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Diversity of Begomoviruses in Florida

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Introduction

Unfortunately we have learned over the two decades that emerging pathogens pose some of the biggest threats to Florida agriculture. The most damaging are often those that are new to Florida. They arrive quietly through various means and points of entry, and then seem to appear overnight in epidemic proportions. Begomoviruses (whitefly-transmitted geminiviruses) have accounted for several of these emerging pathogens in Florida. The genus *Begomovirus* is now considered the world's largest genus of viruses. As of November 2010, more than 300 species of begomoviruses had been recognized, and many more are in the process of recognition. Although accurate yield loss estimates are rarely collected, many of these begomoviruses are recognized as limiting factors in the production of tomato, pepper, squash, melon, and cotton in the subtropics and tropics.

Emerging Begomoviruses in Florida

While begomoviruses had been observed in Florida in wild plant species for many years they were not a concern for Florida vegetable growers. However, from the late 1980's until the present time, new begomoviruses have appeared several times in vegetable crops. While some of these new viruses were introductions from other locations (ex. *Tomato yellow leaf curl virus, Cucurbit leaf crumple virus*) the source of others (ex. *Tomato mottle virus, Bean golden yellow mosaic virus, Cabbage leaf curl virus*) is less clear (Table 1). We do know that the introduction of a new whitefly, Biotype B, which had a host range that included tomato as well as many other plants, may have pulled undescribed viruses from other plant species and put them for the first time into tomato. It may also have permitted the formation of new tomato viruses through a mechanism called recombination, the exchange of parts of genomes from one virus to another. It has been shown in several locations that new begomoviruses can be created by a combination of mutation and recombination (when several begomoviruses infecting the same plant exchange parts of their DNA genome as they replicate). Whiteflies then feed on that plant and pick up the original viruses plus any recombined viruses, and then feed on new hosts. Sometimes the recombined virus is able to replicate in the new host, and a new pathogen is created.

Management of Emerging Begomoviruses

Whether introduced or created, it appears that-plants infected with new begomoviruses start at low concentrations and build up slowly in the agro ecosystem. Currently growers and researchers must wait for an epidemic of a virus to occur before they know that a new begomovirus is present. Our current approach to management is not very efficient and sets us up for epidemic after epidemic. Often new viruses can be hidden due to the presence of other viruses, which mask the symptoms. A recent example of this in Florida is the case of *Cucurbit leaf crumple virus* and *Cucurbit yellow stunting disorder virus*. These viruses were probably present in the state for at least a year or more before they manifested in epidemics. A method which would give an early warning would allow growers to increase their levels of whitefly control and delay the onset of the epidemics. In contrast, early detection of TYLCV in 1997 by UF researchers allowed them to alert the tomato industry, which was able to rapidly respond with appropriate management tactics. This rapid response delayed the development of high incidences of TYLCV-infected plants for several years, mitigating losses during that time and giving researchers time needed to develop improved management tools for growers. Since no one likes surprises when it comes to pest management, a baseline of what viruses are present in the ecosystem would be very helpful to know what viruses are already present and which ones are potential problems.

Table 1. Known begomoviruses in Florida 2010.

Origin of Virus	Begomovirus Name	Year of Recognition
Presumed Native Begomovirus	Tomato mottle virus	1989
	Sida golden mosaic Florida virus	1994
	Cabbage leaf curl virus	1995
	Sida golden mottle virus	1997
	Dicliptera yellow mottle virus	2000
	Macroptilium yellow mosaic Florida virus	2003
	Chenopodium leaf curl virus	2003
Introduced Begomovirus	Bean golden yellow mosaic virus	1993
	Tomato yellow leaf curl virus	1997
	Cucurbit leaf crumple virus	2007

Identification of Begomoviruses

Traditionally the recognition and characterization of viruses was accomplished by long term intensive studies that required sampling and testing large numbers of wild and crop plant species for the presence of begomoviruses. Positive samples were then treated to more in-depth analyses: the viruses present were then cloned, sequenced and compared with known viruses. If the plant studied could be located, cuttings could be taken and propagated to create a live culture, and host range studies using that new plant plus whiteflies might be conducted. In this way researchers were able to identify several new viruses in Florida, *Sida golden mosaic virus, Sida golden mottle virus, and Macroptilium yellow mosaic Florida virus* (Table 1). However this procedure was tedious and slow and restricted the number of viruses that could be identified. Preliminary studies indicate that there are one or more uncharacterized DNA viruses in a number of weeds in Florida – *Sida spp., Chenopodium spp., Euphorbia prunifolia, Rhynchosia minima*, to name just a few. The presence of begomovirus-like symptoms in wild plant species suggests that we might know the identity of less than 20% of the begomoviruses present in Florida. A faster and more efficient approach was clearly needed to determine what begomoviruses are present in Florida.

Development of a New Approach to the Identification of New Begomoviruses

We developed and tested a new approach to determine what begomoviruses are present. Instead of sampling hundreds of plants, we collected adult whiteflies from two fields, one at Citra and one in Homestead, FL. We thought that whiteflies, which can live for many weeks, are able to feed on many plant species and which are highly mobile and capable of feeding on many different plants, could do the virus sampling for us. We purified begomovirus particles from the two collections of whitefly, extracted the DNA, amplified and fragmented the DNA into 100-700 nt pieces, cloned and then sequenced the pieces of DNA. We call this approach, Vector-enabled metagenomics (VEM). (Metagenomics is the identification of all the viruses in a given ecosystem.) Our thinking was that the begomoviruses present in the environment would also be found in the whiteflies and that we could rapidly identify the begomoviruses present in the area where whiteflies were collected.

We examined 58 virus sequences obtained from Citra whiteflies and 158 from Homestead whiteflies using the VEM approach. The results are discussed below.

Results from the Whiteflies Collected from Citra

The VEM approach indicated the presence of two viruses in the Citra whiteflies: *Cucurbit leaf crumple virus* (CuLCrV) and *Sida golden mosaic virus* (SiGMV) (Table 2, Category A). There were many sequences of CuLCV, so many in fact that we could assemble almost the entire genome of CuLCrV from these short sequences. In previous studies we had found both CuLCrV and SiGMV at Citra through traditional approaches so the results of the VEM study were consistent with what we already knew. Although we only know of one strain of CuLCrV, this study suggests that there may be more strains or viruses closely related to CuLCrV at Citra (Table 2, Category B). Further work will need to be conducted to determine their identity. The VEM study did identify two sequences that are most likely those of new viruses (Table 2, Category C). These sequences are not closely related to any begomoviruses known in Florida or elsewhere. We conducted further studies on the sequence that was distantly related to *Tobacco leaf rugose virus*, a virus described from Cuba. We collected over 100 plant samples and found the virus that the sequence came from in a wild plant, *Chenopodium ambroisiodes*. We obtained the full sequence of this new virus, and have named it *Chenopodium leaf curl virus*. This proves that this sequence was that of a unique virus, and that this VEM approach does reflect the diversity of the virus population. In just a few sequences from whiteflies from Citra we found sequences of 3 unique begomoviruses, two of which were previously known and one of which was new.

Table 2. Results from whiteflies collected from Citra, Fla.

Begomovirus with Most Similar Sequence	No. of DNA Fragments		
	Category A Sequence same as virus	Category B Sequence of a closely related strain	Category C Sequence of a different virus
Known Begomovirus in Florida			
Cucurbit leaf crumple virus	34	8	
Sida golden mosaic virus	2		
New Begomovirus			
Cucurbit leaf crumple virus			1
Tobacco leaf rugose virus			1

Table 3. Results from whiteflies collected from Homestead, Fla.

Begomovirus with Most Similar Sequence	No. of Viral DNA Fragments		
	Category A Sequence same as virus	Category B Sequence of a closely related strain	Category C Sequence of a different virus
Known Begomovirus			
Macroptilium golden mosaic virus	1	4	
Sida golden mosaic virus	34	6	
Tomato yellow leaf curl virus (monopartite)	50	10	
Known Virus Not Reported in Florida			
Malvastrum yellow mosaic Helshire virus	3	7	
Malvastrum yellow mosaic Jamaica virus		2	
Sida golden yellow vein virus (monopartite)	9	1	
Wissadula golden mosaic virus		1	
New Begomovirus			
Anodageminivirus (uncharacterized virus)	1		
Macroptilium golden mosaic virus			3
Sida golden mosaic virus			12
Malvastrum yellow mosaic Helshire virus			1
Malvastrum yellow mosaic Jamaica virus			1
Sida golden yellow vein virus (monopartite)			1
Tomato yellow leaf curl virus (monopartite)			2
Wissadula golden mosaic virus			1

Results from the Whiteflies Collected from Homestead

Using the same approach, although increasing the number of sequences studies to 140, we examined the diversity of begomovirus sequences from whiteflies collected from a tomato field in Homestead. We found much greater diversity of viral sequences from Homestead than from Citra. Many of the sequences were those of viruses already known from Homestead. Fifty of the sequences (or 32%) were from *Tomato yellow leaf curl virus* (TYLCV) and 34 (or 22%) were of *Sida golden mosaic virus* (SiGMV), two viruses that infect a large number of plants in this area (Table 3, Category A). TYLCV is known to infect tomato and SiGMV is known to infect various species of the wild plant/weed, Sida. We found one sequence belonging to Macroptilium golden mosaic virus (MaGMV), a virus found in a wild plant (Macroptilium lathyrodies) and known to occur in Homestead. In addition, we found sequences that suggest the presence of strains of SiGMV (10 sequences) and MaGMV (4 sequences), which is not surprising since these viruses are known to produce variants in their wild plant hosts. However we also found 10 sequences which suggest the presence of viruses closely related to TYLCV, which is an unexpected finding (Table 3, Category B). These most likely represent strains of TYLCV, although they could possibly represent the presence of other viruses closely related to TYLCV. To date, only one strain of TYLCV has been recognized in Florida. Further work will be required to determine the significance of these sequences.

We found sequences of viruses that have never been reported from Florida but have been found in the Caribbean. Nine sequences were those of *Sida golden yellow vein virus* (SiGYVV) and 3 sequences were those of *Malvastrum yellow mosaic Helshire virus*, 2 viruses not ever reported from Florida. Eleven sequences were similar to either of 2 Caribbean viruses (*Malvastrum yellow mosaic Jamaica virus, Wissadula golden mosaic virus*) and may represent the presence of strains of these viruses or possibly unique viruses (Table 3, Category B). Again, further work will be required to determine the significance of these sequences.

We found 21 sequences that are definitely begomoviruses but are only distantly related to any known begomovirus (Table 3, Category C). These sequences most likely represent currently undescribed and unique begomoviruses. These sequences may represent an additional 10-15 new viruses. Further work, similar to that at Citra, will need to be conducted to determine the identity of the viruses suggested by these partial sequences.

Based on these VEM results we have confirmed the presence of 5 begomoviruses in these whiteflies, two of which were unknown in Florida previous to this study. In addition, further research on these sequences are likely to reveal the presence of 10 - 15 unique begomoviruses. We have also found evidence for the presence of new strains of TYLCV, which have not been reported before from any location.

Discovery of Satellites of Begomoviruses in Florida

In addition to discovering the presence of many new begomoviruses, we found eight unique satellites of begomoviruses. Satellites are parasites of a virus, they rely on the "helper" virus for their continued existence. They are much smaller than begomoviruses, their helper virus but like begomoviruses they do have a circular ssDNA genome. They are completely dependent upon begomoviruses for their replication, movement and transmission, and are encapsulatedin the virus coat protein produced by begomoviruses. Their genome sequence is very different from that of any begomovirus. In some cases they play significant roles in disease development and the appearance of new diseases. The satellites we found are very different in sequence and size from any reported anywhere in the world, but are closest in size to a satellite reported in tomato from Australia. This is the first finding of any begomovirus satellites in the US. We are currently working on these satellites to determine which viruses they are associated with and what role they play in disease in tomato in Florida.

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Insecticides and Resistant Varieties for Management of Whiteflies and TYLCV

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Tomato yellow leaf curl virus (TYLCV) has been a major concern for Florida tomato growers ever since its first appearance in 1994. Yield losses are correlated with earliness of symptom expression and may reach 90% if symptoms appear within the first few week of transplanting (Schuster et al., 1996). Important cultural controls include use of clean transplants, crop removal and field sanitation followed by a crop free period between crops to reduce vector and virus inoculum. Insecticidal control of the whitefly vector, *Bemisia tabaci*, is usually effective but not always sufficient to avoid losses. The use of TYLCV-resistant (R) varieties provides added insurance against virus-induced losses that can be critical during a high whitefly/TYLCV year.

Making the correct choice of which varieties to plant each year is a cornerstone of a successful tomato industry. The University of Florida/SWFREC TYLCV-R variety testing program provides unbiased information about the adaptability and performance of tomato varieties in Florida's diverse environments, thereby allowing growers to make informed decisions (http://www.imok.ufl.edu/vegetable_hort/variety_testing/tylcv/). There have been several TYLCV-R variety evaluations in Florida (Gilreath et al., 2000; Scott 2004 and Cushman and Stansly, 2006). The TYLCV-R varieties evaluated produced comparable yields to traditional varieties under low virus pressure and greater yields under high virus pressure (Gilreath et al., 2000; Scott, 2004, Cushman and Stansly, 2006) and more recently by Ozores-Hampton et al., 2008 and 2010. However, resistant varieties have yet to be widely grown in Florida, probably due to a perception of lower fruit quality compared with traditional varieties such as 'Florida 47' and 'Sebring'. Additionally, TYLCV-R varieties should also have resistance to other common diseases such as fusarium crown rot (*Fusarium oxysporum* f.sp. *radicis-lycopersici*) and bacterial spot caused by Xanthomonas species (X. *vesicatoria*, X. *euvesicatoria*, X. *perforans* and X. *gardneri*) prevalent in tomato producing areas. The variety testing program has evaluated the horticultural performance of TYLCV-R tomato varieties available in the USA market today (Ozores-Hampton et al., 2008 and 2010).

Here we report on three field experiments conducted to evaluate the relative contributions of insecticidal control and a resistant variety in managing TYLCV.

Materials and Methods

Variety x Insecticide Trial 2010. Seedlings of a TYLCV resistant variety 'Tygress' and a susceptible variety "BHN-602" obtained from a commercial greenhouse were transplanted at the Southwest Florida Research and Education Center in Immokalee Florida on 23-Mar. Plants were spaced 18-in apart on 2 sets of 3 beds 235 ft in length covered with black polyethylene film mulch after incorporating approximately 25% of the fertilizer (13-2-13 NPK) with the rest injected later as liquid 8-0-8 through drip tape with 4 inch emitter spacing. The center row was left untreated throughout the trial with 8 treatments arranged on the other 4 beds in a randomized complete block (RCB) design. Plots in the four treated rows contained 19 plants, with a single plant left between plots as a buffer. Plots were

Table 1. Treatments and application dates, 2010 trial.

		Application Dates			
Product	**Rate (oz/ac)**	**24-Mar Drench (120 ml/plant)**	**4-May Foliar (60 GPA)**	**18-May Foliar (60 GPA)**	**3-Jun Foliar (80 GPA)**
Untreatead	-				
Admire Pro	7.0	X			
Fulfill	2.75		X		
Courier	9.0			X	X
Thionex	21.0			X	
Coragen	5.0	X			
Fulfill	2.75		X		
Courier	9.0			X	X
Thionex	21.0			X	
Coragen	7.0	X			
Fulfill	2.75		X		
Courier	9.0			X	X
Thionex	21.0			X	
Scorpion	10.3	X			
Fulfill	2.75		X		
Courier	9.0			X	X
Thionex	21.0			X	
Admire Pro	7.0	X			
Movento	5.0		X	X	
Admire Pro	7.0	X			
Oberon	8.5		X	X	
Admire Pro	7.0	X			
Rimon	12.0		X	X	X

Table 2. Treatments and application dates for 2011 foliar trial.

Product	Rate/ac	7-Mar	21-Mar	22-Mar	28-Mar	29-Mar	4-Apr	5-Apr	11-Apr	18-Apr	25-Apr	4-May	9-May
Untreated	-	-	-	-	-	-	-	-	-	-	-	-	-
Venom	4.0 oz			X		X		X					X
Admire Pro	10.5 oz	X											
Fulfill	2.75 oz		X										
Baythroid	2.8 oz				X				X			X	
Thionex 3ec	21 oz						X			X			
Admire Pro	10.5 oz	X											
Fulfill	2.75 oz		X										
Baythroid	2.8 oz				X				X			X	
Thionex 3ec	21 oz						X			X			
Movento	5.0 oz						X			X			
Induce	0.25%						X			X			
Fossil Care	8.0 lbs			X		X		X	X	X	X	X	
Scorpion	3.0 oz		X			X		X			X		X
Scorpion	5.0 oz		X			X		X					X
BYI02960	8.6 oz		X			X	X						
Induce	0.25%		X			X	X						
BYI02960	10.5 oz		X			X	X						
Induce	0.25%		X			X	X						
BYI02960	12.0oz		X			X	X						
Induce	0.25%		X			X	X						
BYI02960	14.0 oz		X			X	X						
Induce	0.25%		X			X	X						
Admire Pro	10.5 oz	X											
Pyrifluquinazon	3.2 oz				X		X		X	X		X	
Induce	0.25%				X		X		X	X		X	

Table 3. Drench and drip applications in 2011.

Product	Rate oz/ac	Applied			
		Method	7-Mar	8-Mar	30-Mar
Untreated	-	-	-	-	-
Venom	6.0	Drip	X		
Venom	6.0	Drench	X		
Admire Pro	10.5	Drench	X		
Admire Pro	10.5	Drench	X		
Durivo	13.0	Drip			X
BYI02960	14.0	Drip		X	
BYI02960	21.0	Drip		X	
BYI02960	28.0	Drip		X	
BYI02960	21.0	Drench	X		

split into two subplots of 9 TYLCV susceptible ('BHN-602') and a resistant ('Tygress') plants separated by a TYLCV symptomatic plant from a local farm to provide virus inoculum.

Applications of Scorpion, Coragen and Admire were made 24-Mar by delivering a 120 ml suspension on the base of the plant using an EZ-Dose® sprayer operating at a pressure of 45 PSI and a flow rate of 3.7 gallons per minute. Foliar sprays (Table 1) were applied with a single row high clearance sprayer operating at 180 psi and 2.3 mph provided with two vertical booms fitted with yellow Albuz® hollowcone nozzles, each delivering 10 gpa. Total spray volume increased as nozzles were added to accommodate plant growth. A standard used for 4 of the treatments consisted of 2.75 oz of Fulfill on 4 May, 9 oz of Courier and 21 oz of Thionex on 18 May, and 9 oz of Courier on 3 Jun.

Whitefly adults were evaluated weekly from 8-April to 9-June on five leaflets from one mid-canopy level true leaf on 4 plants per subplot. Immature stages from 3 plants in each subplot were counted on 4,17,31-May under a stereoscopic microscope from eight 0.5 sq inch discs cut from each of three leaflets of one terminal 7th node trifoliate. Samples on 9 Jun (adults) and 9 and 14 Jun (nymphs) were only obtained from 'Tygress' plants due to severe leaf distortion on TYLCV-infected 'BHN-602' plants. All plants were inspected weekly and the date of symptom appearance recorded. Fruit of marketable size was harvested from 6 plants in each sub-plot on 2 and 16-Jun. Fruit was culled for defects due to stink bug damage, bacterial spot and surface deformities such as shoulder cracking and zippering, number, size, and weight of marketable fruit recorded.

2011 foliar trial — Experimental design and procedures were much the same as the previous year except for some details: the susceptible variety was 'Florida 47', 21 transplants per plot (10 of each variety + one infected plant in the middle) were set 2 Mar, in a RCB design with 12 treatments in 4 beds, each with two lines of drip type dry fertilizer was 10-2-10 NPK and liquid 7-0-7, drenches were applied 7 Mar, and sprays as indicated in Table 2. Adults were evaluated weekly from 23 Mar to 11 May and nymphs on 6, 20 Apr and 4 May. All fruit on 6 plants per plot were harvested 16-May

2011 drench/drip trial — Design was identical to 2011 foliar trial except 9 treatments in four replicates were spread across three beds. Drenches were again applied in a 120 ml suspension using an EZ-Dose® sprayer operating at a pressure of 45 PSI and a flow rate of 3.7 gallons per minute (Table 3). Drip tape was sectioned off within each treated plot, pressurized using a 12 volt pump at 0.23 gpm with 2 L water, followed by 3 L of the appropriate suspension and finally a 3 L water chase. Adults were evaluated weekly from 23 Mar to 11 May and nymphs at 13, 27 Apr and 11 May. All fruit on 6 plants per plot were harvested 13-May.

TYLCV-R variety trial — Seven field variety evaluations were conducted in South Florida during a spring season from 2006 to 2011 (Table 4). TYLCV-R variety evaluations were conducted under commercial growing conditions in multiple locations: Estero, Immokalee and Homestead, with a completely randomized block design. In addition to yields and post-

Table 4. Summary of cultural practices used in tomato leaf curl virus (TYLCV) resistant variety trials from spring 2006 to 2011.

