide + mancozeb)	22 / M3	2 lbs	16 lbs	5	See label
	Curzate 60DF (cymoxanil)	27	5 oz	30 oz per year	3	Do not use alone, see label for details
	Previcur Flex or Promess (propamocarb hydrochloride)	28	1.5 pts	7.5 pts	5	Must tank mix with Chlorothalonil, maneb or mancozeb; see label.
	Alude Fosphite Fungi-Phite Helena Prophyte K-phite 7LP Phostrol Topaz (mono-and di-potassium salts of phosphorous acid)	33	SEE INDIVIDUAL LABELS		0	Do not apply with copper-based fungicides. See label for restrictions and details
	Acrobat 50 WP (dimethomorph)	40	6.4 oz	32 oz	4	See label for details
	Forum (dimethomorph)	40	6 oz	30 oz	4	Only 2 sequential appl. See label for details
	Revus (mandipropamid)	40	8 fl oz	32 fl oz	1	Supplemental label; No more than 2 sequential appl.; See label

	Revus Top (mandipropamid + difenoconazole)	40 / 3	7 fl oz	28 fl oz	1	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
	Presidio (Fluopicolide)	43	4 fl oz	12 fl oz/per season	2	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.
Leaf Mold	(maneb) Many brands available.	M3	SEE INDIVIDUAL LABELS		5	See label for details
	(mancozeb) Many brands available.	M3			5	See label for details
	Ziram 76DF (ziram)	M3	4 bls	23.7 lbs	7	Do not use on cherry tomatoes. See label for details.
	Cuprofix MZ Disperss (mancozeb + copper sulfate)	M3 / M1	7.25 lbs	55.2 lbs	5	See label
	ManKocide (mancozeb + copper hydroxide)	M3 / M1	5 lbs	112 lbs	5	See label
	(chlorothalonil) Many brands available.	M5	SEE INDIVIDUAL LABELS		0	Use higher rates at fruit set and lower rates before fruit set, see label
	Inspire Super (cyprodinil + difenoconazole)	9 / 3	20 fl oz	47 fl oz	0	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 ; see label.
	Quadris Top (azoxystrobin + difenoconazole)	11 / 3	8 fl oz	47 fl oz	0	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.
	Tanos (famoxadone + cymoxanil)	11 / 27	8 oz	72 oz	3	Do not alternate or tank mix with other FRAC group 11 fungicides. See label for details
	Gavel 75DF (zoaximide + mancozeb)	22 / M3	2 lbs	16 lbs	5	See label
	Revus Top (mandipropamid + difenoconazole)	40 / 3	7 fl oz	28 fl oz	1	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
Powdery Mildew	(sulfur) Many brands available.	M2	SEE INDIVIDUAL LABELS		1	Follow label closely, may cause leaf burn if applied during high temperatures.
	Rally 40WSP Nova 40 W Sonoma 40WSP (myclobutanil)	3	4 oz	1.25 lbs	0	Note that a 30 day plant back restriction exists, see label
	Inspire Super (difenoconazole + cyprodinil)	3 / 9	20 fl oz	47 fl oz	0	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 ; see label.
	Fontelis (penthiopyrad)					Begin application on a 7- to 14-day interval prior to disease development. Alternate with nonFRAC code 7 fungicides, see label. Labeled for greenhouse production.
	Switch 62.5WG (cyprodinil + fludioxonil)	9 / 12	14 oz	56 oz per year	0	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; see label
	Amistar 80 DF (azoxystrobin)	11	2 oz	12 oz	0	Must alternate or tank mix with a fungicide from a different FRAC group; use of an adjuvant 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; see label.
	Heritage (azoxystrobin)	11	3.2 oz	1.6 lbs	0	
	Quadris FL (azoxystrobin)	11	6.2 fl oz	37 fl oz	0	
	Cabrio 2.09 F (pyraclostrobin)	11	16 fl oz	96 fl oz	0	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.
	Flint (trifloxystrobin)	11	4 oz	16 oz	3	Only suppresses powdery mildew. Limit is 5 appl/crop. Must alternate or tank mix with a fungicide from a different FRAC group, see label.
	Quadris Opti (azoxystrobin + chlorothalonil)	11 / MS	1.6 pts	8 pts	0	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.
	Quadris Top (azoxystrobin + difenoconazole)	11 / 3	8 fl oz	47 fl oz	0	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.
	Ph-D WDG (Polyoxin D zinc salt)	19	6.2 oz	31 oz	0	Limit is 5 apps. on 10-14 day interval. Alternate with a non-FRAC code 19 fungicide. See label.