Cultural practices	2006	2007	2008	2009	2010	--------------2011--------------	
Location	Immokalee	Immokalee	Immokalee	Immokalee	Estero	Estero	Homestead
Experimental Design	CRBD (4 reps)	CRBD (4 reps)	CRBD (3 reps)	CRBD (3 reps)	CRBD (4 reps)	CRBD (4 reps)	CRBD (3 reps)
Irrigation	Drip	Drip	Seepage	Seepage	Seepage	Seepage	Drip
Plot size (ft)	21	21	36	37	37	37	37
Harvest unit (ft)	15.0	15.0	18.3	18.3	18.3	18.3	18.3
Planting date	24-Feb-06	20-Feb-07	4-Jan-08	8-Jan-09	7-Jan-10	7-Jan-11	7-Jan-11
Fumigation	MeBr/CP	MeBr/CP	MeBr/CP	MeBr/CP	MeBr/CP	MeBr/CP	MIDAS
Mulch	Black	Black	Black	Metalized/Silver	Metalized/Silver	Black	Black
Linear ft per acre	7,260	7,260	7,260	7,260	7,260	7,260	7,260
Bed height (in)	8	8	9	8	8	8	6
Bed width	32	32	36	32	32	32	35
Bed spacing (ft)	6	6	6	6	6	6	6
Plant spacing (in)	18	18	22	22	22	22	22
Plant population	4,840	4,840	3,967	3,967	3,967	3,967	3,967
Harvest date							
1st	10-May-06	7-May-07	7-Apr-08	21-Apr-09	3-May-10	13-Apr-11	6-Apr-11
2nd	24-May-06	22-May-07	21-Apr-08	6-May-09	18-May-10	26-Apr-11	20-Apr-11
3rd	6-June-06	29-May-07	30-Apr-08	20-May-09	-	4-May-11	29-Apr-11
Planting to last harvest (weeks)	13	13	16	19	17	17	16

Table 5. Number of adult whiteflies per 5 tomato mid-canopy terminal leaflets in 2010 trial.

Products /Rate/ac	Adult whiteflies/five leaflets							
	8-Apr	5-May	12-May	19-May	25-May	1-Jun	9-Jun	ALL DATES
Untreated	0.63 a	2.09 a	2.63 a	1.84 a	3.44 a	4.66 a	3.28 a	1.99 a
Admire Pro + Std	0.09 c	1.56 abc	1.81 b	0.59 c	1.75 bc	1.31 cde	1.21 bc	0.96 bc
Coragen 5.0 oz + Std	0.41 ab	1.47 abc	1.78 b	0.88 bc	2.25 b	1.75 bcd	2.38 ab	1.19 b
Coragen 7.0 oz + Std	0.50ab	1.66 abc	1.72 b	0.56 c	2.34 b	2.28 b	1.81 bc	1.21 b
Scorpion + Std	0.03 c	1.94 ab	1.53 b	0.69 c	1.47 c	1.78 bc	2.38 ab	1.10 b
Admire Pro + Movento	0.41 ab	1.13 c	1.19 b	1.03 bc	1.38 c	0.81 e	1.06 c	0.78 c
Admire Pro + Oberon	0.28 bc	1.28 bc	1.72 b	0.53 c	1.38 c	0.90 de	0.78 c	0.81 c
Admire Pro + Rimon	0.22 bc	1.09 c	1.60 b	1.38 ab	1.41 c	1.66 bcde	0.84 c	0.95 bc

Table 6. Number of nymphs at the 7th node terminal leaflets and TYLCV incidence on 27, May 2010.

Products used/Rate/ac	Nymphs/4 in2				BHN-602 symptomatic for TYLCV (%)
	4-May	17-May	31-May	14-Jun	27-May
Untreated	9.30 ab	33.58 a	51.4 a	50.33 a	86.11 ab
Admire Pro + std	9.08 abc	23.38 ab	24.68 c	23.17 bcd	83.33 ab
Coragen 5.0 oz + std	7.17 abc	26.71 ab	37.00 b	36.58 abc	91.32 ab
Coragen 7.0 oz + std	6.00 c	25.83 ab	27.79 c	37.50 ab	91.67 a
Scorpion + std	2.42 d	11.46 c	12.54 d	34.50 abcd	51.39 c
Admire Pro + Movento	6.63 bc	12.17 c	5.67 d	16.33 cd	63.89 bc
Admire Pro + Oberon	10.04 a	11.67 c	9.50 d	17.33 bcd	75.00 abc
Admire Pro + Rimon	8.71 abc	18.79 bc	21.29 c	14.58 d	63.89 bc

Means followed by the same letter within a column are not statistically different (LSD P>0.05)

Table 7. Yield in 25-lb boxes per acre from treated and untreated 'Tygress' and 'BHN-602' tomatoes, spring 2010.

Cultivar	Treated (Boxes/acre)		Untreated (Boxes/acre)	
Tygress	613	± 31.6	429	± 73.8
BHN-602	1,174	± 51.5	678	± 195.5

harvest quality, we monitored pest and disease incidents.

Results

Variety x Insecticide Trial 2010. Whitefly infestation was initially light due to cold weather including freezes. Fewer adults than the check were seen with all treatments on 8 Apr. except for Coragen drenches and AdmirePro + Movento, whereas only AdmirePro + Movento, Oberon or Rimon provided significant control on 5 May (Table 5). All products provided significant control of adults for the next 5 weeks, although Scorpion and the low rate of Coragen both with the standard sprays failed to do so on 9 Jun. Over all dates, fewest adults were seen with AdmirePro + either Movento or Oberon, although these were not significantly different from AdmirePro + the standard or + Rimon. Nymphs were most reduced on 4 May before sprays were applied by Scorpion, followed by the high rate of Coragen which was not different from one of the 7 oz AdmirePro treatments (Table 6). On 17 May, only applications of Scorpion + the standard or AdmirePro + Movento, Oberon or Rimon provided control. AdmirePro + Rimon provided best con-

Table 8. Number of adult whiteflies per 5 mid-canopy terminal leaflets in 2011 foliar tomato trial.

Product	Rate/ac	Adults/five leaflets							
		23-Mar	30-Mar	6-Apr	13-Apr	20-Apr	27-Apr	4-May	11-May
Untreated	-	0.50 abcde	0.55 a	0.33 a	0.75 a	1.25 b	1.85 a	2.38 ab	0.83
Venom	4.0 oz	0.73 ab	0.33 abcd	0.10 bc	0.33 bcde	1.05 bc	0.78 de	1.75 bcde	1.03
Admire Pro Fulfill Batythroid Thionex 3ec	10.5 oz 2.75 oz 2.8 oz 21 oz	0.15 f	0.25 bcd	0.05 c	0.15 de	0.48 def	0.98 cde	1.08 e	0.65
Admire Pro Fulfill Baythroid Tiohnex 3ec Movento Induce	10.5 oz 2.75 oz 2.8 oz 21 oz 5.0 oz. 0.25%	0.53 abcd	0.23 bcd	0.15 bc	0.18 de	0.10 f	1.03 cde	1.48 cde	0.65
Fossil Care	8.0 lbs	0.75 a	0.55 a	0.40 a	0.40 bcd	1.40 b	1.68 ab	2.05 abcd	0.68
Scorpion	3.0 oz	0.30 def	0.45 ab	0.25 ab	0.55 abc	2.03 a	1.53 abc	2.68 a	0.73
Scorpion	5.0 oz	0.65 abc	0.35 abc	0.10 bc	0.30 cde	0.73 cd	1.40 abc	1.48 cde	0.48
BYI02960	8.6 oz	0.33 def	0.20 bcd	0.05 c	0.43 bcd	0.58 cdef	0.63 e	1.73 bcde	1.33
Induce	0.25%								
BYI02960 Induce	10.5 oz 0.25%	0.20 ef	0.15 cd	0.10 bc	0.43 bcd	0.63 cde	1.13 bcde	2.48 ab	0.93
BYI02960 Induce	12.0 oz 0.25%	0.38 cdef	0.05 d	0.00 c	0.60 ab	0.95 bcd	1.25 abcd	2.13 abcd	1.13
BYI02960 Induce	14.0 oz 0.25%	0.28 def	0.15 cd	0.00 c	0.43 bcd	0.65 cd	1.00 cde	2.23 abc	0.73
Admire Pro Pyrifluquinazon Induce	10.5 oz 3.2 oz 0.25%	0.43 bcdef	0.33 abcd	0.03 c	0.10 e	0.13 ef	1.13 bcde	1.40 de	0.68

Table 9. Number of nymphs per 4 in^2 7th node terminal leaflets in 2011 foliar tomato trial.

Product	Rate/ac	Nymphs/4 in^2		
		6-Apr	20-Apr	4-May
Untreated	-	7.42 a	12.00 a	24.54 a
Venom	4.0 oz	3.21 cd	6.42cd	24.92 a
Admire Pro Fulfill Baythroid Thionex 3ec	10.5 oz 2.75 oz 2.8 oz 21 oz	2.42 d	5.17 de	15.08 bcd
Admire Pro Fulfill Baythroid Thionex 3ec Movento Induce	10.5 oz 2.75 oz 2.8 oz 21 oz 5.0 oz 0.25%	1.29 d	4.28 de	7.08 de
Fossil Care	8.0 lbs	6.13 ab	9.17 bc	18.79 abc
Scorpion	3.0 oz	2.88 d	9.29 ab	22.88 ab
Scorpion	5.0 oz	5.04 bc	5.54 b	21.00 abc
BYI02960 Induce	8.6 oz 0.25%	2.13 d	5.63 d	14.42 cd
BYI02960 Induce	10.5 oz 0.25%	3.17 cd	5.96 d	25.50 a
BYI02960 Induce	12.0 oz 0.25%	2.67 d	5.42 d	20.04 abc
BYI02960 Induce	14.0 oz 0.25%	2.08 d	5.25 d	17.83 abc
Admire Pro Pyrifluquinazon Induce	10.5 oz	1.58 d	2.38 e	5.33 e

trol on 14 Jun although not different the other treatments that included AdmirePro. The other 3 treatments were not different from the check. Only Scorpion + the standard, or AdmirePro + either Movento or Rimon resulted in significant reduction of virus symptoms in the susceptible BHN-602 variety on 27 May. None of the other treatments resulted in lower incidence of TYLCV on that or any other date.

Surprisingly, higher yields of marketable fruit were seen from the susceptible 'BHN-602' plants due to excessive cracking and zippering of 'Tygress' fruit. Greater yields were seen from all treated plants compared to the check, with no differences among insecticide treatments regardless of variety (Table 7).

2011 Foliar Trial: By 6 April, all effective treatments were working, including rotations with AdmirePro, AdmirePro + pyrifluquinizon and BYI02960 . Three oz of Scorpion was not effective against adults though 5 oz was better and about equivalent to 4 oz of Venom except on 27 Apr (Table 8). Two applications of Movento did not improve adult suppression with AdmirePro followed by rotations of Thiodan and Baythroid but did improve control of nymphs (Table 9). Similar levels of control were obtained with Admire followed by pyrifluquinizon and with BYI102960 except for the latter on 4 May. Incidence of TYLCV rose from an average 1.5% on 31 Mar to 98% on 11 May with no significanct differences among any treatments on any one date. No significant treatment effects were seen on yield, although production of 'Tygress' 9582

Table 10. Number of adult whiteflies per 5 mid-canopy terminal leaflets in 2011 drench and drip tomato trial.

Product	Rate oz/ac	Method	Adult Whitefly/five leaflets						
			23-Mar	30-Mar	6-Apr	13-Apr	20-Apr	27-Apr	4-May
untreated	-	-	0.35 a	0.58 ab	0.35 ab	0.73 a	1.45 a	2.03 a	2.38 a
Venom	6.0	Drip	0.33 ab	0.55 abc	0.15 bc	0.45 abc	1.43 a	1.83 ab	1.18 bc
Venom	6.0	Drench	0.23 abc	0.23 cd	0.13c	0.28 bc	1.13 ab	1.43 abc	1.60 b
Admire Pro	10.5	Drench	0.35 a	0.30 bcd	0.15 bc	0.48 ab	1.08 ab	1.93 a	1.50 b
Admire Pro Durivo	10.5 13.0	drench Drip	0.30 abc	0.58 ab	0.18 bc	0.35 bc	1.28 ab	1.95 a	1.30 bc
BYI02960	14.0	Drip	0.23 abc	0.65 a	0.48 a	0.70 a	0.98 abc	1.10 cd	1.53 b
BYI02960	21.0	Drip	0.15 abc	0.53 abc	0.23 bc	0.25 bc	0.80 bcd	1.18 bcd	1.53 b
BYI02960	28.0	Drip	0.10 bc	0.45 abcd	0.20 bc	0.38 bc	0.45 cd	1.38 abc	1.05 bc
BYI02960	21.0	Drench	0.08 c	0.15 d	0.03 c	0.15 c	0.38 d	0.58 d	0.83 c

Table 11. Number of nymphs per 4 in^2 7th node terminal leaflets in 2011 drench/drip tomato trial.

Product	Rate/ac	Method	Number of whitefly nymphs/4 in2		
			13-Apr	27-Apr	11-May
Untreated	-	-	10.83 a	15.67 a	25.71 a
Venom	6.0 oz	Drip	7.13 b	15.79 a	22.79 ab
Venom	6.0 oz	Drench	3.79 de	11.71 ab	24.83 a
Admire Pro	10.5 oz	Drench	6.50 bc	13.13 ab	17.54 bc
Admire Pro Durivo	10.5 oz 13.0 oz	Drench Drip	4.59 cd	11.83 ab	23.54 ab
BYI02960	14.0 oz	Drip	5.21 bcd	14.71 a	22.71 ab
BYI0–2960	21.0 oz	Drip	2.17 ef	7.21 bc	19.42 ab
BYI02960	28.0 oz	Drip	3.13 def	3.88 c	11.92 cd
BYI02960	21.0 oz	Drench	1.38 f	2.33 c	7.50 d

Table 12. Incidence of TYLCV symptomatic plants during 2011 drip/drench trial.

Product	Rate (oz/ac)	Method	% of plants with TYLCV					
			30-Mar	6-Apr	13-Apr	20-Apr	27-Apr	4-May
untreated	-	-	2.5	7.5	20.0 bcd	70.0 ab	90.0	97.5 ab
Venom	6.0	drip	0.0	10.0	32.5 abc	53.8 bc	87.5	90.0 ab
Venom	6.0	drench	0.0	5.0	17.5 cd	40.0 cd	75.0	92.5 ab
Admire Pro	10.5	drench	5.0	13.8	26.9 abc	55.3 bc	73.6	76.7 bc
Admire Pro Durivo	10.5 13.0	drench drip	7.5	17.5	40.0 a	52.5 bc	80.0	90.0 ab
BYI02960	14.0	drip	2.5	17.5	37.5 ab	77.5 a	92.5	100.0 a
BYI02960	21.0	drip	2.5	17.5	32.5 abc	47.5 bc	75.0	95.0 ab
BYI02960	28.0	drip	7.5	10.0	25.0 abc	42.5 c	57.5	77.5 bc
BYI02960	21.0	drench	0.0	0.0	5.0 d	17.5 d	52.5	62.5 c

± 30.2 boxes/ac) was greater than FL-47 (450 ± 26.4 boxes/ac), reflecting the high incidence of TYLCV compared to the previous year.

2011 Drip/Drench: The drench application of BYI02960 at 21 oz was generally the best treatment for controlling adults, even compared to the 28 oz rate applied through drip (Table 10). However, no differences were seen between Venom treatments applied by drip or drench. Drip application of Durivo following the AdmirePro drench did not improve adult control obtained with the drench alone. By 13-Apr, all treatments significantly reduced the number of nymphs when compared to the untreated control, with the Venom drench application outperforming the Venom drip application (Table 11). Likewise, the BYI02960 drench application resulted in fewest nymphs. On 27 Apr, only the 21 oz drench and 28 oz drip applications of BYI02960 were providing significant levels of control. These two were joined by the drench application of AdmirePro on 11-May. Incidence of TYLCV mirrored the foliar trial except for plants treated with the 28 oz drip rate or 21 oz drench rate of BYI02960 which were significantly lower on 2 or 3 sample dates respectively, including the last on 4 May (Table 12). Due to poor weather conditions near harvest and the general health of the plants, most fruit in both varieties were culled, but the total weight was again greater for 'Tygress', 606 ± 31.2 boxes per acre, compared to 466 ± 22.1 boxes per acre for FL-47 with no differences among insecticide treatments.

TYLCV-R Variety Trials: No clear advantage was found by using TYLCV-R varieties under low TYLCV pressure (Ozores-Hampton et al., 2008 and 2010).In contrast, TYLCV-R varieties were observed to produce a high percentage of unmarketable fruit due to blossom end scar, zippering, catfacing, sunscald, yellow shoulders, odd shapes, and radial or concentric cracking compared to susceptible varieties. 'Tygress', 'SVR 200', 'Security 28', 'Charger' and grafted varieties ('BHN 833'/'Tygrees') have proved to be among the best TYLCV-R varieties for the South Florida Spring tomato market (Table 13). These varieties have high marketable x-large fruit and total marketable yield and tower unmarketable fruits, better fruit firmness and intense red color.

Discussion

We saw in 2011, that drench applications of insecticides protected plants from whiteflies and even virus better than drip applications, which in turn were better than foliar sprays. This has been a consistent pattern in our trials over a number of years. Contrasting results from the insecticide x variety trials run in 2010 and 2011 illustrate the different outcomes that can occur depending on growing conditions and their effect on disease incidence. In 2010 virus movement was relatively slow such that many plants escaped infection until late in the season. Furthermore, a wet spring caused high levels of bacterial spot to which 'Tygress' is more susceptible that 'BHN-602'. Consequently, yield from the susceptible variety was better than the TY-resistant variety that year. In contrast, virus incidence rose quickly in 2011 and consequently, 'Tygress' yielded better than the susceptible

Table 13. Best TYLCV-resistant varieties from South Florida during spring 2006 to 2011.

2006 Low TYLCV Pressure	2007 High TYLCV Pressure	2008 Low TYLCV Pressure	2009 Low TYLCV Pressure	2010 Low TYLCV Pressure	2011 Low TYLCV Pressure
Best Varieties					
Immokalee: HA 3075 (Hazera), S-50257, VT-60774, and VT-60780 (Zeraim Gerdera).	Immokalee: 3078, 3074 (Inbar) and 3075 (Ofri) (Hazera) Roma: Shanty (Hazera).	Immokalee: Tygress (Seminis) & 3074 (Inbar) (Hazera). Roma: 5080 (Sakata).	Immokalee: Tygress & SVR200 (Seminis).	Immokalee: Security 28 (Harris Moran) & Charger (Sakata).	Homestead: SVR 200 (Seminis) Estero: SVR (Seminis), Tygress (Seminis,) Grafting BHN 833/ Tygress (BHN/Seminis).
Good Varieties					
Immokalee: BHN 745 & Tygress (Seminis).	Immokalee: Tygress (Seminis).	Immokalee: Security 28 (Harris Moran), BHN 745 and 764, 3091 & 3075 (Ofri) (Hazera), and 5443 (Sakata).	Immokalee: BHN 765, 8845 (Harris Moran).	Immokalee: Katana (Takii) Tygress and SVR 200 (Seminis).	Homestead: Tycoon (Hazera) Estero: RFT 9773 (Syngenta).

variety, FL-47. We know that TYLCV can be managed with resistant varieties; however the lack of consistent fruit quality is a major factor holding back adoption of TYCLV-R varieties by the Florida tomato industry.

Literature cited

Cushman, K and P. A. Stansly. 2006. TYCLV-resistant tomato cultivar trial and whitefly control. Proceedings: Florida Tomato Institute. P. Gilreath [Ed.], Vegetable Crops Special Series, IFAS, U. of Florida, Gainesville, pp. 29-34.

Gilreath, P., K. Shuler, J. Polston, T. Sherwood, G. McAvoy, P. Stansly, and E. Waldo. 2000. Tomato yellow leaf curl virus resistant tomato variety trials. Proc. Fla. State Hort. Soc. 113:190-193.

Schuster, D. J., P. A. Stansly, and J. E. Polston. 1996. Expressions of plant damage Bemisia, pp. 153-165. In D. D. Gerling and R. T. Mayer [eds.], Bemisia 1995: Taxonomy, Biology, Damage, Control, and Management. Intercept Andover, Hants, UK.

Scott J.W. 2004. Tomato Yellow Leaf Curl Resistant Varieties Available Now and Future Outlook from IFAS. P. Gilreath and W. Stall (Eds.). Vegetable Crop Special Series, IFAS, U. of Florida. Gainesville, PRO 521 pp. 15-17.

Ozores-Hampton M.P., E. J. McAvoy, S. Sargent and P. Roberts. by 2010. Evaluation of tomato yellow leaf curl virus (TYLCV) and Fusarium crown rot (FCR) resistant tomato variety under commercial conditions in Southwest Florida. Fla. Tomato Inst. Proc. PRO 527, pp.11-15.

Ozores-Hampton, M.P., G. McAvoy, E.H. Simonne, and P. Stansly. 2008. Evaluation of TYLC virus-resistant varieties under commercial conditions in Southwest Florida. Fla. Tomato Inst. Proc. PRO525, pp.12-17.

Tracking disease and insect pests using Smartphone technology: a new approach for regional (and local) pest management

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Introduction

In early 2007, a meeting of growers, industry representatives, extension agents, and University of Florida faculty was convened to discuss research ideas that would lead to a better understanding and management of Tomato yellow leaf curl virus (TYLCV). Aproject was initiated to characterize regional patterns of whitefly density and virus incidence in southwest Florida tomato production. In 2008, we received funding through the Specialty Crop Research Initiative (SCRI) to support this effort and, in addition, provided funds that allowed us to develop a decision support system designed to optimize decisions regarding the management of whiteflies and TYLCV. For more information on the project, follow the link to the SCRI Home Page (www.nifa.usda.gov/fo/specialtycropresearchinitiative.cfm) and click on the 'Abstracts of Funded Projects' (#2008-04890).

The Problem

For the past four growing seasons, cooperating growers provided us with their scouting reports of whitefly and TYLCV occurrence. The data obtained from the reports covered approximately 24,000 acres of tomato and vegetable production.