	Revus Top (mandipropamid + difenoconazole)	40 / 3	7 fl oz	28 fl oz	1	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
Pythium, Phytophthora, or Buckeye Rot	Ridomil Gold EC (mefenoxam)	4	2 pts / trtd. Acre	3 pts / trtd. Acre	28	Pythium diseases. See label for details
	Ultra Flourish (mefenoxam)	4	2 qts	3 qts		Pythium and Phytophthora rots. See label for details
	Amistar 80 DF (azoxystrobin)	11	2 oz	12 oz	0	For Buckeye rot. Must alternate or tank mix with a fungicide from a different FRAC group; use of an adjuvant 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; see label.
	Heritage (azoxystrobin)	11	3.2 oz	1.6 lbs	0	
	Quadris FL (azoxystrobin)	11	6.2 fl oz	37 fl oz	0	
	Reason 500 SC (fenamidone)	11	8 oz	24.6	14	Phytophthora blight of foliage and fruit (Phytophthora capsici – suppression only). Must alternate with a fungicide from a different FRAC group. See supplemental label for restrictions and details.
	Quadris Opti (azoxystrobin + chlorothalonil)	11 / M5	1.6 pts	8 pts	0	For Buckeye rot. 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.
	Tanos (famoxadone + cymoxanil)	11 / 27	8 oz	72 oz	3	Only suppresses Buckeye rot. Do not alternate or tank mix with other FRAC group 11 fungicides. See label for details
	Terramaster 4EC (etridiazole)	14	7 fl oz	27.4 ft oz	3	Greenhouse use only. For Pythium and Phytophthora root rots. See label for details
	Ranman (cyazofamid)	21	3 fl oz/ 100 gal	16 fl oz	0	Greenhouse use only. For Pythium spp. Limit is 1 appl. up to 1 week prior to transplanting, see label
	Gavel 75DF (zoaximide + mancozeb)	22 / M3	2 lbs	16 lbs	5	For Buckeye rot. See label
	Previcur Flex or Promess (propamocarb hydrochloride)	28	1.5 pts/ treated acre	7.5 pts/ treated acre	5	For root rots and seedling diseases (Pythium and Phytophthora spp.). Applied to lower portion of plant and soil, or as a soil drench or drip irrigation; see label.
			See label	See label		For GREENHOUSE APPLICATION: 6 apps/crop cycle. Do not mix with other products. Can cause phytotoxicity if applied in intense sunlight. See label for restrictions and details.
	Promess (propamocarb hydrochloride)	28	1.5 pts	7.5 pts	5	For Late blight and Buckeye rot. Must tank mix with Chlorothalonil, maneb or mancozeb; see label.
	Alude Fosphite Fungi-Phite Helena Prophyte K-phite 7LP Phostrol Topaz (mono-and di-potassium salts of phosphorous acid)	33	SEE INDIVIDUAL LABELS		0	For root rots and seedling diseases (Pythium and Phytophthora spp.), Buckeye rot, and Late blight. Do not apply with copper-based fungicides. See label for restrictions and details
	Aliette 80 WDG (fosetyl-al)	33	5 lbs	20 lbs	14	For Phytophthora root rot. See label for warnings concerning the use of copper compounds.
	Presidio (Fluopicolide)	43	4 fl oz	12 fl oz/per season	2	For Late blight and other diseases caused by Phytophthora spp. 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.
Rhizoctonia	(chlorothalonil) Many brands available.	M5	SEE INDIVIDUAL LABELS		0	Use higher rates at fruit set and lower rates before fruit set, see label
	Cabrio (pyraclostrobin)	11	16 oz	96 oz	0	Disease suppression only. ONly 1 sequential appl. allowed. limit is 6 appl/crop. Must alternate or tank mix with a fungicide from a different FRAC group, see label.
	Maxim (fludioxonil)	12	0.16 fl oz/100 lbs of seed			Seed treatment for protection against seed-borne and soil-borne fungi. See label.
	Par-Flo 4F (PCNB)	14	12 fl oz/ 100 gal	2 apps	Soil drench	Limited to only container-grown plants in nurseries or greenhouse; See label.
Septoria Leaf Spot	(copper compounds) Many brands available.	M1	SEE INDIVIDUAL LABELS		0	Mancozeb or maneb enhances bactericidal effect of fix copper compounds. See label for details. **Be aware that reentry intervals have changed for many copper compounds.
	(maneb) Many brands available.	M3			5	*Bacterial spot control only when tank mixed with a copper fungicide. See label for details.
	(mancozeb) Many brands available.	M3			5	
	Ziram 76DF (ziram)	M3	4 lbs	23.7 lbs	7	Do not use on cherry tomatoes. See label for details.
	Cuprofix MZ Disperss (mancozeb + copper sulfate)	M3 / M1	7.25 lbs	55.2 lbs	5	See label
	ManKocide (mancozeb + copper hydroxide)	M3 / M1	5 lbs	112 lbs	5	See label