The data were used to track and identify regional hot spots with the idea that more intensive scouting could be applied to these areas to identify environmental, geographical and/or management practices that may be linked to TYLCV epidemics as well as to identify alternate hosts that may exist in neighboring fallow fields, hedge rows, or unmanaged fields and forests. The data showed that the severity of TYLCV closely followed the increase in mean whitefly density, as well as the average age of the fields in production. Most importantly, the data showed a strong correlation between both disease and insect pressure of neighboring fields, including 2nd and 3rd order neighbors (i.e., your neighbor's neighbor and their neighbors!). In terms of distance, the data showed that a "hot field" can affect fields within a 1.5 mile radius. Moreover, spatial analysis of the surveyed region showed the existence of hot spots for both whiteflies and virus. But, the whiteflies and virus were not necessarily associated with each other or with a single grower or farm. A prominent hot spot was associated with the central growing area, which is typical given the concentration of production. Smaller hot spots were located around the edges or perimeters of farms and would be good areas to concentrate future surveys of the plant population.

Working Towards a Solution

The spatial analysis of the TYLCV epidemics argues for a greater regional effort in managing whiteflies and TYLCV. To this end, we hired ZedX Inc., (www.zedxinc.com) to develop the technology portion of our so-called decision support system. This decision support system encompasses a web-based and mobile technology platform (WMTP). Users of the WMTP will use their mobile device (i.e., smartphone) to collect and uploadGPS-labeled scouting data (insect, disease, and production information) to a central server where it is processed and then delivered as real-time reports and management recommendations to growers and/or their scouts. The plan for and early development of the WMTP was introduced at last year's Florida Tomato Institutemeeting and we are now in the final phase of developing the WMTP. Since the last meeting, we have refined the smartphone application to function as an all inclusive scouting tool. Once the data has been uploaded and processed, the data can be mapped in variety of formats to allow participating growers to visualize the pest pressure on a regional scale. This will enable growers to manage pests based on a regional, as well as local (e.g., farm), assessment of pest pressure.

The WMTP was developed to be broad and encompass not only TYLCV and whiteflies, but the multitude of insect pests and diseases that affect tomato and the wide variety of crops grown in Florida. The system is also designed to track various management practices that impact insect movement. For example, a drop-down menu prompts the user to enter the field status with choices: In Production, Spray Today, Spray Tomorrow, Harvesting, Harvested, Burned Down, or Not Planted. Once the information is entered and uploaded, the field status can be mapped to show which neighboring fields are in jeopardy of, say, a whitefly influx due to the disturbance of the neighboring field and alerts the grower to protect those fields if they are not currently protected. The WMTP has the capacity to allow scouts to develop field-specific, pest management recommendations that can be delivered directly to growers on their phone or by email. This will be enabled through customizable forms. Lastly, the WMTP will have various security features that will allow only certain data fields to be shared among the community of growers. Thus, the tool can serve the growers needs while also serving the community needs.

Conclusion

Representative growers and scouts have been testing the WMTP to help us fine-tune the system. When fully implemented, this "area wide" approach should ultimately reduce pest and disease pressure within the entire region.

Blossom Drop and Reduced Fruit Set in Tomato

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Blossom drop and reduced fruit set in tomato can seriously impact yields. Growers in Florida routinely experience such problems and inquire about the cause and possible preventative measures to reduce flower loss and improve yields. The problem can be frustrating and difficult to manage under some situations.

Tomato flowers are complete flowers in that they have both male (stamens) and female (pistil) parts within the same flower. The 'yellow' stamens wrap around the 'greenish' pistil in the center of the flower (Mills, 1988). The stamen has two parts: filament and anther and the pistil has three parts: ovary, style and stigma. The style is the long stalk reaching up to the bumpy and sticky stigma, which extends beyond the surrounding stamens. Tomatoes are self-pollinated at the rate of 98% or more. Pollination occurs primarily between 10 am to 4pm during the day (Levy et al., 1978). Tomatoes need biotic or abiotic agents to assist in pollination. Biotic agents include insects such as bees (e.g. bumblebee sonicates for pollination in green-house production). Sonication is the vibration of the wing muscles without flight, causing the whole flower to vibrate, and a cloud of pollen to be released onto the bee's body and at the same time, onto the stigma. Abiotic agents can be wind under open field production or mechanical shaking in green-house production. Shaking by wind or mechanical means stimulates the release of the pollen, which drops down (the blossoms normally hanging downward) through the stamen tube to the stigma (Figure 1). Insect pollinators are not important for pollination of tomatoes grown in open field production (Levy et., 1978; Ozores- Hampton and McAvoy, 2010).

Blossom drop is defined as the loss of flowers (Figure 2). Several factors, usually related to some type of stress, can cause tomato plants to drop their blooms. The stress may be either nutritional, environmental or a combination of the two. However, anything which interferes with the pollination-fertilization process may result in flower loss (Mills, 1988; Levy et al., 1978; Ozores-Hampton and McAvoy, 2010). Without pollination, which stimulates fruit set, the flowers die and drop. This condition can affect tomatoes, peppers, snap beans, and other fruiting vegetables. In tomatoes, blossom drop is usually preceded by the yellowing of the pedicle. Tomato flowers must be pollinated within approx. 50 h (2 days) or they will abort and drop off. This is about the time it takes for the pollen to germinate and travel up the style to fertilize the ovary at temperatures above 55°F.

Potential Causes of Blossom Drop

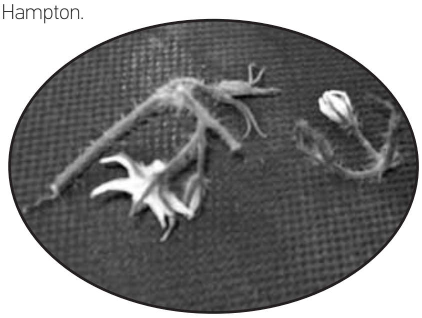
The primary causes of blossom drop in tomatoes are environmental; such as temperature and relative humidity (RH) or cultural; such as the lack or excess of nitrogen (N) fertility. The secondary causes can be lack of water, reduced or extended light exposure, excessive wind, insect damage, foliar disease, excessive pruning or heavy fruit set.

Primary causes of blossom drop

1. Temperature: Under extreme temperature regimes, such as high day-time temperatures (above 85°F), or high night time temperatures (above 70°F), or low night-time temperatures (below 55 °F), tomato plants will drop their flowers (Table 1). Optimal growing conditions for tomatoes are daytime temperatures between 70°F and 85°F. While tomato plants can tolerate more extreme temperatures for short periods, several days or nights with temperatures outside the optimal range will cause the plant to abort flowers and fruit, and focus on survival (Mills, 1988). Temperatures over 104°F for only four hours can cause the flowers to abort. If the night temperatures fall below 55°F or rise above 70°F or if the day temperatures are above 85°F, the pollen becomes tacky and non-viable, then pollination doesn't occur and the blossom dries and drop (Levy et al., 1978; Chester, 2004; Mills, 1988; Ozores-Hampton and McAvoy, 2010).

Figure 1. Open tomato blossoms hanging downward directs the pollen from the anthers to the stigma. Credits: Monica Ozores-Hampton.

Figure 2. Blossom drop on tomatoes, January 2010, Immokalee, FL. Credits: Monica Ozores-Hampton.



Low temperature: Low temperatures interfere with the growth of pollen tubes preventing normal fertilization. The pollen may even become sterile, causing blossoms to drop. Tomato

Table 1. Summary of optimal temperatures for tomato flowering production and fruit set.

Temperature (° F)	Duration	Effect
Daytime		
Over 85° F	Several days	Flower drop and fruit abort
Over 104° F	4 h	Flower drop
Nighttime		
Over 70° F	Several days	Flower drop
Below 55° F	Several days	Flower drop

fruit will not set until nighttime temperature is above 55°F for at least two consecutive nights (Chester, 2004; Ozores- Hampton and McAvoy, 2010).

High temperature: Due to the sustained high temperatures, especially at night, the food reserves in the tomato produced during the day are rapidly depleted. The result is sticky pollen, altered viability and poor or no pollination. Ultimately the blossom dries and falls off. Female flower parts can also undergo morphological changes such drying of the stigma (Mills, 1988; Ozores- Hampton and McAvoy, 2010).

2. Relative Humidity: The ideal RH for tomatoes growth and development ranges are between 40 to 70%. Relative humidity plays major role in pollen transfer. If the RH is lower than optimal, it will interfere with pollen release as the pollen is dry and unable to stick to the stigma and if RH is higher than optimal the pollen will not shed properly. (Mills, 1988; Ozores- Hampton and McAvoy, 2010).

3. Nitrogen: High or low application rates of N fertilizer can cause blossom drop. High rate of N encourages the plant to produced excessive vegetation at the expense of fruit set. Low N produces spindly vines with low food reserves that cannot support a tomato crop (Levy et al., 1978; Chester, 2004; Mills, 1988; Ozores- Hampton and McAvoy, 2010).

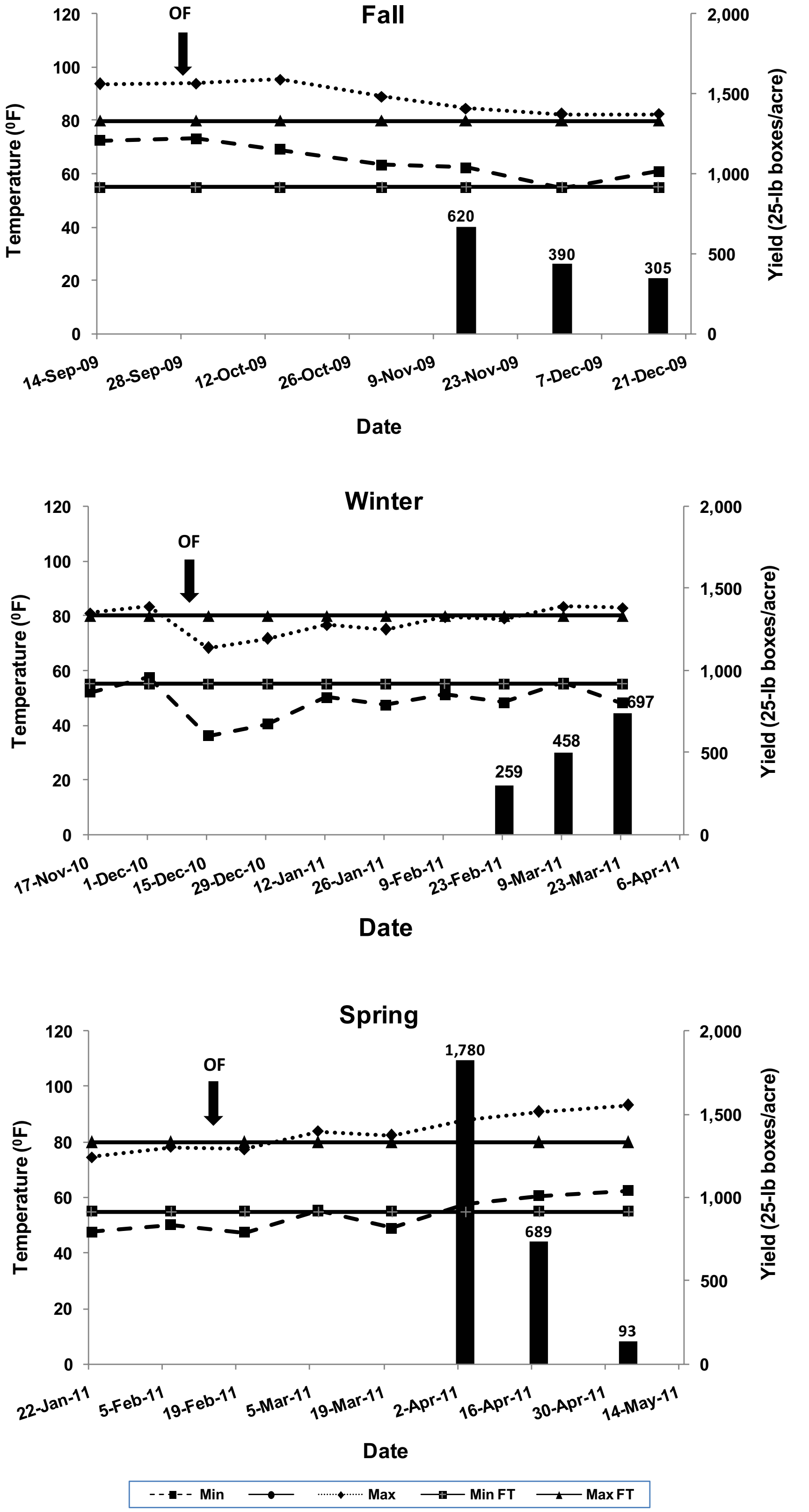
Secondary potential sources of blossom drop

Low or high soil moisture: Tomatoes have deep roots that can penetrate up to five feet. Low soil moisture will stress and weaken the plants. The root zone should be kept uniformly moist throughout the growing season to develop a large root system and reduce plant stress (Chester, 2004; Ozores- Hampton and McAvoy, 2010).

Heavy fruit set: When a tomato plant has produced a large amount of blossoms, the resulting fruits compete for the limited food supplied by the plant. The plant will automatically abort some flowers. Once the initial crop is harvested, the problem should subside as the plant nutritional status comes into balance. (Levy et al., 1978; Mills, 1988; Ozores- Hampton and McAvoy, 2010).

Wind/pruning: Excessive wind will desiccate flowers and/or physically knock off flowers reducing fruit set. Excessive pruning can reduce the amount of energy the plant can produce and thus reduce yield, can expose the tomatoes to

Figure 3. Overview of fall, winter and spring season minimum and maximum temperatures and tomato marketable yields in Immokalee, FL.



*FT = Flower Temperature, OF = Open Flower
Weather data was obtained from Florida Automatoed Weather Network (FAWN) from University of Florida/IFAS, Southwest Florida Research and Education Center in Immokalee, FL.

excessive sun and thus cause sunscald.

Light: Lack of sufficient light or extended exposure to light can reduce fruit set.

Insect damage or disease: Gowers should use adequate cultural practices and control insects and diseases. Fungal diseases such as botrytis or heavy bacterial spot or speck pressure will have a negative effect in fruit set.

Hormone and Tomato Fruit Set

Hormones are natural organic compounds produced in the plant that regulate responses such as bud development, root growth and fruit setting. Hormones can be produced artificially and be applied to regulate plant growth. Hormone treatment can be effective during periods of low night temperature only, but the resulting fruit may be seedless and of poor quality suffering from puffiness and a large blossom end scar (Mingers and Mann, 1949). However, favorable results were obtained when the hormones were applied with hand sprayers directly on the flowers rather than the whole plant (Chen and Henson, 2001). Whole plant application can result in plant injury. Hormone treatments do not increase total marketable yields of tomatoes but can shift a portion of the yield earlier in the season (by increased fruit size). Normally, one application at flower and then 15 days later produced improved flower and fruit set (Chen and Henson, 2001). There are many hormones and nutritional products commercially available that may increase tomato blossom and fruit set, but generally these products do not produce consistent results. Currently at the UF/SWFREC Vegetable Program we are testing commercially available products that may have in effect on tomato and pepper flower and fruits set in growth chambers under high and low temperature and RH.

How to Control Tomato Blossom Drop

1. Grow varieties suited to your climate
2. Ensure pollination
3. Used recommended N rates
4. Water deeply during dry weather
5. Control insect and diseases

High temperatures and low RH: Under controlled production situations (greenhouses), directing a gentle spray of water at the blossoms twice during a hot day will improve flower set when daytime temperatures range between 90° and 100° F and below 75° F at night. The evaporating moisture lowers the temperature, raises the humidity and jars the pollen loose, therefore improving flower set. If daytime temperatures exceed 100°F and night temperatures above 75° F, this technique is not effective.

High temperatures and high RH: Water application to the foliage is not recommended especially when fungus diseases are present.

Post-Pollination Disorders

1. Catface: A condition involving malformation and scarring of fruits, particularly at blossom ends. Affected fruits are puckered with swollen protuberances and can have cavities extending deep into the flesh (Zitter and Reiners, 2004).

Causes: Possible extreme heat, cold weather with night temperatures 58° F or lower at flowering, drought, high N levels, or herbicide injury spray. The tomato varieties with very large fruits are more susceptible (Olson, 2009).

Control: Avoid setting transplants too early in the season, grow catface resistant varieties, and avoid herbicide injury.

2. Zippering: It is characterized by the presence of brown tissue (resembling a zipper) usually running from the stem end to the blossom end due to abnormalities in early flower development (Zitter and Reiners, 2004; Cox et al., 2011)

Causes: The result of an anther remaining attached to newly forming fruit. It is also associated with incomplete shedding of flower petals when the fruit is forming. It may sometimes be attributed to high humidity. In cooler weather, parts of the flower may adhere to the developing fruit and result in zippering (Olson, 2009).

Control: select varieties that are not prone to zippering.

3. Puffiness: Fruit appear bloated, flat-sided or angular leading to oddly shaped fruit. The locular gel (the liquid that surrounds the seeds) fails to fill the fruit's inner cavity resulting in a fruit with flattened sides that lacks firmness (Olson, 2009; Cox et al., 2011).

Causes: Incomplete fertilization or seed development due to cool temperatures, under greenhouse production, lack of vibration or shaking that assists in releasing the blossoms' pollen can result in poor pollination and puffiness. Other factors such as low light or rainy conditions, high N or low K may also contribute to puffiness.

Control: Ensure adequate growing conditions and plant nutrition.

In south Florida, tomatoes are planted continuously between August and February, and growing seasons for tomatoes are typically defined as fall, winter and spring with planting dates between 15 Aug. and 15 Oct., 16 Oct. and 15 Dec., and 16 Dec. and 15 Feb. respectively (Ozores-Hampton et al., 2006). Based on planting season, the length of the growing season averages 18, 20, and 16 weeks for fall, winter and spring, respectively. Historical temperature (average +/- standard deviation, in °F) from a weather station located in Immokalee, FL are 79.6 +/- 1.5, 69.0 +/- 4.4, and 67.4 +/- 6.2 for fall, winter and spring, respectively. Hence, restrictions in marketable tomato yields in the fall planting season are primarily due to temperatures higher than 85°F during the day and 70°F during the night together with high rainfall and RH (Figure 3a). During the winter, temperatures lower than 55°F during the night often lower marketable tomato yields (Figure 3b). In the spring season high marketable tomato yields are due to ideal temperatures during the day and night [70°F and 85°F (Figure 3c)].

In Southwest Florida tomato variety recommendations are normally based on disease packages, especially resistance to soil pathogens prevalent in the area and not on optimal flower and fruit set temperature and RH which is a main driving force for increasing tomato production. Table 2 shows two variety recommendations program for Southwest Florida (with and without fusarium crown rot). The majority of the these varieties were not breed to optimized flower and fruit set production under our weather conditions - hot and wet in the fall and cold and cool in the winter (Ozores-Hampton et al., 2011).

In conclusion, temperature and RH are usu-

Table 2. Tomato variety recommendation based in disease incidence and flower production and fruit setting in Immokalee, FL.

Month	Week 1	Week 2	Week 3	Week 4
	No Fusarium Crown Rot			
August	Phoenix/FL 91	Phoenix/FL 91	Phoenix/FL 91	Phoenix/FL 91
September	FL 91/FL 47	FL 91/FL 47	FL 47	FL 47
October	FL 47	FL 47	FL 47	FL 47
November	FL 47	FL 47	FL 47	FL 47
December	FL 47/Tygress/SVR 200	Fl 47/Tygress/SVR 200	Tygress/SVR 200	Tygress/SVR 200
January	FL 47/Tygress/SVR 200	FL 47/Tygress/SVR 200	FL 47/Tygress/ SVR 200	FL 47/Tygress/SVR 200
	Fusarium Crown Rot			
August	Phoenix	Phoenix	Phoenix	Phoenix
September	Sunkepper/Crown Jewel	Sunkepper/Crown Jewel	Sunkepper/Crown Jewel	Sunkepper/Soraya
October	Soraya/BHN 585	Soraya/BHN 585	Soraya/BHN 585	Soraya/BHN 585
November	Soraya/BHN 585	Soraya/BHN 585	Soraya/BHN 585	Soraya/BHN 585
December	Sebring/BHN 585	Sebring/BHN 585	Sebring/BHN 585	Sebring/BHN 585
January	Sebring/BHN 585	Sebring/BHN 585	Sebring/BHN 585	Sebring/BHN 585

Note: While this list includes a number of varieties currently popular with Florida growers, it is by no means a comprehensive list of all potential varieties that may be adapted to the state under the above conditions.

ally out of the grower's control. Sometimes the only thing you can do is to wait for favorable weather conditions. If weather conditions are optimal and other growers are not having flower and fruit set problems, the grower should consider cultural causes of tomato blossom drop and poor fruit set. Selecting a suitable tomato variety, adequate N fertilizer and water and controlling insect and diseases will potentially insure high tomato yields. In Florida, during the early fall growing season, growers can get around the heat issue by selecting heat tolerant varieties.

References

Chester T. 2004. Tomato harvest versus planting dates. Tom Chester's Webpages. July 12, 2011. Available online at http://tchester.org/analysis/tomatoes/

Cox, B., O. Tilth and T. Coolong. 2011. Management of non-pathogenic fruit disorders of tomato in organic production systems. University of Kentucky, Extension. June 29, 2011. Available online at http://www.extension.org/article/18629

Chen, J. T. and P. Henson. 2001. Summer tomato production using fruit setting hormones. AVRDC February 2001C # 01-511.

Levy, A., H. D. Rabinowitch and N. Kedar. 1978. Morphological and physiological characters affecting flower drop and fruit set of tomatoes at high temperatures. Euphytica. 27: 211-218.

Mills, L.1988. Common tomato disorders under desert conditions. University of Nevada. Cooperative Extension. FS-88-60.
Minges, P. A. and L. K. Mann. 1949. Improving tomato fruit set. California Agriculture. (July): 8-12.

Ozores-Hampton, M., G. McAvoy, S. Olson, K. Cushman, and N. Roe. 2011. Tomato varieties for Florida — Florida "Red Rounds," Plums, Cherries, and Grapes. EDIS HS-1189, June 29, 2011 available online at http://edis.ifas.ufl.edu/hs1189

Ozores-Hampton, M. and G. McAvoy. 2010. What causes blossom drop in tomatoes?. The Tomato Magazine. (August): 4-5.

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.

Olson, Stephen, M. 2009. Physiological nutritional and other disorders of tomato fruit. EDIS HS-954. June 29, 2011. Available online at http://edis.ifas.ufl.edu/hs954

Zitter, T.A. and S. Reiners. 2004. Common tomato fruit disorders. Vegetable MD Online. Cornell University. June 29, 2011. Available online at http://vegetablemdonline.ppath.cornell.edu/NewsArticles/Tom_ComDis.htm

Tomato Breeding at University of Florida: Present Status and Future Directions

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Tomato Yellow Leaf Curl Virus (TYLCV)

Breeding for resistance to TYLCV has been a major goal of the program since 1990. Efforts have focused on resistance derived from several accessions of the wild tomato relative, *Solanum-chilense*, as well as from the cv. Tyking. The UF breeding program was responsible for the identification and deployment of the resistance genes Ty-3 and Ty-4 (Ji et al., 2007; Ji et al., 2009), both of which were introgressed from *S. chilense*. However, these two genes do not alone explain all of the variation for resistance in the program, and it is clear that other important genes have not yet been found. This lack of knowledge with respect to the additional gene(s) has been a major impediment to the development of resistant hybrids.

Recently,Ty-5 was mapped to chromosome 4by Anbinder et al. (2009). We phenotyped and genotyped multiple populations in 2009, and it was determined that a major resistance gene in our program is located in the Ty-5 region. Our Ty-5 "allele" is derived from 'Tyking' and provides a high level of resistance; but since gene action is recessive, it will be needed in both parents of a hybrid (Table 1). Moreover, other studies report on a recessive 'Tyking'-derived resistance allele that is effective against multiple monopartite and bipartite begomoviruses (Bian et al., 2007; Giordano et al., 2005); we hypothesize that these studies also describe this Ty-5 "allele," and we expect this gene will be useful in delaying the emergence of new virus strains that overcome presently used resistances. Our Ty-5 "allele" did not, however, explain all of the resistance in our populations, which is evidenced by the fact that parental levels of resistance or susceptibility were not on average recovered in the F2 population (Table 1); this suggests the presence of another resistance gene in our material.

Table 1. Mean Tomato Yellow Leaf Curl Virus disease severity and genotype at the Ty-5 locus of F_2 tomato progeny and their parents in fall 2009.

Line	Genotype at the Ty-5 locus1	Mean DSI2
Fla. 7547	-/- (Susceptible parent)	4.0^{A} ± 0.0 (n = 18)
Fla. 344	+/+ (Resistant parent)	1.1^{D} ± 0.1 (n = 18)
	+/+	1.8^{C} ± 0.1 (n = 34)
(Fla. 7547 x Fla. 344) F2	+/-	3.4^{B} ± 0.1 (n = 59)
	-/-	3.3^{B} ± 0.1 (n = 28)

[1]Genotype determined by the Ty-5-linked marker, SlNAC1. +/+ homozygous resistant; +/- heterozygous; -/- homozygous susceptible
[2] DSI disease severity index, lower number means less disease; results are displayed as mean ± SE; n number of plants in each group; means with the same letter are not significantly different at P≤ 0.05 based on Duncan's multiple range test.

Table 2. Mean non-viral foliar disease severity of advanced TYLCV-resistant breeding lines as affected by genotype at three resistance loci.

	Mean Foliar DSI2		
Genotype1	Ty-3	Ty-4	Ty-5
+/+	6.1 a (n = 130)	4.6 b (n = 16)	5.4 a (n = 174)
+/-	5.7 b (n = 46)	6.0 a (n = 5)	4.4 b (n = 15)
-/-	5.3 c (n = 346)	5.6 a (n = 501)	5.7 a (n = 333)

[1] +/+ homozygous resistant; +/- heterozygous; -/- homozygous susceptible
[2] DSI disease severity index of non-viral infections (primarily bacterial spot and early blight) based on the Horsfall-Barratt scale, lower number means less disease; n number of plants in each group; means in column with the same letter are not significantly different at P≤ 0.05 based on Duncan's multiple range test.

Resistance in commercial varieties is mainly-based on either Ty-1 or Ty-3, and in some cases on Ty-2. Both Ty-1 and Ty-3 appear to have significant linkage drag associated with their respective introgressions on chromosome 6. Expression of this linkage drag includes greater susceptibility to foliar diseases such as early blight and bacterial spot. A survey was conducted in spring 2011 on our most advanced TYLCV-resistant inbred lines in the program; more than 50 different lines were genotyped at the Ty-3, Ty-4, and Ty-5 loci and were also evaluated for TYLCV resistance as well as non-viral foliar disease severity. Data indicated that linkage drag, as expressed by greater foliar disease severity, is a real problem in Ty-3 material but not in Ty-5 material (Table 2). These two genes appear to be equally important sources of resistance to the program. But resistance in some lines was not based on any of the known resistance genes Ty-1 through Ty-5, further indicating the presence of an additional resistance gene in the program. We have tentatively named this gene "Ty-6" and have research underway to locate it. Considering that most of our advanced breeding lines with either Ty-3 or Ty-5 have a higher level of resistance than either of these genes provides alone, we speculate that Ty-6 is a major factor in our program and that its identification will greatly increase our ability to develop TYLCV-resistant hybrids.

Because of the linkage drag associated with Ty-3, we undertook a research project to fine-map this gene and reduce the introgression size. Much of our advanced Ty-3 material contained an approximately 27 cMTy-3 introgression on chromosome 6. In spring 2009, more than 10,000 seedlings were individually screened with molecular markers to identify recombinants within this introgression. From this screen, roughly 300 recombinant plants were selected, 100 of which were used to better locate the resistance gene. Tests for resistance clearly mapped Ty-3 to a narrow (~0.2 cM) interval near 20 cM. We have since developed Ty-3 material which has a minimal introgression contained within this interval and may have no linkage drag. Preliminary data in spring 2011 indicated that the foliar problems previously associated with the Ty-3 introgression are not present in this material. We are aggressively incorporating this minimal introgression into our most advanced inbred material lines.

Germplasm Highlights

We are continuing to evaluate a number of interesting hybrids and inbreds. Among these is Fla. 8806, a large-fruited, heat-tolerant hybrid with excellent eating quality and high lycopene due to the crimson gene. Parents of Fla. 8806 are Fla. 8735 and Fla. 8059, the latter being one of the parents of Tasti-LeeTM. Trials in Homestead last year showed that Fla. 8806 was comparable to Sanibel and FL 47 for total yield, but yields were significantly higher than either control at first harvest. Both Fla. 8735 and the FCR resistant inbred, Fla. 8776, are routinely parents of our top hybrids and thus show particular promise as having good combining ability. The incorporation of bacterial spot resistance from the plum line, Fla. 8517, has resulted in an influx of plum-type material into the breeding program. Breeding plum tomatoes has not been a major focus of the program, but this introduction of germplasm is being used as an opportunity to significantly expand this project. Emphasis in this project will be placed on the development of TYLCV and FCR-resistant varieties.

Trait Introgression

A marker-assisted backcross breeding approach was recently established to quickly and efficiently incorporate key traits into a panel of advanced inbred lines. The panel consists of more than 40 inbreds, many of which are elite parents that have consistently shown good combining ability for hybrid development. As mentioned previously, the Ty-3 minimal introgression is one of the traits involved in this project. Other traits include the TYLCV resistance genes,Ty-1, Ty-2, Ty-4 and Ty-5; the FCR resistance gene, Frl; the TSWV resistance genes, Sw-5 and Sw-7; the bacterial speck resistance gene, Pto; and the late blight resistance genes, Ph-2 and Ph-3. Traits that will soon be added to this scheme include Ty-6 and the crimson gene, ogc. As molecular markers linked to additional traits of importance are identified, these will also be incorporated. This approach will not only provide the opportunity to re-create superior hybrids with "value-added" traits, but will also allow us to incorporate these important traits into most or all of our material in the future. As a result, such traits will gradually become part of a standard package for future releases.

Bacterial Spot and Non-Blighting

Bacterial spot resistance remains a major focus of the breeding program. As mentioned previously, Fla. 8517 has been one of our best sources of resistance to this disease. In contrast, Fla. 7946 (the Fusarium wilt race 3 resistant parent in 'Solar Fire') is one of the most susceptible lines in the program. Several resistance QTL (quantitative trait loci) have been identified in Fla. 8517, including one on chromosome 11 and one on chromosome 3 (Hutton et al., 2010). We recently determined that greater susceptibility to bacterial spot is associated with the I-3 gene that confers resistance to Fusarium wilt race 3. The line '0630' is an advanced selection from a cross between Fla. 8517 and Fla. 7946, which was described at the Tomato Institute in 2009. This line carries both the chromosome 11 and chromosome 3 QTL and has good resistance to bacterial spot, despite the fact that it also carriesI-3. Moreover, '0630' also has a "non-blighting" characteristic which contributes to its ability to maintain healthy foliage, even under moderate infection by some foliar pathogens such as early blight and bacterial spot. Research is underway to understand the genetics of this trait to allow its efficient incorporation into advanced materials.

Summary

The development of TYLCV-resistant material with superior yield and horticultural characteristics has long been a major focus of the breeding program, and we anticipate that our recent progress with respect to Ty-3 will soon be evidenced by significant improvements in variety performance. Progress in the "non-blighting" area could have tremendous implications. When combined with bacterial spot resistance, the foliage retention should not only contribute to greater yields by maintaining better fruit protection and providing higher photosynthate production, but should also lower expenses by reducing pesticide costs. Besides the projects mentioned, there is much work going on in the UF breeding program: the bacterial wilt resistance project has realized incredible progress with respect to developing impressively large fruit; we've made considerable headway in our advancement of the TSWV resistance gene, Sw-7; whitefly resistance is steadily being advanced into cultivated tomato; and work is ongoing toward improving the appearance of fruit with a glossy, deep red exterior color. As always, we appreciate grower input and feedback.

Literature Cited

Anbinder, I., M. Reuveni, R. Azari, I. Paran, S. Nahon, H. Shlomo, L. Chen, M. Lapidot, and I. Levin. 2009. Molecular dissection of Tomato leaf curl virus resistance in tomato line TY172 derived from Solanumperuvianum. TheorAppl Genet 119:519-530.

Bian, X.Y., M.R. Thomas, M.S. Rasheed, M. Saeed, P. Hanson, P.J. De Barro, and M.A. Rezaian. 2007. A recessive allele (tgr-1) conditioning tomato resistance to geminivirus infection is associated with impaired viral movement. Phytopath 97:930-937.

Giordano, L.B., V.L. Silva-Lobo, F.M. Santana, M.E.N. Fonseca, and L.S. Boiteux. 2005. Inheritance of resistance to the bipartite Tomato chlorotic mottle begomovirus derived fromLycopersiconesculentum cv. 'Tyking'. Euphytica 143:27-33.

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

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

Ji, Y., J.W. Scott, D.J. Schuster, and D.P. Maxwell. 2009. Molecular mapping of Ty-4, a new tomato yellow leaf curl virus resistance locus on chromosome 3 of tomato. J. Amer. Soc. Hort. Sci., 134:281-288.

Estimating Financial Losses to Vegetable Crop Production from a Freeze Event

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Introduction

A favorable climate allows southwest Florida growers to produce and sell fresh vegetables to the northern markets in Philadelphia, New York, Boston, and Chicago during the winter months. The growing season for Southwest Florida growers is from October-April with the greatest production from November through January (Ozores-Hampton, et al., 2007). While southwest Florida enjoys relatively warm winter temperatures, growers face the likelihood of freeze events on a regular basis. At least once a year, weather forecasters predict night temperatures to approach freezing. If temperatures drop below 32°F and are sustained for several hours, significantly damage to tender vegetable plants occurs despite the growers' best cold protection efforts. The horticultural impact and resulting financial losses can be enormous. A freeze on 19 Jan 1997 caused at least $200 million of damage to Florida's winter vegetable industry and displaced thousands of migrant workers (Sharp, 1997). More recently an extended period of cold weather gripped southwest Florida from January 4 to 13, 2010. The cold spell reached its lowest point during the early morning hours of January 11th when air temperatures dropped to less than 26°F and were less than 31°F for nine continuous hours (FAWN, 2010).

Almost as soon as daylight came to southwest Florida on January 11th, news media, civic leaders, and government agencies wanted to know how badly were farmers hurt and to what extent were farm workers affected. Providing quick and accurate answers to such questions could facilitate a coordinated response from public and private agencies who want to lessen the adverse effects of a freeze or other extreme weather event. The purpose of this paper is to: 1) outline a framework to estimate the total monetary losses resulting from a freeze or other adverse weather event that disrupts agricultural production; and 2) allocate those losses among growers, farm workers, and the general public. The focus of this paper is on vegetable production in southwest Florida, but the methodology can be extended to other crops and across a wider geographic region.

Approach and Data Requirements

Three sources of data are required to estimate financial losses to agricultural crops stemming from an extreme weather event: 1) enterprise budgets, 2) estimates of crop acreage by stage of production, and 3) estimates of the extent of crop damage.

Enterprise budgets list the inputs, their quantities and unit costs, which are required to grow, harvest, and market a particular crop. Quantities and costs are expressed on a per-acre basis and are based on an assumed yield. In the case of fresh vegetable production, an assumed yield is the quantity that is marketable, not necessarily the total quantity of fruit produced. Growers provide basic information on the type and quantity of inputs used to produce a given crop. By interviewing and collecting information from several growers, University personnel can describe typical or "representative" farming practices, list the required inputs and their amounts by each practice. Budgets are developed for specific regions (i.e. southwest Florida) to capture differences in production systems that may vary by area. Salesmen from fertilizer and chemical wholesaling companies provide information on input product prices. The Florida Agricultural Statistics Service (FASS) reports historical crop yields, which serve as a basis for expectations on future crop yields. Enterprise budgets for selected vegetable crops are compiled and maintained by the University of Florida's Center for International Trade and Policy (http://www.iatpc.ifas.ufl.edu/budgets.php).

Data on planted acreage are available from Florida Agricultural Statistic Service (FASS), county property appraisers, and from industry publications. More important is the knowledge of local University extension faculty, who through their experience with the local growers are able to more accurately estimate the number of acres planted to various vegetable crops. In addition to knowing the total number of acres that are annually planted, extension faculty know the number of acres planted in any given week of the growing season. Most vegetable crops require between 90 to 120 days to be grown and harvested. Crops are planted sequentially over a 2 to 3 month time period in order to maintain production over an extended period.

Vegetable crop damage from a freeze is estimated by county extension faculty who use a variety of methods including field visits and grower surveys. Once the affected acreage and damage percentage by crop are determined, information from the crop budgets can be applied to estimate financial losses.

Results and Discussion

An enterprise budget presented in Table 1 for mature-green round tomatoes is typical of any enterprise budgets for vegetable crops in Florida. Total costs to plant, grow, harvest, packing, and sell tomatoes in southwest Florida are estimated to be $17,485 per acre. The budget assumes that 1,500 (25-lb) cartons per acre will be sold. The budget allocates costs to various stages of production, as well designates which costs are for material, equipment and labor. Interviews with growers allow labor costs to be separated between permanent farm employees (i.e. tractor drivers, mechanics, field supervisors, etc) and for services from seasonal and migrant farm workers. In the case of round tomatoes, more than two-thirds of total cost, or $12,100 per acre, were spent on "pre-harvest" activities and materials. Most of these costs were for production inputs such as transplants, fertilizer, pest control chemicals, bedding plastic, and irrigation tape. A small percentage of pre-harvest costs ($670 per acre) were paid to seasonal workers, who transplant, stake, tie, and prune young plants. Also included in the pre-harvest category were payments made to seasonal farm workers for post-harvest "clean-up" services. Harvest, packing, and selling costs of round tomatoes make up slightly more than 30% of total costs. More than 72% ($3,900 per acre) of harvest costs went to workers who harvested and packed fruit, as well as to the crew leaders who hauled fruit from the fields to the packing house. Packing cartons, marketing commissions, organization fees and assessments made up the remainder of the costs associated with the "harvest" stage.

The budget values in Table 1 are used to allocate financial losses among growers, farm workers, and the general public in the event of a freeze or extreme weather event. For much of the acreage affected by the January 2010 freeze, the freeze damage occurred just prior to harvest. Hence, growers had invested in the pre-harvest inputs but had not as yet received any revenues from crop sales. Consequently, mature-green tomato growers incurred losses estimated to be $12,100 per acre, or the amount of pre-harvest costs. Since the crop had not been harvested, growers did not incur any of the costs associated with harvesting. Growers, however, still had to pay for "clean-up" costs to remove plastic bedding, irrigation tape, and plant stakes from the affected acreage.

Farm workers collectively lost $3,900 of income for every acre of mature-green tomatoes destroyed. This loss equaled the amount of money that would have been paid to workers who harvested and packed 1,500 cartons of tomatoes. In addition to field workers who lost income from not having fruit to harvest, potential income is lost by farm labor contractors who in

Table 1.Enterprise budget by production stage for mature green tomatoes yielding 1,500 (25-lb) marketable cartons in southwest Florida, 2009.

Production Stage	Item	Cost by input category $/ac	Cost by stage of production $/ac
Pre-Harvest	Materials Labor Overhead (fixed)	$7,090 $670 $4,340	$12,100
Harvest	Materials Labor (inc packing) Selling, overhead	$1,125 $3,900 $360	$5,385
Total Costs			**$17,485**

Source: Van Sickle, Smith, and McAvoy, 2009.

Table 2. Vegetable acreage in southwest Florida1 that were lost or damage during the freeze on January 11 to 13, 2010.

Crop	Total Annual Acreage[2] (ac)	Percent lost – Early Est.[3] (%)	Percent Lost/Damage - Revised Est.[2] (ac)	Acreage lost – Early Est. (ac)
Tomato, round	20,000	30	15/15	6,000
Bell pepper	7,000	40	20/20	2,800
Hot pepper	3,500	na[4]	15/15	-
Squash/zucchini	2,500	30	25/5	750
Potatoes	4,500	na[4]	0/100	-
Bush Beans	13,000	30	30/0	3,900
Sweet corn	3,000	30	30/0	900
Cucumbers	1,500	30	25/5	450
Watermelon	13,000	na[4]	10/20	1,300
Cantaloupe	2,000	na[4]	na[4]	-
Eggplant	1,200	40	35/5	480
Misc. Vegetables	7,500	na[4]	5/15	-
Total	**78,700**	**30-40**	**0-100**	

[1] Southwest Florida includes Collier, Hendry, Lee, Charlotte, and Glades Counties.
[2] Source: Ozores-Hampton, et al., 2010.
[3] Source: McAvoy, 2010. Preliminary estimates made within two weeks after Jan. 11, 2010.
[4] not available.

many cases use their own trucks and equipment to haul fruit from a field to a packing house. This paper considered packing house workers as part of the farm worker community as well, and hence included their lost income resulting from shut-downs in packing operations as a result of fruit losses from the freeze. It was important to note that as part of pre-harvest costs, farm workers had already been paid for their services in transplanting, staking, tying, pruning, and other cultural practices. In addition, most, if not all of the costs associated with field clean-up activities are paid to farm workers.

Most of the financial losses from a freeze event fall on growers and farm workers. It is important to keep in mind, however, that the general non-farming public is another constituency that suffers financial losses from a significant disruption in agricultural production. When the crop has been destroyed at the pre-harvest stage, the grower will not spend the money on harvest activities. Therefore, there will be a drop in demand for packing cartons, sales commissions, and the operational expenses associated with packing houses. In the example of round tomatoes, $1,485 of costs per acre is associated with packing house supplies, selling costs, organizational fees and assessments (Table 1). In addition to the direct impacts of lost farmworker income and expenditures on fruit selling activities, there are indirect economic impacts. Just as an extra dollar earned by a vegetable grower generates an additional 50-cent to the regional economy through indirect economic impacts, one less dollar spent by a vegetable grower has an equal but contracting effect on the regional economy (Roka, 2010). Less income to farmworkers, growers, and to the employees of agricultural input suppliers translates into lower regional economic activity as now less income is available to spend on general consumer items.

University extension faculty estimated both total acreage planted annually by crop type and the extent to which the freeze impacted the production (Table 2). Estimating the acreage lost to the freeze was based multiplying the annual acreage by the percent of annual acreage in the ground as of early January 2010 and further multiplying the percentage of planted acreage affected by the freeze. Early estimates of loss percentages were made within the first two weeks following the freeze. During this time there was considerable pressure to provide local and state officials with estimates of crop damage. By mid-February 2010, crop loss estimates were revised to reflect a small percentage of acreage that growers were able to salvage from their freeze protection strategies. Estimates of crop acreage losses were combined with enterprise budget information to calculate estimates of total financial losses to growers, farm workers, and the general public in southwest Florida (Table 3). An important assumption of this analysis was that the acreage lost as a result of the freeze was at the end of the pre-harvest stage. Ideally, there would be a comprehensive damage assessment that would account for the stage of production across every planted acre. Realistically, such an assessment is not feasible given the expanse of affected acreage and the number of individual fields. Assuming all affected acreage was at the end of the pre-harvest stage reflects an "average" condition, where some acreage had been partially harvested and other acreage remained a couple weeks ahead of first harvest.