	Inspire Super (difenoconazole + cyprodinil)	9 / 3	20 fl oz	47 fl oz	0	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 ; see label.
	Fontelis (penthiopyrad)	7	24 fl oz	72 fl oz	0	Begin application on a 7- to 14-day interval prior to disease development. Alternate with non-FRAC code 7 fungicdes, see label. Labeled for greenhouse production.
	Amistar 80 DF (azoxystrobin)	11	2 oz	12 oz	0	Must alternate or tank mix with a fungicide from a different FRAC group; use of an adjuvant 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; see label.
	Heritage (azoxystrobin)	11	3.2 oz	1.6 lbs	0	
	Quadris FL (azoxystrobin)	11	6.2 fl oz	37 fl oz	0	
	Reason 500 SC (fenamidone)	11	8.2 oz	24.6 lbs	14	Must alternate with a fungicide from a different FRAC group. See supplemental label for restrictions and details.
	Cabrio 2.09 F (pyraclostrobin)	11	12 fl oz	96 fl oz	0	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.
	Flint (trifloxystrobin)	11	4 oz	16 oz	3	Only suppresses Septoria leaf spot. Limit is 5 appl/crop. Must alternate or tank mix with a fungicide from a different FRAC group, see label.
	Quadris Opti (azoxystrobin + chlorothalonil)	11 / M5	1.6 pts	8 pts	0	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.
	Quadris Top (azoxystrobin + difenoconazole)	11 / 3	8 fl oz	47 fl oz	0	Do not apply until 21 days after transplant or 35 days after seed-ing. 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.
	Tanos (famoxadone + cymoxanil)	11 / 27	8 oz	72 oz	3	Do not alternate or tank mix with other FRAC group 11 fungicides. See label for details
	Gavel 75DF (zoaximide + mancozeb)	22 / M3	2 lbs	16 lbs	5	See label. Addition of a Latron surfactant will improve perfor-mance.
	Revus Top (mandipropamid + difenoconazole)	40 / 3	7 fl oz	28 fl oz	1	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
Southern Blight	Aftershock Evito (fluoxastrobin)	11	5.7 fl oz	22.8 fl oz	3	Limit is 4 appl/crop. Must alternate or tank mix with a fungicide from a different FRAC group, see label.
	Cabrio (pyraclostrobin)	11	16 oz	96 oz	0	Disease suppression only. Only 1 sequential appl. allowed. Limit is 6 appl/crop. Must alternate or tank mix with a fungicide from a different FRAC group, see label.
	Blocker 4F Terraclor 75 WP (PCNB)	14	See label	See label	Soil treat-ment at planting	See label for application type and restrictions
Target Spot (Corynespora cas-siicola)	(chlorothalonil) Many brands available	M5			0	Use higher rates at fruit set and lower rates before fruit set, see label
	Ridomil Gold Bravo 76.4 W (chlorothalonil + mefenoxam)	4 / M5	3 lbs.	12 lbs	14	Limit is 4 appl./crop, see label
	Endura (boscalid)	7	3.5 oz	21	0	Limit is 6 apps per season at rates less than 3.5 oz/A. Alternate with non-FRAC code 7 fungicides, see label. Resistance to FRAC 7 fungicides has been detected for the causal agent of this desease in Florida.
	Inspire Super (difenoconazole +cyprodinil)	3 / 9	20 fl oz	47 fl oz	0	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
	Amistar 80 DF (azoxystrobin)	11	2 oz	12 oz	0	Must alternate or tank mix with a fungicide from a different FRAC group; use of an adjuvant 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; see label. Resistance to FRAC 11 fungicides has been detected for the causal agent of this disease in Florida.
	Heritage (azoxystrobin)	11	3.2 oz	1.6 lbs	0	
	Quadris FL azoxystrobin)	11	6.2 fl oz	37 fl oz	0	
	Cabrio 2.09 F (pyraclostrobin)	11	12 fl oz	96 fl oz	0	Only 2 sequential appl. Allowed. Limit is 6 appl/crop. Must alter-nate or tank mix with a fungicide from a different FRAC group, see label. Resistance to FRAC 11 fungicides has been detected for the causal agent of this desease in Florida.
	Aftershock Evito (fluoxastrobin)	11	5.7 fl oz	22.8 fl oz	3	Limit is 4 appl/crop. Must alternate or tank mix with a fungicide from a different FRAC group, see label. Resistance to FRAC 11 fungicides has been detected for the causal agent of this desease in Florida.