The January 2010 freeze was estimated to cost the economy of southwest Florida $196 million in lost vegetable production. Of that total amount, grower losses accounted for more than 70%, or $140 million. Farm workers collectively lost nearly $36 million. If 16,000 farm workers (Roka and Cook, 1998) were in southwest Florida at the time of freeze, the average farm worker lost $2,250 of income from not being able to harvest the impacted vegetable crops. More than $21 million, or 11% of the total budget costs for the vegetable crops listed in Table 3 were not spent within the southwest Florida region, and therefore represent lost income to the non-farming public in southwest Florida. If a multiplier of 1.57 (Roka, 2010) represents the total economic impact from an external shock, the combined farm worker and non-farm losses of $57 million translated to more than an $89 million loss of economic activity to southwest Florida as a result of the January 2010 freeze.

The January 2010 freeze was an extreme weather event in southwest Florida that either destroyed or significantly impaired vegetable production. Between mid-January and mid-April, very little fresh vegetable produce moved out of the southwest Florida (Immokalee) area (McAvoy, 2010). Major supply disruptions usually result in higher market prices for fresh vegetables. However, growers without fruit cannot capitalize on these higher market prices. When growers are able to salvage part of their crops, the higher market prices may offset part of their financial losses. Losses to farm workers and the regional economy, however, are certain in that their incomes are dependent on fruit volume and not market prices.

References

FAWN, 2010. Average hourly temperatures from January 10 through January 11, 2010. Florida Automated Weather Network. Accessed data on June 15, 2010, http://fawn.ifas.ufl.edu/data/reports/

McAvoy, G. 2010. Personal communication. Movement of vegetables out of Immokalee, FL after the January 2010 freeze.

Ozores-Hampton, M., G. McAvoy, M. Lamberts, and D. Sui. 2010. A Survey of Effectiveness of Current Methods Used for the Freeze Protection of Vegetables in South Florida. Proceedings of the Fla State Hort. Soc, Vol 123: 128-133.

Ozores-Hampton, M.P., E.H. Simonne, E. McAvoy, F. Roka, P. Roberts, P. Stansly, S. Shukla, K. Cushman, K. Morgan, T. Obreza, P. Gilreath, and D. Parmenter. 2007. Results of the nitrogen BMP tomato trials for the 2006-2007 seasons. Florida Tomato Inst. Proc., PRO524, pp. 8-13.

Roka, F. 2010. Economic Importance of Agriculture to Southwest Florida. UF/SWFREC website: http://swfrec.ifas.ufl.edu:9000/, updated March 2010, 4 pages.

Roka, F. and D. Cook. 1998. Farmworkers in Southwest Florida. Final report to the Florida Department of Community Affairs. Available at the UF/SWFREC website: http://swfrec.ifas.ufl.edu:9000/.

Sharp, D. 1997. Surprise freeze burns farmers. USA Today, 23 January, 9A.

VanSickle, J.J., S. Smith, and G. McAvoy. 2009. Production Budget for Tomatoes in Southwest Florida. Electronic Data Information Source EDIS document FE818. Food & Resource Economics Department, University of Florida, Gainesville, FL. http://edis.ifas.ufl.edu/FE818

Table 3. Estimated financial losses to growers, farmworkers and southwest Florida economy from the January 2010 freeze.

Crop (yield-unit size)	Total Loss $/ac	Grower Loss $/ac	Farmworker Loss $/ac	Non-farm Loss $/ac
Bell peppers				
(1,000 28-lb)	$18,500	$14,100	$3,000	$1,400
Cucumbers				
(600 55-lb)	$6,000	$3,200	$2,190	$610
Eggplant				
(1,400 33-lb)	$12,150	$8,175	$1,890	$2,085
Squash				
(300 42-lb)	$4,750	$2,725	$1,330	$695
Bush beans				
(225 bu)	$4,310	$2,815	$0	$1,495
Tomatoes (MG)				
(1,500 25-ctn)	$17,485	$12,100	$3,900	$1,485
Sweet corn				
(250 42-lb)	$5,325	$4,505	$345	$475
Watermelon				
(340 cwt)	$4,975	3,975	$650	$750
Total Losses for crops listed above ($M)[1]	**$196.0**	**$139.7**	**$35.8**	**$21.4**

[1] Total loss in millions of dollars ($M) by group calculated by multiplying estimated losses per acre by the number of "lost acres" estimated in Table 2.

Initial Characterization of *Corynespora cassiicola* and *Alternaria* spp. affecting Florida Tomatoes: Fungicide Resistance, Pathogen Variability, and Host Resistance

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Florida is the largest producer of fresh market tomatoes in the United States. However, increases in production costs and foreign imports into the US continue to challenge the industry, diminishing crop returns. Minimizing losses to disease and the expenses associated with disease management will help Florida growers to remain competitive. Early blight (*Alternaria solani*) and target spot (*Corynespora cassiicola*) are two of the most important foliar fungal diseases of tomato in Florida. Both diseases can lead to severe yield losses as a result of blighting of foliar tissues and fruit infections.

Initial foliar symptoms of target spot and early blight consist of small, pinpoint, water-soaked lesions that appear on the upper leaf surface that eventually turn tan to dark brown. These initial lesions can be easily mistaken for bacterial spot or speck. However, as the lesions increase in size they become quite distinct. Target spot lesions have tan centers surrounded with circular bands and often a chlorotic halo, while early spot lesions are chocolate to black in color with narrow concentric circles often associated with extensive chlorosis. Expanding lesions of each pathogen can coalesce leading to the rapid collapse of leaflets. Similarly, these expanding lesions can girdle petioles and stems leading to a rapid blight of affected foliar tissues.

Tomato fruit are also quite susceptible to both diseases. On ripe fruit, large brown circular lesions develop with pale brown centers that often crack. Lesions on green immature fruit begin as small, dark brown, sunken lesions that can quickly develop into craters as they expand, especially when exposed to ethylene to stimulate ripening. Early blight lesions usually develop around the hip of the fruit, under the calyx, or at the stem scar. Shipments of tomatoes containing excessive numbers of fruit with symptoms of target spot can be rejected at the final destination or require the packinghouse to cover the repacking costs associated with sorting out defective fruit. Since no commercially resistant varieties are yet available to either disease, growers rely on cultural practices and the judicious application of fungicides for disease management (Pasche et al. 2004; Pernezny et al. 1996 & 2002; Schlub et al. 2009). Fungicide resistance has been documented for *A. solani* throughout the world (Pasche et al. 2004; Pasche and Gudmestad, 2008) and *C. cassiicola* in Japan (Date et al. 2004, Ishii et al. 2007; Miyamoto et al. 2007), but no efforts have been made to assess either pathogen for resistance in Florida.

While much is known about *A. solani* in regards to pathogen diversity and fungicide resistance in North America, there are few published reports for *C. cassiicola* which is mostly a pathogen of tropic and sub-tropic environments.

Unfortunately, the little published literature available for *C. cassiicola* suggests that there is considerable variation among isolates for host range and virulence towards tomato. Dixon and colleagues (2009) revealed that more diversity exists among global isolates of *C. cassiicola* than previously recognized, including isolates recovered from hosts in Florida. Of the 50 isolates from American Samoa, Brazil, Malaysia, Micronesia, and the U.S. tested for pathogenicity on 8 known hosts of *C. cassiicola*, 23 were rated as moderately to highly virulent on tomato. Of these 23 isolates, 14 were originally isolated from tomato and the remaining nine from diverse hosts like basil, bean, cucumber, lantana, papaya, pumpkin, and sweet potato. Most of the isolates were pathogenic on several of the hosts tested, but one isolate, GU28 from Guam, was only pathogenic on tomato. More importantly, these 23 isolates clustered into 4 of the 5 phylogentic clades described by Dixon and colleagues (2009) based on variation from ribosomal DNA internal transcribed spacer (rDNA ITS), ga4, caa5, and act1 sequences. This agrees with a prior study showing that diversity exists among isolates of *C. cassiicola* regarding host range, with some isolates exhibiting some level of host-specificity (Onesirosan et al. 1974).

There have also been some changes in Alternaria taxonomy. At least two distinct subgroups of *A. solani* isolates causing early blight on potato and tomato have been recognized based on morphological and genetic differences, in addition to some evidence of host specialization (Lourenço et al. 2009; Martínez et al. 2004; Simmons, 2000). It has been proposed that the subgroup associated with early blight of tomato be classified as *A. tomatophila*, while the other subgroup associated with potato retain the name *A. solani* (Simmons, 2000). However, a recent report from Brazil suggests that there may even be a third Alternaria species capable of causing early blight on tomato and potato (Rodriguez et al. 2010). With large acreage of tomato and potato production throughout Florida, sometimes occurring in neighboring fields, it would be wise to monitor both crops for resistance issues among *A. solani* isolates since the same classes of fungicides are used in both crops. In addition, it is unclear how "specialized" these two *A. solani* subgroups truly are towards tomato, potato, and other Solanaceous hosts.

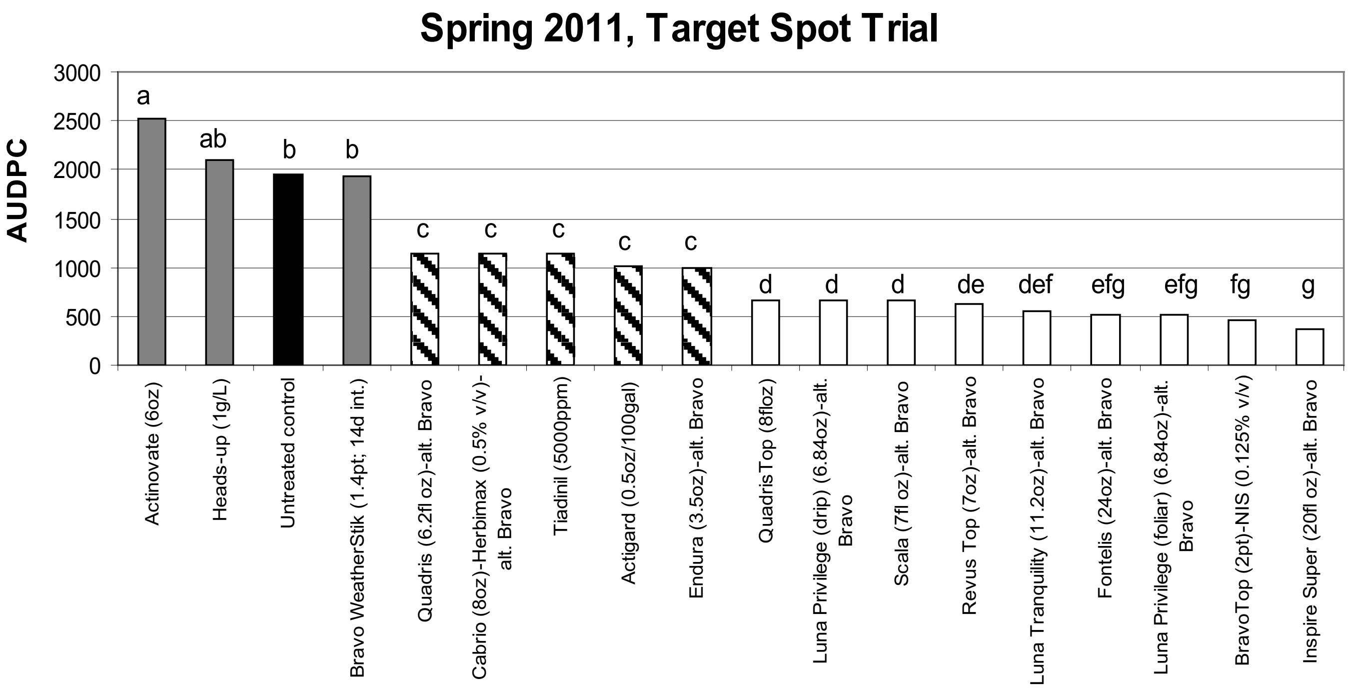
The following report describes some of our recent efforts to characterize *A. solani* and *C. cassiicola* populations in Florida, focusing mostly on the latter pathogen. To date, we have conducted numerous field trials to assess the efficacy of several fungicide classes against *A. solani* and *C. cassiicola*; to include multi-site action fungicides, quinone outside inhibitors (QoI), succinate dehydrogenase inhibitors (SDHI), demethylation inhibitors (DMI), and an anilino pyrimidine (AP) inhibitor of methionine biosynthesis. Most of these trials were limited in scope, since they consisted of mixed infections of both pathogens, used single field isolates, and rarely included all fungicide classes in the same trial. However, in spring 2011, a field trial was conducted at Gulf Coast REC that assessed all classes of fungicides against 10 field isolates of *C. cassiicola* (Figure 1). We were able to separate treatments into three major groups based on the area under disease progress curve values (AUDPC); with the two biopesticides (Actinovate and Heads-up) and chlorothalonil (Bravo) not differing statistically

Table 1. Sensitivity of Corynespora cassiicola isolates collected from Florida tomato production fields to a QoI and several SDHI fungicides.

Isolate	Fungicide: Estimated EC50 (µg/ml)			
	azoxystrobin	boscalid	fluopyram	penthiopyrad
GEV-1P	> 1.0	0.73	0.93	0.13
GEV-2P	> 1.0	0.76	1.21	0.21
GEV-7P	> 1.0	> 5.0	0.35	0.50
GEV-081208	> 1.0	0.30	0.45	0.11
GEV-111408	> 1.0	0.61	0.41	0.09

EC50 values represent fungicide concentrations that inhibited isolate growth by 50% compared to a non-fungicide amended medium (half-strength potato dextrose agar). Fungicide concentrations ranged from 0.05 to 5 µg/ml for boscalid, and 0.01 to 1 µg/ml for azoxystrobin, fluopyram and penthiopyrad.

Figure 1. Results of Spring 2011 target spot trial at Gulf Coast REC, Wimauma, FL. Disease severity was assessed 7 and 14 days after inoculating plots with *Corynespora cassiicola* and summarized as the area under disease progress curve (AUDPC). Treatments are listed with their per acre rate, unless noted otherwise in parenthesis. Treatments with the same letter are not statistically different at the 5% level of confidence. Treatments are color-coded into three groups based on efficacy. The untreated control is shaded black.



from the untreated control. The second group consisted of Tiadinil and Actigard (plant defense elicitors), the SDHI boscalid (Endura), and the two QoIs, azoxystrobin (Quadris) and pyraclostrobin (Cabrio) that reduced overall disease progress by 44%. The last group represents several classes of fungicides, including the lone AP pyrimethanil (Scala); those fungicides containing the DMI difenoconazole formulated with several other active ingredients [mandipropamid (RevusTop), azoxystrobin (QuadrisTop), chlorothalonil (BravoTop), and cyprodinil (Inspire Super)]; and those fungicides containing the newer SDHIs, penthiopyrad (Fontelis) and fluopyram (Luna Privlege and Luna Tranquility), not commercially available yet. This third group on average reduced overall disease progress by 71%, with Inspire Super conferring the greatest level of control at 82%. Unfortunately, we were unable to assess residual control after final fungicide applications were made due to severe bacterial spot in the trial.

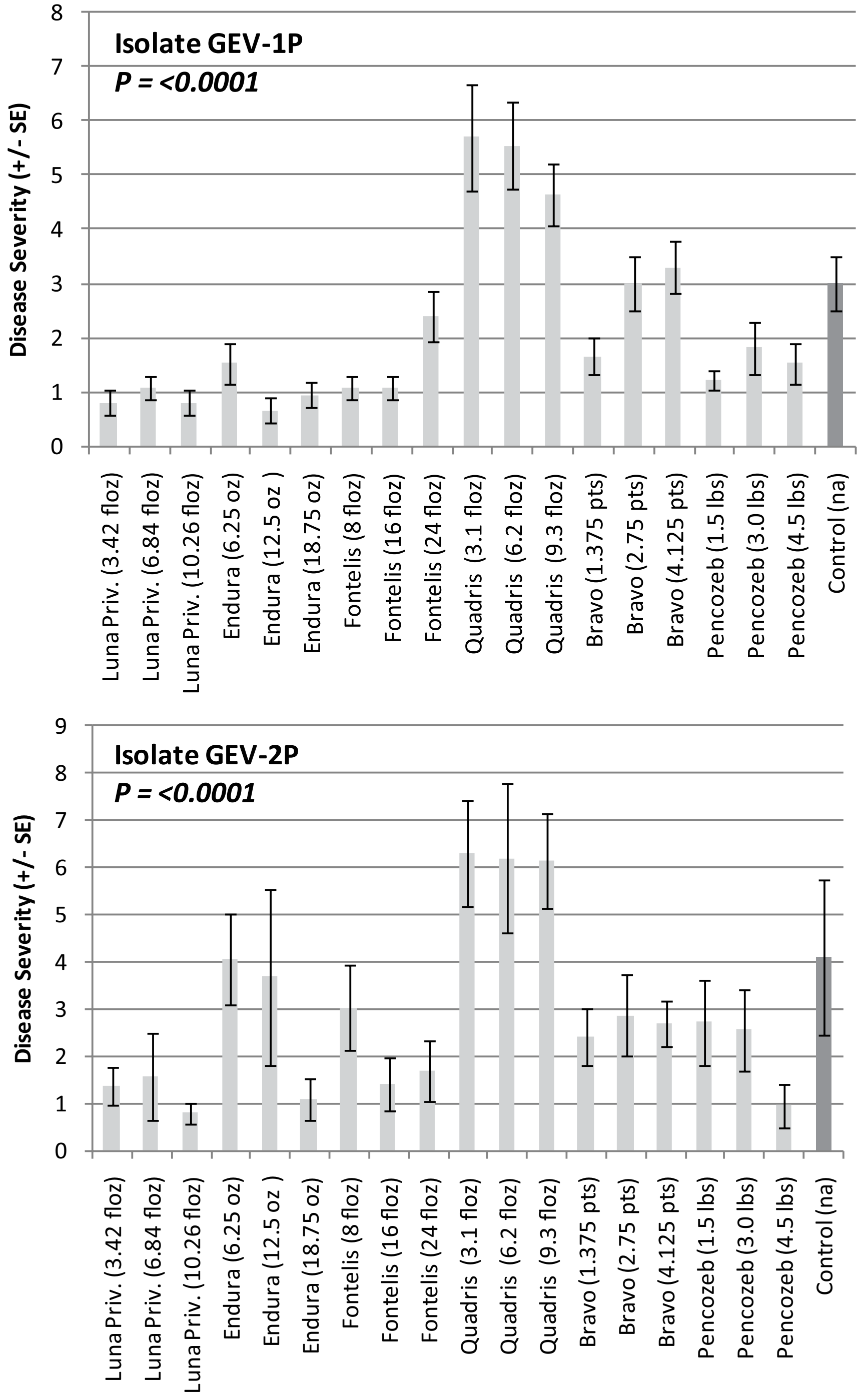
Similar to previous trials, overall efficacy of the two QoIs (Quadris and Cabrio) and older SDHI (Endura) were less than expected; especially when one compares Endura to some of the newer SDHI compounds awaiting final labeling (Luna Privlege and Fontelis). These results, in addition to field observations at grower sites, suggests that there may be some level of resistance to QoI and SDHI fungicides among *C. cassiicola* isolates in Florida. Resistance to SDHI fungicides would be large concern, because of the new SDHI fungicides entering the market.

Using a media-based assay (Förster et al. 2004), 5 field isolates were tested for sensitivity to the QoI fungicide azoxystrobin (Quadris), and the SDHI fungicides boscalid (Endura), fluopyram (Luna Privlege), and penthiopyrad (Fontelis) (Table 1). All five isolates exhibited high levels of tolerances to azoxystrobin with calculated EC50 values that greatly exceeded the upper concentration of 1 ug/ml used in this assay, as little reduction in growth was observed. Of the five isolates, isolate GEV-7P exhibited a high level of tolerance to boscalid with calculated EC50 values far exceeding the 5 ug/ml upper concentration; while EC50 values for the other isolates ranged from 0.30 to 0.76 ug/ml. Sensitivity to fluopyram (Luna) and penthiopyrad (Fontelis) ranged from 0.35 to 1.21 ug/ml and from 0.09 to 0.50 ug/ml, respectively.

To confirm our findings, controlled growth room studies were constructed to test individual *C. cassiicola* isolates on small seedlings treated with 0.5, 1.0, and 1.5 times the maximum labeled field rate of Quadris (azoxystrobin), Endura (boscalid), Bravo Weatherstik (chlorothalonil), Luna Privlege (fluopyram), Penncozeb (mancozeb), and Fontelis (penthiopyrad) (Figure 2). For both isolates, the application of Quadris, regardless of rate, caused a significant increase in disease severity. Pasche et al. (2004) observed a similar increase in virulence among QoI resistant isolates of *A. solani* when inoculated onto tomato plants treated with a QoI fungicide. The other single mode of action fungicides gave fairly consistent disease suppression, with the exception of the 0.5 and 1 x rates of Endura on isolate GEV-2P. While for the two multi-mode of actions, Penncozeb (mancozeb) appeared to be more effective than Bravo Weatherstik (chlorothalonil) for suppressing target spot. Further testing of the other isolates, including the potential boscalid tolerant isolate, GEV-7P, is underway.

To date, we only have 15 *C. cassiicola* isolates from tomato production fields throughout South Florida. To get a better idea of the extent of tolerance/resistance to certain fungicides and make appropriate fungicide recommendations we plan to collect additional isolates from throughout Florida this fall. Similar studies are

Figure 2. Results of greenhouse target spot trials using single field isolates of *Corynespora cassiicola*. Fungicides were applied at 0.5, 1, and 1.5 times the maximum field rate 1 to 2 days prior to inoculation. Disease severity was assessed 7 days after inoculating plants with *C. cassiicola* isolates GEV-1P (top) and GEV-2P (bottom). Error bars represent the standard error of each treatment (N = 10). Treatments are listed with their equivalent per acre rate.



also underway to test several *A. solani* isolates collected last fall and for those to be collected this fall. Furthermore, we are developing a microtiter plate based assay using a vital stain similar to that described by Rampersad (2011). The additional throughput of a 96-well microtiter plate combined with the level of sensitivity possible when using a vital stain on a fluorescent plate reader will enhance the precision and accuracy of our fungicide assays.

Although *C. cassiicola* and *A. solani* can both be controlled with fungicides, crop resistance remains the most practical, economical, and environmentally sound way to control disease. A renewed effort towards identifying new sources of resistance against common foliar pathogens should lead to the development of cultivars that require fewer chemical inputs for production. Progress in breeding of resistance to early blight has already led to the development of resistant lines for production areas to the North. Such traits combined with resistance to target spot would be ideal for Florida production. Previous efforts by Bliss and colleagues (1973) identified 2 lines, PI 120265 (*L. esculentum*) and PI 112215 (*L. pimpinellifolium*) in a screen of 242 accessions exhibiting a high level of resistance to target spot. Assessment of F1 and F2 progenies from crosses between PI 120265 and PI 112215, and crosses of each PI to a susceptible parent suggested that resistance in each PI was conferred by the same single recessive gene (Bliss et al. 1973). PI 120265 and PI 112215 were also found resistant in previous field trials in Florida (J.W. Scott, personal communication). Unfortunately, recent controlled greenhouse inoculations of PI 120265 with a single *C. cassiicola* isolate (GEV-1P; an isolate recovered from Parrish, FL in Fall 2010) found little evidence of resistance, suggesting that the pathogen population has changed. However, based on the findings of Dixon and colleagues (2009) showing the large amount of variation among *C. cassiicola* isolates, the possibility of specific races or pathotypes existing can't be dismissed. Based on our initial testing of 150 PI and LA lines, we've identified 18 candidate lines with resistance to target spot. We are in the process of increasing seed of these lines for subsequent greenhouse and field trials; and further testing of additional germplasm.

Literature Cited

Bliss, F.A., P.T. Onesirosan, and D.C. Arny (1973) Inheritance of resistance in tomato to target leaf spot. Phytopathology 63: 837-840.

Date, H., E. Kataoka, K. Tanina, S. Sasaki, K. Inoue, H. Nasu, and S. Kasuyama (2004) Sensitivity of Corynespora cassicola, causal agent of Corynespora target spot of tomato, to thiophanate methyl and diethofencarb.Japanese Journal of Phytopathology 70: 7-9.

Dixon, L.J., R.L. Schlub, K. Pernezny, and L.E. Datnoff (2009) Host specialization and phylogenetic diversity of Corynespora cassiicola. Phytopathology 99:1015-1027.

Förster, H., Kanetis, L., and Adaskaveg, J. E. 2004. Spiral gradient dilution, a rapid method for determining growth responses and 50% effective concentration values in fungus–fungicide interactions. Phytopathology 94:163-170.

Ishii, H., J. Fountaine, T. Miyamoto, K. Nishimura, and Y. Tomita, Y. (2007), Occurrence of a mutation in the succinate dehydrogenase gene found in some isolates of cucumber Corynespora leaf spot fungus resistant to boscalid. Japanese Journal of Phytopathology 74: in press.

Lourenço, V., Jr., Moya, A., González-Candelas, F., Carbone, I., Maffia, L. A., and Mizubuti, E. S. G. (2009) Molecular diversity and evolutionary processes of Alternaria solani in Brazil inferred using genealogical and coalescent approaches. Phytopathology 99:765-774.

Martínez, S. P., Snowdon, R., and Pons-Kuhnemann, J. (2004) Variability of Cuban and international populations of Alternaria solani from different hosts and localities: AFLP genetic analysis. Eur. J. Plant Pathol. 110:399- 409.

Miyamoto,T., H. Ishii, T. Seko, Y. Tomita, S. Kobori, and T.Ogawara (2007) Occurrence of boscalid-resistant isolates of cucumber Corynespora leaf spot fungus (C. cassiicola). Japanese Journal of Phytopathology 74: in press.

Onesirosan, P.T., D.C. Arny, and R.D. Durbin (1974) Host specificity of Nigerian and North American isolates of Corynespora cassiicola. Phytopathology 64: 1364-1367.

Pasche, J.S., C.M. Wharam, and N.C. Gudmestad (2004) Shift in sensitivity of Alternaria solani in response to QoI fungicides. Plant Disease 88:181-187.
Pasche, J.S. and N.C. Gudmestad (2008) Prevalence, competitive fitness and impact of the F129L mutation in Alternaria solani from the United States. Crop Protection 27:427-435.

Pernezny, K., L.E. Datnoff, T. Mueller, and J. Collins (1996) Losses in fresh-market tomato production in Florida due to target spot and bacterial spot and the benefits of protectant fungicides. Plant Disease 80:559-563.

Pernezny, K., P. Stoffella, J. Collins, A. Carroll, and A. Beaney (2002) Control of target spot of tomato with fungicides, systemic acquired resistance activators, and a biocontrol agent. Plant Protection Science 38:81-88.

Rodriguez, T.T.M.S., M.L. Berbee, E.G. Simmons, C.R. Cardoso, A. Reis, L.A. Maffia and E.S.G. Mizubuti (2010) First report of Alternaria tomatophila and A. grandis causing early blight on tomato and potato in Brazil. New Disease Reports 22:28 [doi:10.5197/j.2044-0588.2010.022.028].

Rampersad, S. N. 2011. A rapid colorimetric microtiter bioassay to evaluate fungicide sensitivity among Verticillium dahliae isolates. Plant Dis. 95:248-255.

Schlub, R.L., L.J. Smith, L.E. Datnoff, and K. Pernezny (2009) An overview of target spot of tomato caused by Corynespora cassiicola. Acta Horticulturae 808:25-28.

Simmons, E.G. (2000) Alternaria themes and variations (244–286), species on solanaceae. Mycotaxon, LXXV: 1–115.

Comparison of Soil Test Extractants for High pH Sandy Soils in South Florida

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Tomatoes are produced on approximately 20,000 acres in south Florida (Gene McAvoy, personal communications). Soils on nearly all of the acres are sandy in the upper 18 inches, typically low in water and nutrient holding capacities, and have low organic matter. Soil pH in this area of Florida has increased over the past 50 years to levels greater than 6.5 with high to very high concentrations of calcium (Ca) due to repeated lime applications. Farms containing these sandy soils border the Everglades Agricultural Area and both ultimately drain into the Everglades. The Everglades Forever Act mandates that landowners ensure water leaving the agricultural areas do not exceed well-defined phosphorus (P) loads. Agricultural producers are required to implement best management practices (BMPs) that maintain long-term economic viability while fostering environmental stewardship.

Tomato production timing and conditions in south Florida differs dramatically from production in other areas of the state. Winter production dominates south Florida production, with seasons ranging from late summer to early spring. Due to hydrological characteristics of sandy soils of south Florida, the industry relies in a large part on seepage irrigation from elevated water tables. These elevated water tables in combination with the low nutrient holding capacity of the sandy soils increases the potential for leaching of nutrients from these soils.

Fertilizer can be a large production cost to most farmers. Unfortunately, nutrients (including P) can also be major contributors to groundwater contamination. Management strategies such as soil tests should be used as a BMP in vegetable production to maximize crop yields and quality while minimizing loss of nutrients to the environment. Nitrogen concentrations in soil are typically not determined because it leaches so readily, does not accumulate in our sandy soils, and must be replaced each year for optimum production. However, it is recommended that soil be tested each year to determine the amount of P required to maintain high production levels. Nitrogen and P move at different rates in the soil based on their affinity for soil particles and soil water content. However, once these elements reach the groundwater they can move off the farm by mass flow as water enters ditches. Large quantities of P reach the water table and impact off-site surface water bodies. The dynamics of soil P must be understood to

Figure 1. Regression of extractable soil P using five soil extractants and water and carbonate-extractable soil P as an estimate of plant available P in soils with high soil pH and Ca concentrations. Note that extractions were taken using currently recommended soil to extractant ratios and results in large data scatter.

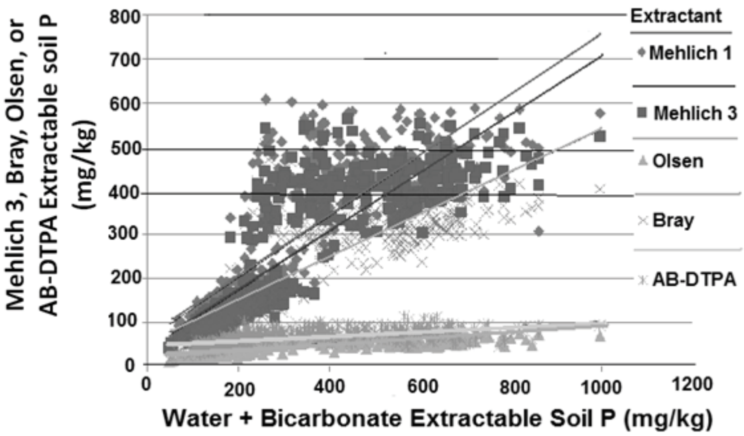


Table 1. Soil extracted P of soil characterized as low (< than 100 mg/kg), medium (250 to 350 mg/kg) and high (> 400 mg kg-1) water and carbonate-extractable soil P using five selected soil extractants at standard and optimum soil to extractant ratio, expressed as mean±std error.

Extractant	P concentration Category	P Conc.(mg/kg Standard ratio	Optimum Ratio	P Conc. (mg/kg) at Optimum ratio
M1	Low	59.9 ± 3.86	1 : 40	70.4 ± 4.88
M1	Low	69.2 ± 9.72	1 : 40	74.8 ± 3.38
M1	Medium	134.3 ± 5.17	1 : 40	162.7 ± 26.84
M1	Medium	139.4 ± 6.52	1 : 40	160.9 ± 35.16
M1	High	431.2 ± 2.93	1 : 40	441.2 ± 16.27
M1	High	364.8 ± 33.66	1 : 40	409.0 ± 52.81
M3	Low	43.6 ± 1.78	1 : 40	49.5 ± 5.47
M3	Low	46.5 ± 1.60	1 : 40	53.4 ± 3.34
M3	Medium	124.1 ± 5.31	1 : 40	153.3 ± 7.77
M3	Medium	128.1 ± 8.06	1 : 40	141.9 ± 12.37
M3	High	362.4 ± 14.49	1 : 40	375.7 ± 43.62
M3	High	326.9 ± 8.74	1 : 40	378.2 ± 18.06
Bray	Low	37.7 ± 1.76	1 : 40	48.5 ± 1.36
Bray	Low	48.1 ± 1.14	1 : 40	53.8 ±3.16
Bray	Medium	124.5 ± 4.58	1 : 40	137.1 ± 6.88
Bray	Medium	113.0 ± 5.35	1 : 40	117.5 ± 1.01
Bray	High	316.6 ± 9.27	1 : 40	369.4 ± 65.07
Bray	High	317.0 ± 33.48	1 : 40	345.1 ± 20.65
Olsen	Low	11.6 ± 0.18	1 : 50	16.3 ± 2.22
Olsen	Low	13.6 ± 0.52	1 : 50	20.1 ± 1.19
Olsen	Medium	28.7 ± 1.20	1 : 50	50.1 ± 2.37
Olsen	Medium	29.0 ± 2.74	1 : 50	46.9 ± 1.13
Olsen	High	63.2 ± 7.66	1 : 50	88.3 ± 3.27
Olsen	High	48.0 ± 3.54	1 : 50	72.8 ± 3.63
AB-DTPA	Low	15.6 ± 0.30	1 : 30	33.1 ± 0.92
AB-DTPA	Low	18.4 ± 0.11	1 : 30	37.1 ± 6.67
AB-DTPA	Medium	47.9 ± 0.85	1 : 30	89.1 ± 5.81
AB-DTPA	Medium	45.5 ± 0.32	1 : 30	72.3 ± 0.88
AB-DTPA	High	79.7 ± 1.53	1 : 30	268.5 ± 42.15
AB-DTPA	High	53.0 ± 0.51	1 : 30	198.5 ± 8.99

determine the impact of fertilizer application on the environment.

High soil pH and the presence of large quantities of iron, aluminum, and/or calcium cause soluble P applied as fertilizer to precipitate out over time and become unavailable to crop plants. Therefore, growers on high pH soils must apply large quantities of P to support crop production. If P is not provided, the crop can become deficient resulting in stunted plants with drooping curled leaves that are purple in color. Soluble P that has not been transformed into insoluble precipitates is vulnerable to leaching. Sequential fractionation schemes, such as that represented by Hedley et al. (1982), extract inorganic P and organic P that are presumably associated with different soil P compounds. By extracting different forms of P, this method may allow one to trace P movement or transformation within soil upon application to determine whether P is becoming more available or more strongly less available over time. The sequential fractionation analysis of cropped soils at various pH levels will allow for better soil test procedures and improved understanding of P availability for crop growth.

Standard soil test methods developed for agriculture have been used to assess environmental risk of P loss from soils (Nair and Harris, 2004). Application of soil test P as an environmental indicator requires additional calibration to specific soil types (Sharpley, 1995). A demonstration project was conducted over a five year period to look at the effect of P applications to soils with high pH (greater than 6.0) and high Ca content on crop growth and yield. Several different soil tests for P were used to estimate P available P (e.g., Mehlich-1, Mehlich-3, Bray, Olsen and AB-DTPA). Mehlich-1 is a soil test extractant containing two acids (hydrochloric and sulfuric acids) and is sometimes called a double acid extraction. The strong acids dissolve nutrients in the soil that would normally be available to plants in acidic soils and are only appropriate for acidic soils (pH< 6.0). The University of Florida – IFAS has been utilizing the results to base P recommendations, but is considering use of Mehlich 3 extractant which is not as acidic and can be used with wider range of soil pH. Bray and Olsen extractants are typically used for alkaline soils (pH>7.0), and Olsen is most used for soils high in Ca. ammonium bicarbonate-diethylene triamine penta acetic acid (AB-DTPA) is a relatively new extractant to determine available nutrient in neutral and calcareous soils and was also used in this study. Therefore, there was a need to compare and/or determine the best soil P test method on which the growers can base their P application recommendations.

Demonstration Study

Biomass and yield data from six tomato crops grown in 2006, 2007, and 2008 were combined to determine the effect of soil pH and extractable soil P content at time of planting on crop growth and productivity. The data were separated into initial soil pH values less than 7.2, 7.2

Figure 2. Extractable soil P using selected extractants compared with water plus bicarbonate extractable soil P using revised soil to extractant ratios. Use of the new ratios provide more accuarate and reliable values of extractable soil P at high soil P concentrations. Comparison of the five extractants indicate that Mehlich 1 and 3 and Bray represent similar extractable soil P fractions while Olsen and ABDTPA extractions respresent lower soil P concentrations.

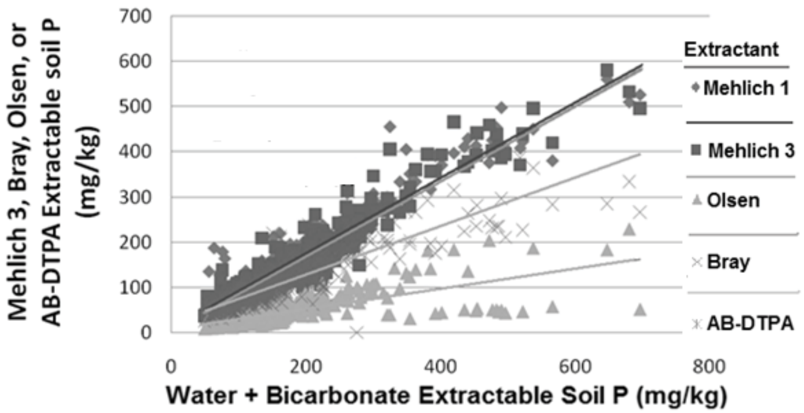


Figure 3. Results of sequential analysis for two growing seasons. Hydroxide and bicarbonate (available P) decreases through the growing season. Other forms of P are not soluble in th soil solution and are not available to the plant that thus do not change.

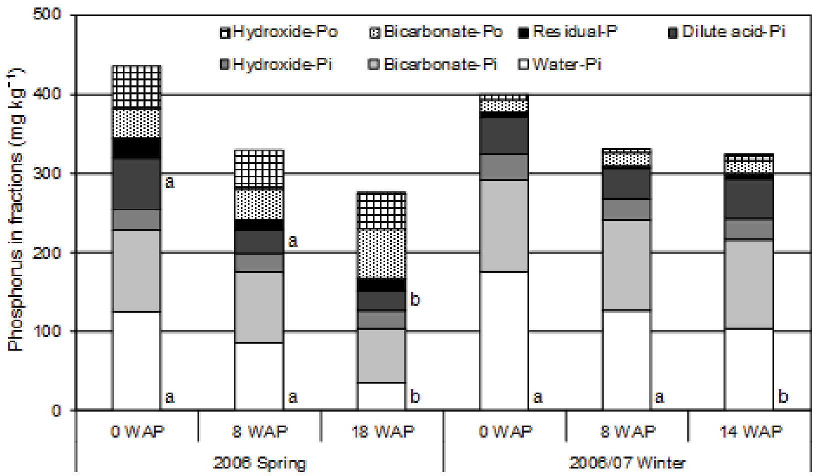
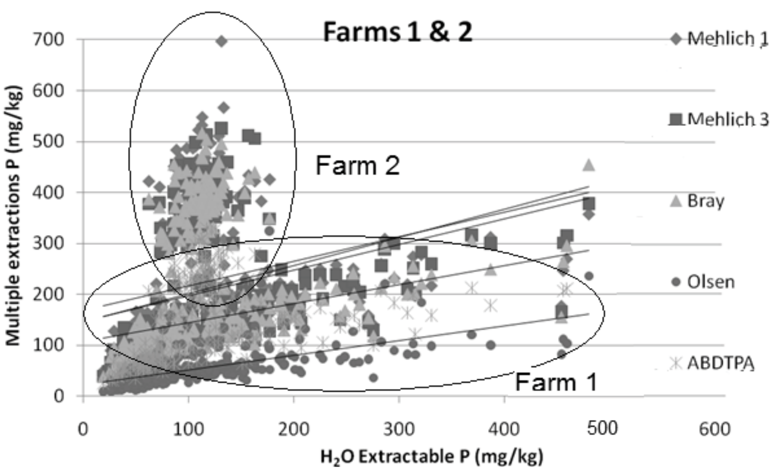


Figure 4. Comparison of water extractable soil P with extractable soil P with Mehlich 1, Mehlich 3, Bray, Olsen, and AB-DTPA. Note that extracts of soil from Farm 1 are lower in P concentration and close to the water extractable P. However, extractable soil P for Farm 2 do not correlate well with water extractable P indicating a large amount of extractable P that is not water soluble.



to 7.6 to determine if soil pH at time of planting affected tomato growth and productivity among selected fertilizer P rates. The same data were also separated in ranges of initial extractable soil P content of 25 to 75, 75 to 125, 125 to 250, 250 to 400 and 400 to 600 ppm. The extractable soil P content requiring no additional fertilizer P was also determined. Results for crops grown in the last two years were not used because of injury or possible reduced growth due to the cold weather during the winters of 2009/10 and 2010/11. This study first determined the proper ratio of soil to each of the five extractants for soil with very high concentrations of P. We then compared extracted soil P with different forms of P determined using sequential analysis

Extractant to Soil Ratio

It was concluded from the wide scatter and low slope of extractable soil P data compared with water and bicarbonate-extractable P in Fig. 1 that the extractants did not provide reliable soil P concentrations at extractable soil P concentrations greater than 300 mg/kg. Therefore, we increased extractant volume to soil dry weight ratios to determine optimum extraction in soils with high soil P concentrations. Soil samples with pH greater than or equal to 7.0 were selected and separated into three categories based on water and bicarbonate-extractable soil P. Four replications of soils with low water and bicarconate extractable (available) soil P (less than 100 mg/kg), medium soil P (200 to 350 mg/kg) or high soil P (>350 mg/kg) were extracted with ten soil to extractant ratios ranging from 4:1 to 100:1.

Numerically, extracted soil P concentrations using higher soil to extractant ratio values were not significantly greater than soil P extracted using currently recommended ratios (Table 1). Therefore, a conclusion of this study is that current soil to extractants ratios for all extractants are inadequate in soils with high soil pH, and P and Ca concentrations should be adjusted to attain maximum P extraction (Fig. 2). Soil samples collected during the Fall 2009 and Spring 2010 seasons were extracted using the higher soil to extractant ratios detemined in the above study. Better comparisons between available P and extractable P can be seen where higher soil to extraction ratios were used, providing better soil test P data.

Sequential Analysis

The sequential analysis procedure determines the amount of P in a soil at increasingly less available forms of P (Fig. 3). The most readily available form of P in the soil is water soluble P followed by bicarbonate-extractable forms. However, most but not all bicarbonate P forms are readily available to plants. Thus extractants that extract soil P concentrations similar to or greater than the sum of water and bicarbonate-extractable P will over estimate the amount of P available to plants while extractants that remove soil P nearly equal to the sum of water and bicarbonate soluble P are most useable to

Figure 5. Comparison of plant available P and extractable P using the five extractants. The relationship between available soil P and extractable P is good for Farm 1 but samples from Farm 2 contain large amounts of P that is not available to plants.