	Quadris Opti (azoxystrobin + chlorothalonil)	11 / MS	1.6 pts	8 pts	0	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. Resistance to FRAC 11 fungicides has been detected for the causal agent of this desease in Florida.
	Quadris Top (azoxystrobin + difenoconazole)	11 / 3	8 fl oz	47 fl oz	0	Do not apply until 21 days after transplant or 35 days after seed-ing. 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. Resistance to FRAC 11 fungicides has been detected for the causal agent of this desease in Florida.
	Tanos (famoxadone + cymoxanil)	11 / 27	8 oz	72 oz	3	Do not alternate or tank mix with other FRAC group 11 fungicides. See label for details. Resistance to FRAC 11 fungicides has been detected for the causal agent of this desease in Florida.
	Revus Top (mandipropamid + difenoconazole)	40 / 3	7 fl oz	28 fl oz	1	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
Timber Rot, Sclerotinia stem rot, or White mold (Sclerotinia sclero-tiorum)	Cabrio 2.09F (pyraclostrobin)	11	16 fl oz	96 fl oz	0	Disease suppression only. Only 1 sequential appl. allowed. Limit is 6 appl/crop. Must tank mix with a fungicide from a different FRAC group, see label.

[1]FRAC code (fungicide group): Numbers (1-44) and letters (M, NC, U, 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. M = Multi site inhibitors, fungicide resistance risk is low; NC = not classified, includes mineral oils, organic oils, potassium bicarbonate, and other materials of biological origin; U = Recent molecules with unknown mode of action; P = host plant defense inducers. Source: FRAC Code List 2011; 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 list-ing 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 Natural Disease Control Products

Ordered alphabetically by commercial name. (Updated June 2012).