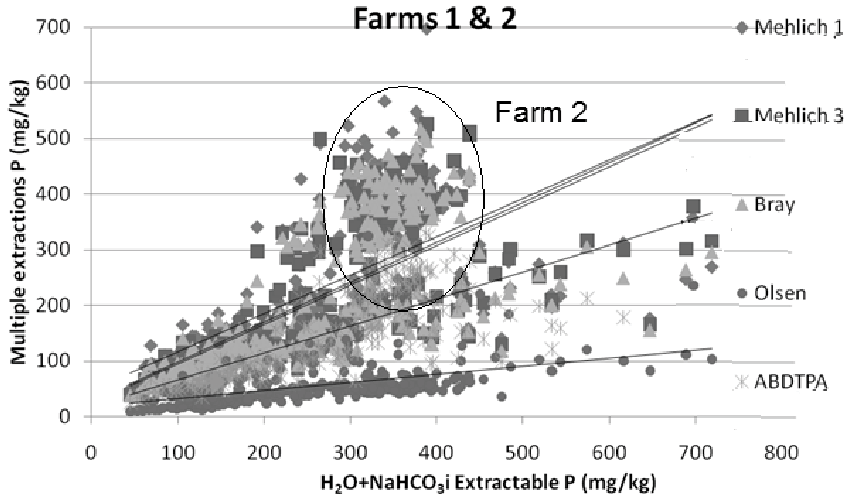
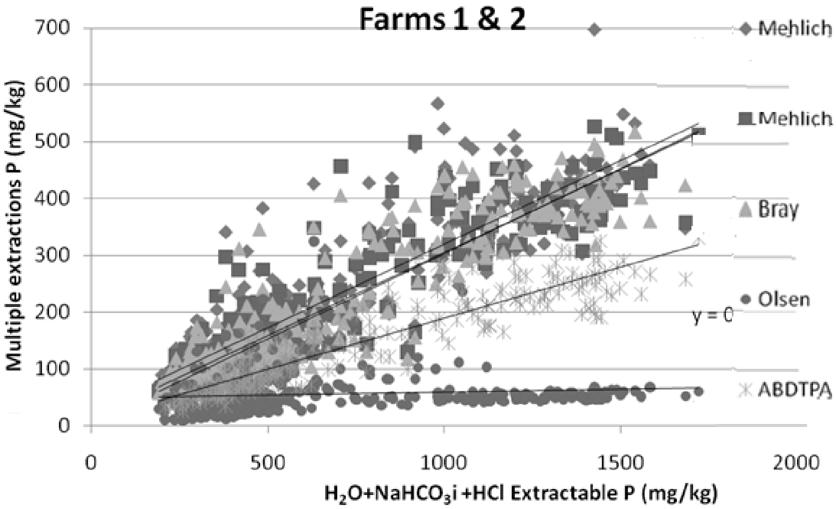


Figure 6. Comparison of acid extractable soil P compared with extractable soil P. Notice that all acid extractable soil P points compare well to extractable soil P for both Farms.



determine soil P requirements. Figure 3 illustrates change in soil P forms during two tomato growing seasons. The three forms listed as water or hydroxide soluble indicate the P available to plants from fertilizer and organic matter sources. The two forms listed as bicarbonate soluble are likewise from fertilizer and organic sources but not all of the P from the organic source may be available immediately but could be during the growing season. These five forms of P are considered plant available sources. However, the residual and dilute acid soluble forms are either in organic matter or solid (precipitated) forms that are not available to plants. As indicted in Fig. 3, the concentrations of available P sources are reduced during the growing season but the unavailable forms do not change.

Extractable Soil Phosphorus

Farm 1 contained less than 300 ppm Mehlich-1 extractable soil P, Ca concentrations less 1500 ppm, and pH between 6.5 and 7.3. Whereas, Farm 2 contained more between 200 and 500 ppm of Mehlich-1 extractable soil P, Ca concentrations of 1000 to 3000 ppm, and pH as high as 7.8. Extractable P for the two farms were compared with water soluble P. Results from Farm 1 indicate that the extractable soil P correlated well with water soluble P (Fig. 4). However, extractable soil P for Farm 2 was 150 to 250 ppm while extractable soil P ranged from 100 to 500 ppm. This indicates that the extracts were removing soil P that was not water soluble. When water and bicarbonate soluble P were added together and compared to extractable soil P, Farm 1 once again correlated well, but water and bicarbonate souble soil P for Farm 2 remained below 400 ppm (Fig. 5). This lack of comparability, further indicates the presence of P that is extractable but not avaialble to the plant. Both Farms compared well, when acid soluble P was compared with extractable soil P providing further evidence that all extractants over estimated soil P avaialbility when soil contains high Ca at pH greater than 7.3 (Fig. 6).

Reduction in data variability at high water and bicarconate extractable soil P concentrations can be noted providing a higher coefficient of determination (r2) for the relationship between water and bicarbonate extractable P and extractable soil P using the five extractants, thus providing a better correlation between extractable soil P and a measure of crop available soil P . Using the improved extraction to soil ratios, correlation between extractable soil P and soil water and bicarbonate-extractable soil P are greatly improved. These results provide insight into the correlation of the selected extractants and the plant availability of P in soil solution. Mehlich 1, Mehlich 3 and Bray extracted more soil P than did water soluble P and nearly 100% of the bicarbonate-extractable P. Whereas, both Olsen and AB-DTPA extracted less soil P compared with water and bicarbonate soluble P. Olsen and AB-DTPA currently appears to provide the best fit of extractable soil P with available P under high soil Ca and pH conditions.

Conclusions

The results from this demonstration project would indicate that the current soil P test using Mehlich 1 may not correctly represent available soil P in soils with high pH and Ca concentrations due to reduced P availability. Sequential analysis of soils with apparent soil P precipitation by Ca, indicate that the water and bicarbonate soluble forms are most available to tomato plants. Tests comparing sequential analysis results and extractable soil P indicated that all common soil P test extracts overestimated available soil P when compared with water and bicarbonate soluble forms of soil with pH greater than 7.2. However, all extractants worked well in soil with P below 300 ppm, Ca below 1500 ppm and pH below 7.2. The Mehlich 1 and 3 along with Bray provided results similar or greater than available P, thus Olsen and AB-DTPA may provide better numbers for soil test P indexing.

Literature Cited

Hedley, M.J., J.W. Stewart, and B.S. Chauhan. 1982. Changes in inorganic and organic soil phosphorus fractions induced by cultivation practices and by laboratory incubations. Soil Science Society of America Journal 46:970–976.

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

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

General Horticultural Aspects of Tomato Production under Protective Structures

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Introduction

Tomato production under protective structures has increased dramatically during the last decade in Europe and North America. This tendency is mainly due to the relatively high prices of premium tomatoes, particularly vine-ripe, round beefsteak and cluster cultivars. The leading countries include Spain, Mexico, Canada, and the Netherlands, all of which export part of their production to the U.S. A detail of the acreage under protective structures is listed below (Table 1).

Table 1. Tomato production under protective structures in selected regions around the world.

Country (year)	Acres
Central and South America and the Caribbean	
Spain (2010)	35,100
Netherlands (2008)	3,697
North America	
Mexico (2005)	7,500
Canada (2010)	1,625
United States (2010)	875
Europe	
Argentina (2003)	2,500
Guatemala (2011)	250
Dominican Republic (2009)	75

Protective culture for vegetable production uses permanent or temporary structures that provide an enclosed or semi-enclosed environment for plant growth and development. This broad definition comprises structures such as greenhouses, high and low tunnels, screen houses, and net houses. Each type of structure has certain advantages and limitations for tomato production in subtropical climates. Protection against rain and freezing conditions, isolation against diseases, insects, and weeds, and production of premium crops are among the most important advantages of this technology. On the other hand, the relatively high capital investment and maintenance costs, the lack of information about specific market niches, and the limited technological knowledge are among the most frequent restrictions for its adoption.

In Florida, the acreage of vegetables and small fruits under greenhouses, tunnels, and screen houses has increased slowly but steadily during the last decade. Clear and reliable statistics are not available, but it is estimated that more than 200 acres are devoted currently to tomato, pepper, strawberry, blueberry, and cucurbit production. However, as foreign competition, labor constraints, and statewide regulations threaten the sustainability of traditional field tomato operations, there is an opportunity to educate growers, stakeholders, researchers, and extensionists on the advantages and limitations of protected culture. Therefore, the objective of this paper is to present some of the most critical horticultural production aspects of tomato under protective structures using recent experiences from around the world. This paper is not intended to recommend specific practices, but rather to provide very general references on this technology.

Structures

The most common structures used to produce indeterminate-type tomatoes, which last between 8 and 14 months, are permanent greenhouses, although high tunnels and screen houses are low-cost alternatives to this type of structure. Depending on the ventilation system, greenhouses could have either fixed or retractable roofs and/or sides. In Florida's subtropical environment, it is advisable to carefully consider the ventilation system during the planning process. Successful, year-long tomato production is unlikely in a greenhouse with fixed roofs and sides without electric cooling and heating. Fixed roof and side greenhouses frequently have anti-insect netting and ground covers that minimize the need for chemical pest control. A more detailed description of greenhouse structures and materials (e.g. flat top, round, sawtooth, and multi-chapel roofs) is available elsewhere and interested growers are encouraged to search for the most convenient type for their needs.

High tunnels and screen houses are temporary structures that reduce the initial capital investment. The roofs of these structures could be covered with polyethylene film or fine screening sheets to reduce rain damage and to improve freeze protection and passive ventilation. However, due to prevailing moderate to high winds in Florida, it is possible that the roofing of these structures may not last more than three years, depending on maintenance. There are several types of polyethylene films and other covers (e.g. infra-red and ultra-violet films, silver reflective netting, black and white saran) that could be used to reduce temperatures inside the structures. A careful balance between solar radiation and air temperature should be exercised to avoid excessive stem elongation (etiolation or "stretching"). Recent experiences in west-central Florida indicated that regular 30% to 50%-reduction polyethylene film provided an adequate radiation/temperature balance for tomato growth.

Soilless Media and Cultural Practices

Production in normal soil under protected cul-

Table 2. Summary of soilless media, transplanting, and general cultural practices for indeterminate "cluster" tomato production under protective structures.

Practice or Activity	Comments
	Soilless media
• Mineral origin	Vermiculite, perlite, rockwool.
• Vegetable origin	Coconut coir, pine bark, peat, burned rice hulls, compost.
• Container	Bags, pots, trenches, troughs.
	Transplanting
• Planting density	8000-12,000 plants/acre (2-3 plants/m2).
• In-between rows distance	Cultivar and equipment dependent. Usually in double rows separated 5-6 ft.
• In-row distance	8-10 inches in single rows.
	Trellising, training, and pruning
• Ventilation	Flower abortion and dropping occurs when air temperatures are above 120°F for longer than 3-4 hours.
• Trellis	Single stem. Single heavy duty wire on row center, 8-10 ft high. One fine string per plant. Plastic clips, tape or hooks to attach string to soilless medium bag or container.
• Training	String is attached to the stem with plastic clips or tape every 1-1.5 ft. String twined around the main stem.
• Pruning	All axial branches or "suckers" are removed starting when plants are 2-ft tall.
• Kneeling	After harvesting the first cluster, vines are bent in an "L" shape or twisted in concentric circles around the planting hole. It allows keeping vines under the top wires. It may need to be done 8-12 times per season.
• Fruit thinning	Some cultivars require leaving 5-6 fruit per cluster to obtain commercial size. It must be done during early fruit setting.
• Pollination	Bumble bee colonies. Wire shakers and manual shaking of wires. It must be performed at least once per week.

Table 3. Summary of irrigation, fertilization, and harvesting practices for indeterminate "cluster" tomato production under protective structures.

Practice or Activity	Comments
	Irrigation
• Delivery	Drip tape or "spitters".
• Volume	Depends on crop growth stage, temperature, relative humidity, evaporation, wind, and medium retention. A 12-14 month season could use between 50 and 80 acre-inch/acre (at least 0.5 gal/plant/day).
• Frequency	Varies widely (2-12 times/day).
• Monitoring equipment	Tensiometers and time domain reflectometers (TDR). Tensiometers and TDR readings may need to be kept below 8 cbar and 10%, respectively, for most substrates. Calibration of the media to determine water holding capacity must be done before planting. Electric conductivity should be maintained below 2.5-3.0 dS/m.
	Fertilization
• System	Single or multi-tank injection. Single-tank systems are based on liquid formulas, similar to those used in open field production. Leaf and petiole analyses should be conducted periodically to assess nutritional status and determine if additional single-nutrient injections are needed. Multi-tank systems generally have four tanks that inject simultaneously into the water stream to avoid precipitation in the solution. These tanks may contain compatible nutrient sources (nitrates, sulfates and phosphates, micronutrients, and acids).
• Injection equipment	Venturi®, Dosatron®, electric valves.
• Frequency	Most operations inject fertilizer with each irrigation, if the crop is irrigated more than 5 times per day. Others inject 2-3times/day.
• Rate	Assuming a 12 month season: 1,100-1,900 lb/acre N; 250-400 lb/acre P; 1,400-2,000 lb/acre K.
	Harvesting
• Yield	Cluster tomato typical yield: 70-150 ton/acre.
• Timing	One biweekly harvest for 8-14 months, starting at 5-6 weeks after transplanting and depending on tomato type and market. Typical operations may harvest about 20 times in a 10-month season.

ture follows similar conditions as for open-field operations, where soil fumigation or disinfection is a primary activity to reduce the incidence of soilborne diseases, nematodes, and weeds. On the other hand, soilless media utilizes mineral or vegetable substrates to replace the normal soil functions for plant growth and development (Table 2). Each substrate has specific properties with regards to water and nutrient retention, as well as recyclability. Mineral substrates are very easy to process and prepare for transplanting, but they are usually more expensive than vegetable substrates and are not easily disposable. In contrast, substrates of vegetable origin may require "loading" with nutrients, especially nitrogen (N), prior to planting to satisfy the carbon to N ratio (usually 20:1 or 25:1) that bacteria in soilless media need for normal functions and structures.

Irrigation, Fertilization, Pest Management, and Harvesting

Water management in a protective structure greatly differs from open-field production because of the differences in temperature, relative humidity, and evaporation created inside the structures. Therefore, each production setup requires careful calibration and monitoring of soil or medium moisture to avoid plant stress symptoms, such as leaf rolling and wilting. Some guidelines and monitoring equipment are suggested below (Table 3). Similarly, the fertilization program for indeterminate tomatoes should be based on quantities needed to satisfy the crop requirement and account for leaching and volatilization losses and medium retention.

Pest management inside greenhouses, tunnels, and screen houses depends on the pest pressure and ventilation of the structures. In high tunnels and screen houses, pest management programs are very similar to those in the open fields, whereas in enclosed greenhouses the labels should be carefully read to identify if a given product can be applied inside a greenhouse.

The Food Safety Modernization Act (FSMA)

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The Food Safety Modernization Act (FSMA), which was signed into law on January 4, 2011 (1), is one of the most sweeping food safety regulations since the Food, Drug and Cosmetic Act (FDCA) passed in 1938. As with the FDCA, public pressure on lawmakers greatly influenced the creation and ultimately the passing of this regulation. The burden of foodborne illness is considerable. The Centers for Disease Control and Prevention (CDC) estimates that every year foodborne diseases cause approximately 9.4 million illnesses, 55,961 hospitalizations and 1,351 deaths in the US (Scallan et al., 2011).

While not specifically written for produce, recent foodborne disease outbreaks associated with fresh produce also contributed to the structuring of this regulation. Produce-associated foodborne illnesses have increased significantly in recent decades. Between the 1970s and 1990s, reported produce-associated outbreaks increased 5.3% and the median number of illnesses associated with the outbreaks increased by 11% (Sivapalasingam et al., 2004). In 2007 there were 37 reported outbreaks attributed to vegetables, which were responsible for over 800 illnesses (CDC, 2010). While many categories of produce have been linked to outbreaks, fresh tomatoes have been linked to numerous multistate outbreaks in the US since 1990 (CDC, 2002; 2005; and 2007). Fresh tomatoes are of particular concern in Florida because the state is the number one producer of fresh tomatoes in the US, with the industry generating $630 million in 2010 (USDA, 2011).

Some of the Highlights

The goal of FSMA is to enhance public health and safety. In general, it transforms FDA's approach to food safety from investigation to prevention. FSMA gives FDA mandatory recall authority if a company fails to do so voluntarily. It also establishes an FDA-based inspection system for fruits and vegetables and science-based standards for microbial content. It requires almost all supply chain partners to undergo auditing/inspections at least annually and, depending on their risk (i.e., leaf, fresh-cut processing), operations may see more frequent random inspections. The law also establishes importer requirements for bringing produce into the country including ensuring that all foreign suppliers have a valid GAP (farm) and/or GMP (cooler, packing, processing) food safety inspection/certification (Larsen, 2011).

A traceability partnership will also be established to track produce by box from farm to consumer (PTI). High-risk facilities will see inspections within three years of enactment, while low-risk will see inspections within seven years. High-risk/low-risk definitions have yet to be determined. The FDA budget is already stretched but will be given additional funding. Where the money is coming from has yet to be determined. Partnerships with state agencies like FDACS and/or third-party auditing companies may take place. We may see a program similar to the Worker Protection Standard. There is a "watchdog clause" stating that any employees providing information to inspectors are protected from monetary fines and retribution and from their employer.

One of the initial concerns of FSMA was that this regulation would put too large of a burden on the small farmer. To that end, Senator Jon Tester successfully put forth an amendment to protect small, family operations. The Tester Amendment includes inspection exemptions for "small operations" that hold less than $500,000 in food annually, but said operations must still have proper documentation and programs in place. This amendment remains one of one of the most controversial. While some producers laud its inclusion, others contend that food safety should apply to all producers, both large and small (FDA 2011).

Record-keeping and Audits

The regulation gives FDA legal access to see and copy records related to food safety plans and related documents. This includes environmental and finished product testing, corrective actions and related rationale and monitoring of supply chain. While documentation has been part of Good Agricultural Practices (GAPs) for years, good documentation practices will be even more critical. If FDA has a "reasonable belief that a food presents a health concern", the agency now has the authority to copy all records relating to that food and any "other article of food" that "the Secretary reasonably believes is likely to be affected in a similar manner" (summarized by United Fresh, 2011). The implication of this is that it extends FDA's authority from only a potentially contaminated food, to any food produced in the facility.

Inspection and Compliance

The legislation recognizes that inspection is an important means of holding industry accountable for their responsibility to produce safe product. FDA will meet this expectation by applying its inspection resources in a risk-based manner and innovating in its inspection approaches to be the most efficient and effective with existing resources. Increased inspectional frequency of high-risk facilities is mandated on date of enactment. For domestic high-risk facilities, an initial inspection will be conducted within five years of enactment and every three years thereafter. For domestic non-high risk, the facility will be initially inspected within seven years of enactment and every five years thereafter (FDA, 2011).

Recalls

For the first time in history, FDA will have mandatory recall authority for all food products under their regulation. While FDA expects that it will only need to invoke this authority infrequently since the food industry is largely compliant with FDA's requests for voluntary recalls, this new authority is a critical improvement in FDA's ability to protect the public health (FDA, 2011).

Summary

This is only a brief summary of the new regulation. There are many more parts and provisions not covered in this brief summary. It's important to note that many more conversations are going to occur before this law is in full implementation. Many questions surround how FDA is going to be able to enact this law with current resources. With more budget cuts looming, it's very probable that FSMA will continue to evolve.

References

Centers for Disease Control and Prevention (CDC). 2002. Outbreak of Salmonella serotype Javiana infections--Orlando, Florida, June 2002. MMWR Weekly 51:683-4.

Centers for Disease Control and Prevention (CDC). 2005. Outbreaks of Salmonella infections associated with eating Roma tomatoes--United States and Canada, 2004. MMWR Weekly 54:325-8.

Centers for Disease Control and Prevention (CDC). 2007. Multistate outbreaks of Salmonella infections associated with raw tomatoes eaten in restaurants--United States, 2005-2006. MMWR Weekly 56:909-11.

Centers for Disease Control and Prevention (CDC). 2010. Surveillance for foodborne disease outbreaks, United States, 2007. MMWR Weekly 59:973-9.

FDA. 2011. Last accessed on July 5, 2011. www.fda.gov and http://www.fda.gov/Food/FoodSafety/fsma/default.htm

Larsen, K.H. 2011. Food Safety Modernization Act Summary. Personal Communication.

Scallan, E, R. M. Hoekstra, F. J. Angulo, R. V. Tauxe, M. A. Widdowson, S. L. Roy, J. L. Jones, and P. M. Griffin. 2011. Foodborne illness acquired in the United States--major pathogens. Emerg Infect Dis 17:7-15.

Sivapalasingam S, Friedman CR, Cohen L, Tauxe RV. 2004. Fresh produce: A growing cause of outbreaks of foodborne illness in the United States, 1973 through 1997. J Food Prot 67:2342-53.

United Fresh. 2011. FDA Food Safety Modernization Act of 2010: Likely Impact on the Produce Industry. Last accessed on July 5, 2011. http://www.unitedfresh.org/assets/food_safety/FDA_FSMA_White_Paper_January_2011.pdf

USDA. 2011. Vegetables 2010 summary. Washington, D.C.: USDA, National Agricultural Statistics Service. Available from: http://usda.mannlib.cornell.edu/usda/current/VegeSumm/VegeSumm-01-27 2011.pdf. Accessed May 5, 2011.

Achieving Consistency with Methyl Bromide Alternative Fumigants

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In reflecting on previous 'Tomato Institutes', it becomes clear to us that we have talked a lot previously about the end of an era with methyl bromide soil fumigation and to the transition to use of other fumigant alternatives. In none of our presentations at these meetings have we ever indicated that the transition was going to be necessarily easy or seamless, or without penalty or consequence. We have repeatedly indicated if growers became vested in on-farm alternative testing and developed an understanding of their differences, then any transition problems that might be encountered could be recognized early. Through knowledge and experience, problems could be addressed and avoided as the farm more broadly adopted use of the alternatives. Unavoidably, we have also reported, and growers continue to discover, that some factors that affect the success or failure of an alternative fumigant, such as the environment, may not be predictable or completely manageable or resolvable. For example, seasonal differences in soil temperature and rainfall patterns can adversely effect fumigant dissipation from soil, and thus can cause phytotoxicity to the newly planted crop or reduce the production value of the alternative by causing treatment inconsistency. We continue to observe that growers can create significant response variability due to improper planning, inappropriate land preparation, and substandard application procedure or irrigation practice. The purpose of this paper is therefore to briefly define and discuss those grower considerations which could minimize performance inconsistency with the methyl bromide alternative fumigants.