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

Chemical (active ingredient)	Fungicide Group[1]	Maximum Rate/Acre/ Applic.	Pertinent Diseases or Pathogens	Remarks[2]
Actinovate (*Streptomyces lydicus* WYEC 108)	NC	See label	See label	See label for details. OMRI listed
AgriPhage (bacteriophage)	NC	2 pts /100gal.	Bacterial spot Bacterial speck	See label for details.
Armicarb 100 Armicarb "O" (Potassium bicarbonate)	NC	5 lbs/ 100 gal	Anthracnose Botrytis Phoma Powdery mildew Septoria leaf spot	See label for details.
Cease (*Bacillus subtilis* strain QST 713)	44	6 qts/ 100 gal.	Bacterial spot Bacterial speck Botrytis Early Blight Late Blight Powdery mildew Target spot	For foliar applications mix with copper compounds or other effective fungicides.
		8 qts/ 100 gal.	*Rhizoctonia* spp. *Pythium* spp. *Fusarium* spp. *Verticillium* spp. *Phytophthora* spp.	Compatible with soil drench and in-furrow applications. See label for details. OMRI listed.
JMS Stylet-Oi (paraffinic oil)	NC	3 qts.	Potato Virus Y Tobacco Etch Virus Cucumber Mosaic Virus	See label for restrictions and use (e.g. use of 400 psi spray pressure)
Kaligreen (Potassium bicarbonate)	NC	3 lbs	Powdery mildew	See label for details.
Milstop (Potassium bicarbonate)	NC	5 lbs/ 100 gal	Anthracnose *Alternaria* spp. Botrytis Powdery mildew Septoria leaf spot	See label for details.
Oxidate (hydrogen peroxide)	NC	1 gal/ 100 gal	*Alternaria* spp. Anthracnose Bacterial speck Bacterial spot Botrytis Early blight Late blight *Phytophthora* spp. Powdery mildew *Pythium* spp. Rhizoctonia	See label for additional rates and recommendations for transplant production and details for specific diseases.
Oxidate (hydrogen peroxide)	NC	1.25 fl oz/ gal	*Fusarium* spp. Rhizoctonia *Phytophthora* spp. *Pythium* spp.	Use as a soil drench at transplant and periodically throughout the season. Can also be used as a seed treatment. See label for details.
PlantShield HC (*Trichoderma harzianum* Rifai strain KRL-AG2)	NC	5 oz	*Fusarium* spp. Rhizoctonia *Pythium* spp.	Can be applied to plant as a direct drench, furrow spray, chemigation, or in transplant starter solution. See label for details. OMRI listed.
Regalia SC (Extract of *Reynoutria sachalinensis*)	NC	1 % (v/v)	Bacterial canker Bacterial speck Bacterial spot Botrytis Early blight *Phytophthora* spp. Powdery mildew Target spot Late blight	Tank mix at 1-4 qts/A with other effective fungicides for improved disease control under heavy pressure. See label for details. OMRI listed.
Rhapsody (*Bacillus subtilis* strain QST 713)	44	6 qts/ 100 gal.	Bacterial speck Bacterial spot Botrytis Early Blight Late Blight Powdery mildew Target spot	For foliar applications mix with copper compounds or other effective fungicides for improved disease control. See label for details. OMRI listed.

RootShield Granular (*Trichoderma harzianum* Rifai strain KRL-AG2)	NC	12 lbs/A 1.5 lbs/ Cubic yard	*Fusarium* spp. Rhizoctonia *Pythium* spp.	Can be applied in furrow in the field. Applied to greenhouse planting mix. See label for details. OMRI listed.
RootShield WP (*Tricho-derma harzianum* Rifai strain KRL-AG2)	NC	5 oz/ 100 gal 32 oz	*Fusarium* spp. Rhizoctonia *Pythium* spp.	Can be applied as a greenhouse soil drench, or by chemigation in field and greenhouse operations. In furrow or transplant starter solution.
Serenade Max (*Bacillus subtilis* strain QST 713)	44	3 lbs	Bacterial speck Bacterial spot Botrytis Early Blight Late Blight Powdery mildew Target spot	For foliar applications mix with copper compounds or other effective fungi-cides for improved disease control. See label for details. OMRI listed.
Serenade ASO (*Bacillus subtilis* strain QST 713)	44	6 qts	Bacterial speck Bacterial spot Botrytis Early Blight Late Blight Powdery mildew Target spot	For foliar applications mix with copper compounds or other effective fungi-cides for improved disease control. See label for details. OMRI listed.
Serenade Soil (*Bacillus subtilis* strain QST 713)	44	6 qts soil drench 13.2 floz/ 1,000 row foot in furrow	*Fusarium* spp. *Phytophthora* spp. *Pythium* spp. *Rhizoctonia* spp. *Verticillium* spp.	Formulation compatible with soil drench, in-furrow, and chemigation ap-plications. Mix with other effective fungicides for improved disease control. See label for details. OMRI listed.
Sil-Matrix (Potassium silicate)	NC	4 qts	Broad spectrum fungicide	Must be used in a rotational program with other fungicides when conditions are conducive for disease development. See label for details. OMRI listed
Soilgard 12G (*Gliocladium virens* GI-21)	NC	2 lb/ 100 gal\ Transplant production; Drench 10 lb/ 100 gal Drench; directed spray; chemiga-tion	Fusarium root and crown rot *Phytophthora capsici* *Pythium* spp. Rhizoctonia *Sclerotinia* spp. *Sclerotium* spp.	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. OMRI listed
Sonata (*Bacillus pumilus* QST 2808)	NC	4 qts	Early Blight Late Blight Powdery mildew	Mix or alternate with other effective fungicides for improved disease control. See label for details. OMRI listed.
Sporatec (oils of clove, rosemary and thyme)	NC	3 pts /100 gal	Bacterial spot Botrytis Early blight Gray mold Late blight Powdery mildew	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. OMRI listed
Tenet (*Tricholdrma asperellum* ICC 012; *Trichoderma gamsil* ICC 080)	NC	5 lbs	*Fusarium* spp. *Phytophthora* spp. *Pythium* spp. *Rhizoctonia* spp. *Sclerotium* rolfsii *Sclerotinia* spp. *Thielaviopsis* basicola *Verticillium* spp.	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 incompatability.
Terraclean (hydrogen dioxide)	NC	See label	Soilborne plant pathogens caused by species of *Fusarium*, *Phytophthora*, *Pythium* and *Rhizoctonia*	Can be applied by flood irrigation, drip irrigation or as a soil drench. See label for application details.
Trilogy (clarified hydrophobic extract of neem oil)	NC	1 % v/v solution	*Alternaria* spp. Anthracnose Botrytis Early blight Powdery mildew	See label for details. May cause leaf burn if applied during high tempera-tures. Avoid tank mixes with sulfur, chlorothalonil, or other chemically similar products. OMRI listed
Vacciplant (laminarin)		14.4 fl oz	Anthracnose, Bacterail speck, Bacterial spot, Early blight, Phytophthora blight, Powdery mildew	Start applications preventively, when weather conditions are favorable for disease development. Repeat applications until disease conditions end. Add a copper product to VacciPlant if the disease symptoms appear.

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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 (bif-enazate)	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, stink-bugs, 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	11	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	3	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	3	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)	3	(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.
Biobit HP (Bacillus thuringiensis subspecies kurstaki)	0.5-2.0 lb	4	0	caterpillars (will not control large armyworms)	11	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	3	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.
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	11	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	3	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	11	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)	4EC: 0.5-1.0 pt	48	7	aphids, leafhoppers, leafminers	1B	Will not control organophosphat e-resistant leafminers.
DiPel DF (Bacillus thuringiensis subspecies kurstaki)	0.5-2.0 lb	4	0	caterpillars	11	Treat when larvae are young. Good coverage is essential. Can be used for organic production.
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	3, 4A	Do not exceed a total of 19.0 fl oz per acre per season. See label for limites on each active ingredient.
Entrust (spinosad)	0.5-2.5 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 9 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).
Intrepid 2F (methoxyfenozide)	4-16 fl oz	4	1	beet armyworm, cabbage looper, fall armyworm, hornworms, southern armyworm, tomato fruitworm, true armyworm, yellow-striped armyworm, suppression of tomato fruitworm and tomato pinword	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)	11	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.	3	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	3	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]	3	[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	3	Pyrethrins degrade rapidly in sunlight. Thorough coverage is important. ORMI-listed[2]
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.
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 0.32EC (novaluron)	9-12 fl oz	12	1	armyworms, Colorado potato beetle, foliage feeding caterpillars, loopers, tomato fruitworm, tomato hornworm, tomato pinworm, stink bugs, thrips, whiteflies	15	Do not apply more than 36 ft oz per acre per season. Minimum of 7 days between applications.
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.
Synapse WG (flubendiamide)	2-3 oz	12	1	armyworms, hornworms, loopers, tomato fruitworm	28	Do not apply more than 9 oz/acre per season.
*Telone C 35 (dichloropropene + chloropicrin) *Telone II (dichloropropene)	See label	5 days (See label)	preplant	garden centipedes (symphylans), wireworms	--	See supplemental label for restrictions in certain Florida counties.
*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, yellow-striped 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.
*Vydate L (oxamyl)	foliar: 2-4 pt	48	3	aphids, Colorado potato beetle, leafminers (except Liriomyza trifolii), 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)	3	(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	11	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. 6.1 August 2008.

1A. Acetyl cholinesterase inhibitors, Carbamates (nerve action)
1B. Acetyl cholinesterase inhibitors, Organophosphates (nerve action)
2A. GABA gated chloride channel antagonists (nerve action)
3. Sodium channel modulators (nerve action)
4A. Nicotinic acetylcholine receptor agonists (nerve action)
5. Nicotinic acetylcholine receptor allosteric activators (nerve action)
6. Chloride channel activators (nerve and muscle action)
7A. Juvenile hormone mimics (growth regulation)
7C. Juvenile hormone mimics (growth regulation)
9B and 9C. Selective homopteran feeding blockers
10. Mite growth inhibitors (growth regulation)
11. 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)
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

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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.