Planning

Achieving consistency, not necessarily perfection, with the alternative fumigants requires planning on the part of growers and applicators. Recognizing that aeration problems can and do occur with the alternative fumigants, we believe that growers should be encouraged to consider and practice the old adage of the five P's: "Proper Planning Prevents Poor Performance". The plain and simple fact is that none of the alternatives disappear from soil as quickly as methyl bromide (5-10 days). As a result, planning horizons for fumigation activities with the alternatives should begin as much as 6-8 weeks in advance of anticipated planting and arrival of transplants onto the farm. We understand that this is a long time, but feel it is necessary to consistently avoid problems of fumigant persistence and crop phytotoxicity.

We should be aware that all of the fumigants, including their gas and water phases, are toxic to plants and that soil dissipation and the persistence of these toxic residues is strongly influenced by environmental conditions. Any change in soil condition which promotes a cooling and or wetter soil condition will typically delay soil dissipation of any fumigant compound. As a result, fumigant applications should be made well in advance of the delivery date of the transplants (i.e., planting date) to ensure sufficient time for dissipation of fumigant residues from soil and to avoid long unscheduled delays in planting after the plants have arrived from the nursery. Grower planning horizons should consider beginning field preparation and soil application two to three weeks earlier than normal to avoid problems of potential phytotoxicity that may result from use of impermeable mulches, or unexpected cold fronts or storm(s) producing abundant rainfall.

Soil Moisture

Clear and simple, water effectively blocks efficient diffusion of fumigant gases in soil. Once injected into soil and at temperatures above 70-75°F, most fumigants vaporize (some more slowly than others) into a gas and diffuse through open soil pore space. Soil moisture content is thus very important in this regard. Some fumigants, like 1,3-D (Telone®), are more vulnerable to high soil moisture conditions than that of fumigants like methyl bromide with higher vapor pressure. As a soil injected liquid, 1,3-D slowly volatilizes into a gas which then moves through unrestricted, open air space. It is the unrestricted movement of 1,3-D through soil air spaces which three dimensionally defines treated soil volume and the overall zone of pest control. Any soil zone in which water fills open pore spaces between soil particles, or where soil particles are compressed and closely compacted will inhibit 1,3- D diffusion. High levels of rainfall or irrigation can thus potentially reduce 1,3-D treatment efficacy and persistence by filling open pore air space before, during, or even after fumigation has been completed. This reduced efficacy can occur via containment (trapping the liquid, preventing further volatilization, movement and degrading the product via hydrolysis), or by inhibiting unrestricted movement radially from the chisel stream flow of injected product. Because of their differences in vapor pressure with methyl bromide, 1,3-D and all of the other alternative fumigants require much more consideration of appropriate soil preparation, drainage, and moisture condition to ensure satisfactory performance in the field.

Irrigation

For a shank applied fumigant product, the fumigant must move through soil air to maximize the volume of treated soil. If irrigation is applied which saturates the soil, then further fumigant movement will be blocked until open air passages in soil are restored. During its travel as a gas in soil, there is a need for these gases to dissolve back into soil water to come into contact with and kill weed seed and other soil pest organisms. For example, as an aquatic pest, nematodes exist within surface films of water surrounding soil particle grains. So even as fumigants are moving through open air passages, they must dissolve into these surface water films, and as they do they establish a dynamic equilibrium, moving back and forth from the air to the water phase as the fumigant diffuses through the soil mass. That portion of the fumigant dissolved in the soil water establishes the concentrations responsible for the kill of nematodes and most other soil-borne pest organisms. In this regard, irrigation becomes a very important soil attribute which can negatively affect not only the diffusing capability, but fumigant efficacy and persistence. For example, repeated irrigations of soil after fumigation will not only restrict movement but also serve to enhance fumigant containment and further inhibit fumigant out gassing from soil. Research has shown that under wet, saturated and acidic conditions, fumigant degradation is slowed and persistence of the parent fumigant compound significantly enhanced in saturated soil. Because of this growers should avoid any rewetting of the soil which could serve to extend the persistence of the fumigant in soil. Growers who operationalize their irrigation immediately after fumigation and bedding, would thus be wise to allow the soil aeration process to complete before scheduling any lengthy irrigation within the field.

Soil Temperature

Soil temperature is also an important consideration as it relates to achieving consistency, since it directly influences the rate of fumigant volatilization in soil. For example, as temperature increases, so then does the volatilization rate of the fumigant. The importance of soil moisture and temperature to treatment efficacy cannot be overemphasized. When fumigants are applied to dry, sandy soil, under conditions of high air and soil temperatures, substantial losses of the escaping fumigant can occur from soil. It is also very important to recognize that changes in soil temperature also change the solubility of fumigants in air and water. More fumigant is dissolved in the soil water at 40°F than at 80°F; which means the solubility of a fumigant in water increases at lower temperatures, while the percent of the fumigant in soil air decreases. The decrease in the amount of fumigant in the soil air because of the cold soil results in slower movement of the fumigant compared with warm soil. It also means that the fumigant will want to stay in solution longer, and thus persist in soil longer. Again, it tells us that appropriate conditions of soil moisture, temperature, and land preparation need to be present at the time of fumigation and after to optimize outward diffusion and soil retention of any soil fumigant. Any added rainfall or irrigation which will rewet the soil will serve to slow the dissipation and extend the aeration period, particularly under cooler spring conditions where the fumigant wants to persist in the dissolved state in soil water.

Bed Compaction

After a fumigant is injected and the bed is formed over it, it begins to vaporize and a portion of it begins to move upward. As it approaches the soil surface, particularly after a delay in mulch installation, it usually tends to move more rapidly, and will even channel or 'chimney' towards those areas of drier soil condition and increased porosity. In this case, if the bed is not pressed properly or uniformly, then fumigant movement across the bed can be disproportional, following a path of least resistance. With the objective of insuring fumigant retention and treatment consistency, growers and applicators should periodically inspect for any differences in the 'tightness' of soil between and across individual beds to insure uniform compaction and closing-off of soil air spaces, and making the necessary correction in level and tilt of the bed press during bedding and laying of plastic.

Fumigant Injection Depth

Seep irrigation is extensively used in Florida as a prefumigation land preparation practice to increase soil moisture to levels which structurally allow a raised bed to be formed. To achieve the bed forming soil moisture condition, typically in excess of 100% of soil capacity, the shallow water table must be raised closer to the soil surface. With a raised water table, there are instances in the field where fumigant injections may actually be made into the water saturated soil zone. Fumigant injections which are made into cold wet soils will require a significantly longer period to move out of the soil as a gas. Therefore, applicators may want to consider adjusting fumigant injection depth to be a little above the saturated soil conditions that may exist in seepage irrigated fields. On deeper, better drained soils applicators may want to increase the depth of application because the fumigant will still gas rapidly through the soil because it is not restricted by excess moisture.

Plastic Mulch Considerations

After a fumigant is applied, the bed is covered with a plastic polyethylene mulch to provide, among other things, an additional measure of fumigant containment to soil. There are a range of different mulches which growers currently use to reduce fumigant emissions from soil. From low density polyethylene (LDPE) to VIF and now TIF, the last two of which offer significant barrier to fumigant out gassing from soil. Compared to LDPE, these VIF and TIF films are typically over 20,000 times less permeable to fumigant compounds, and as a result, can significantly increase the residence time of fumigants in soil. Use of the more gas retentive mulches such as the metalized, the VIF and particularly the new TIF mulches will require additional grower consideration concerning the risks they might pose to delaying fumigant aeration from soil. Because of their excellent barrier properties, fumigant application rates should probably be reduced to decrease soil aeration times, particularly when reoccurring afternoon showers rewet the soil or should reoccurring cold fronts arrive in the spring to cool the soil.

Fumigant Detection and Bioassay Tests:
There a couple of different devices which are capable of detecting the presence of a fumigant in the soil air profile. You can use a detector tube (i.e. Drager, Sensodyne, etc) that changes color in the presence of the product or you can use a device such as a MiniRae that measures the level of volatile organic compounds (VOC) in the soil air. Both of these products measure the level of fumigant in the air in the raised bed. They cannot measure a fumigant that is still trapped in the liquid phase within the soil. If the grower keeps the ground wet, this method will not give accurate results.

An important portion of the planning process for a current season is the determination if conditions are safe for transplant. Each individual fumigant label lists a method of detection of fumigant residues, often in the form of a bioassay. It is important that each field has a bioassay completed prior to the planting of any crop following fumigation. We have had too many incidents where it was assumed the fumigant had left the soil and upon planting of the crop, severe crop injury occurred. Bioassays can take a couple of different forms. One method is the planting of the small seeds of a sensitive crop such as lettuce or radish and waiting for germination. The other method requires the transplanting of the desired crop into the field and waiting to see if there are fumigant effects. In using both methods it is important to schedule the initiation of the bioassay at least 7 days prior to planting the crop. When conducting the bioassay, all areas of the field must be sampled, e.g. dry and wet portions, sandy and loamy portions. Only plant when all assays show no injury from the fumigant. Take note that the use of the sensitive seed test (lettuce and radish) does not work when herbicides are being applied underneath the plastic mulch.

Conclusions
Various edaphic, environmental, biological, and cultural factors are known to directly influence fumigant treatment performance and consistency. We have attempted to describe how prevailing soil and climatic conditions, pre and post fumigant application, become very important determinants of gas phase movement in soil, and thus fumigant efficacy and crop response. In general, the best case scenario describing fumigant aeration from soil probably occurs during the fall under hot soil conditions in a field with good soil drainage, using a HDPE plastic, and punching aeration holes into plastic of the bed shoulder (when and if necessary), with a rolling fertilizer wheel. Under these conditions, higher fumigant rates or reduced rates with VIF or TIF plastics typically provide excellent results with a shorter plant back interval. The worst case scenario might best be described by an early spring application made to cold, poorly drained, wet soils where soil moistures are then maintained in a saturated state from seepage irrigation or where rainfall or a drip irrigation schedule maintains a saturated soil condition. The worse case spring condition would surely be aggravated by using impermeable plastic such as VIF or TIF plastic and where higher fumigant application rates are used in the field.

Because of the potential plant back issues, transition to the alternatives requires that growers implement significant changes to current practices, including new planning, land preparation and planting timelines, and irrigation practices to enhance the performance of alternatives. Growers should also be discovering that the new labels for all of the currently registered fumigant alternatives have new mandatory Good Agricultural Practices (GAP's) which demand implementation of many of these same principals and practices to be compliant with the new fumigant labels. In general we would like to conclude by saying that any soil condition that restricts fumigant diffusion or favors rapid escape will effect the overall performance of soil fumigation and that solving the soil aeration problem should be addressed and resolved prior to a last minute recourse action of punching holes in the plastic, and wondering whether plants will survive the fumes.

FARM LABOR CONTRACTOR (FLC) CORE TRAINING PROGRAM

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Introduction
A new educational program directed toward Farm Labor Contractors (FLCs) was launched in fall 2010 by the University of Florida/IFAS at the Southwest Research and Education Center in Immokalee, Florida. The goals of the FLC Core Training program were to enhance the knowledge and professionalism of FLCs, also known as crew leaders.

A primary function of FLCs in Florida is to supervise seasonal and migrant farm workers as they perform harvesting and other field activities on fruit and vegetable farms. Other duties of Florida FLCs may include recruitment, hiring, transportation, payroll disbursement, and housing of farmworkers. Regardless of their job titles and responsibilities, FLCs must carry federal and state Farm Labor Contractor licenses. Licenses vary among FLCs with respect to specific conditions for which they need to be "authorized." FLCsmust have appropriate authorizations to transport workers, own buses or vans that transport workers, and/or provide housing to workers. Farm personnel who perform any or all of the duties of a FLC, but are considered to be full-time employees of a farm, are NOT required to obtain an FLC license. They are, however, obligated to follow the same rules and regulations concerning treatment of farm workers.

State and federal laws that protect farmworkers are extensive and have evolved over time. Many FLCs are not aware of the full scope of labor regulations or how the regulations have changed. Aside from passing a test to receive their initial license, formal training of FLCs has not been required by state or federal agencies. Opportunities for continuing education for FLCs have been limited. In many instances, FLCs violate workplace rules in part because they are unaware of or do not fully appreciate their responsibilities.

There are a few instances when training has been made available to FLCs. Worker Protection Standards (WPS) is one example. In 1995 the U.S. Environmental Protection Agency (EPA) mandated that all agricultural workers, including FLCs,be trained in pesticide safety and be knowledgeable about decontamination procedures and where to find information about chemicals recently applied to the fields where they work. The University of Florida Extension faculty and several agricultural grower associations in Florida have been providing training in cooperation with state and federal regulatory compliance officials.

The University of Florida Farm Labor Contractor Core Training program was designed as a voluntary educational program that targets FLCs and farm supervisors who have direct responsibility for the physical and economic welfare of migrant and seasonal farmworkers. The goals of this program were to develop and implement an educational curriculum that provides FLCs with an comprehensive picture of their regulatory responsibilities. The underlying rationale of the training program is that enhanced knowledge about farm labor laws and regulations will improve the professionalism of FLCs, reduce the number of field violations, and improve overall working conditions of farm workers.

Background work to design the FLC Core program
Development of the FLC Core Training program began in July 2009. For the next twelve months, time was spent interviewing various stakeholders about the concept and specific content of a training program directed toward FLCs. In addition, data were collected on demographics and scope of the FLC community. These came from informal group meetings, formal advisory committees, and several individual interviews.

The Florida Department of Business and Professional Regulations (DBPR) maintains a database on licensed FLCs. According to this database, there are just over 800 licensed FLCs within a two-hour driving radius of Immokalee, Florida. A few vegetable growers in Collier County surveyed 48 FLCs on relevant demographic information. While this survey cannot be considered a representative sample, the information does provide a partial picture of what FLCs look like. Of the 48 FLCs, 87% were male and 13% female. Only 27% felt comfortable communicating in English while 65% were more comfortable in Spanish. The average time spent in formal education ranged from no school to some college, with the majority saying 6 - 7 years. Their average age was 48, and the average length of time working as a FLC was 16 years. To get into this business, 21% started as field workers, another 21% grew up in a FLC family, 11% had been truck drivers, and 27% marked "other" (friend, needed to work, or did not answer.) After the agricultural season in southwest Florida, 65% migrate north to follow summer croppingcycles. The remaining percentage either stay in Immokalee or vacation in Texas or Mexico.

Numerous group and individual interviews provided important insights into the work environment of FLCs and contributed to the development of training content.

Farm Labor Contractors.
Generally, FLCs believedthat they knew the laws but nevertheless were confused in some areas, such as when the payroll clock actually started. Specifically, they were challenged with food safety and field sanitation regulations. Several mentioned that they had taken the FLC test years ago (in some cases as many as 20 years) and that they were unfamiliar with changes in the laws that have taken place over time. Their lack of knowledge was most apparent in driver and vehicle regulations enforced by the Florida Department of Transportation. They expressed concerns for the welfare of their workers in terms of wages and access to water and field sanitation facilities. Paper work and record keeping were significant issues, particularly in tracking worker time and piece rates. Some of the FLCs had trouble with quarterly taxes and filing procedures. Safety was a concern, particularly when it involved workers' desires to work rapidly during piece rate work like harvesting. Techniques for managing workers were brought up, related to partial filling of buckets, coming to work inebriated, not reporting for work when they said they would, etc. Several FLCs expressed frustration with news reports that generally portrayed FLCs as committing rampant violations and not caring about worker welfare. Several FLCs asserted that many violations are actually committed by "pinhookers," who are not required to obtain a FLC license and are therefore not as closely regulated as licensed FLCs.

Growers/Farmers.
Growers who employ FLCs were concerned mostly that FLCs understand and comply with laws that protect farm workers. The concept of "joint employment" has been well established and growers wanted to reinforce their concerns that violations carried out be a FLC could have serious legal and financial implications to the entire farming operation. Some growers assist FLCs in obtaining licenses, maintaining payroll records, and may even carry the Workers' Compensation insurance policy.

Farm Worker perspectives.
Workers characterized FLCs/crew leaders as either "good" or "bad" by how much they respected the workers they managed. Bad crew leaders yell at workers, criticize their efforts, and threaten to fire them. Good FLCs treat the people with respect. Good FLCs provide work and treat workers fairly. Bad crew leaders tended to give preferential treatment to only those workers with legal documents and/or could speak English fluently. Bad Crew Leaders did not respect women and gave them less desirable jobs, such as placing them on the opposite side of a ditch and farther away from the loading truck. Chief complaint among workers was the lack of adequate access to water and sanitation facilities. In some cases, the FLC told them not to drink much water so they would not have to lose time using the toilet facilities. Many times lunch periods were cut short, in part because it could take up to 15 minutes of a 30 minute lunch period to walk from where they were working to a hand washing facility.

Government Agencies.
Regulatory compliance officers from DBPR (Department of Business and Professional Regulation), DOL (Department of Labor), AWI (Agency for Workforce Innovation), DOT (Department of Transportation) and DOH (Department of Health) provided information on common FLC violations, as well as their impressions on how a training program could improve overall compliance. Biggest violations were related to transportation and condition of buses; adequate insurance; posting of Terms and Conditions of work; proper calculation of field payroll records; and field sanitation (more in citrus than vegetables); These inspectors also suggested ways to make the inspection process easier, including having all documentation readily available, being pleasant, and assisting the inspectors wherever possible.

Local Organizing Committee (LOC).
A Local Organizing Committee (LOC) was formed and first met on 11 February 2010. The committee was charged with advising UF/IFAS staff as to the program content, training times, and scheduling logistics. The committee included growers, government compliance officers, worker advocates, and FLCs. This committee met five times between February 11 and November 9, 2010.

Design of the FLC Core Training Program
Based on the information collected during the 2009-10 agricultural season and the direction of the Local Organizing Committee, the "Core" program evolved into four (4) units with 3.5 hours of educational content each. The units were: General Administration, Transporting Workers, Agricultural Worker Safety, and Personnel Management. All units focused on legal compliance, and paid particular attention to commonly misunderstood concepts. The Core units are outlined below with some detail on the points that the training program covered.

1. General Administration – training topics focused primarily on provisions set forth by the FLSA (Fair Labor Standards Act) and MSPA (Migrant and Seasonal worker Protection Act.)

- FLC licensing process
  - o State and Federal Licensing
  - o Documents required for authorizations for transportation, driving, and housing.
- Wage & Hour issues
  - o Disclosure of terms and conditions of work
  - o Wage summary required information
  - o Minimum wage and hours worked
  - o Properly recording hours worked
  - o Deductions
  - o Worker rights
  - o Joint liability and its implications
- Field Sanitation
  - o Number of portables per worker population
  - o Potability of water in handwashing units
  - o Responsibilities of both FLCs and workers related to using field sanitation units
- Workers' Compensation
  - o Purpose behind Workers' Compensation insurance
  - o Responsibilities of the employer and the employee
- Surviving an inspection from a state or federal compliance agency.
  - o Who checks what? A checklist of which agencies govern which regulations.
  - o Inspection versus Investigation
  - o Suggested Do's and Don'ts during a meeting with inspectors.

2. Transporting Workers – Department of Transportation (DOT) rules and regulations for buses and vans that transport farm workers in Florida.

- Controlled substances and alcohol testing o "Drug-free workplace" versus DOT-approved D&A testing program

- Commercial Driver's Licenses
- DOT numbers – application process and displaying them on buses
- Driver Qualification files
  - o Prior employer and state record checking
  - o DOT Medical exam long form versus DOL Medical Card
- Bus inspection (an activity)
  - o A farm labor bus was provided on loan by Farmworker Village and deliberately made non-compliant with respect to DOT, DOL (MSPA), and DBPR regulations.
- Hours of Service permitted under DOT regulation
  - o 12 hour or 15 hour daily rule
  - o 60/70 hour weekly rule
  - o Log books versus time records
- Inspection, Repair and Maintenance of vehicles
- Compliance reviews.

3. Agricultural Worker Safety –
   - Worker Protection Standard (WPS)
     - o History and purpose of WPS Laws
     - o Five Basic protections – Training, information, decontamination, information exchange, emergency assistance
     - o Preventing and handling pesticide residue exposure
   - First Aid Response
     - o Types of first aid, eye injuries, allergic reactions, heat stress, heat stroke, lightning storms, fainting, insect stings, wounds, snake bites, splinters, broken bones
   - Moving Agricultural Equipment and farm vehicles
     - o Drug & alcohol use, CDL, traffic regulations, driving agricultural transportation vehicles on public roads, securing loads
   - Farm Equipment Safety
     - o Responsibilities of employers, recommendations to protect workers, types of accidents,
     - o Personal Protection Equipment,
     - o Lifting Safely: Muscle strain/back injuries, pregnant women

4. Personnel Management –
   - Human Trafficking
     - o In the fields and in brothels
     - o What to look for and how to report suspicious activity
   - Discrimination
     - o Age Discrimination
     - o Issues with pregnant women working in the fields and groves
   - Sexual Harassment
     - o Work-place behavior versus non-work place behavior
     - o Responsibilities of the victim, the accused, and the employer
     - o The importance of notretaliating against a complaining worker
   - Child Labor –
     - o Reasons for child labor laws
     - o Minimum ages, exceptions, how to determine a worker's age
   - Managing People –
     - o Basics of motivating hand laborers
     - o Nine techniques for dealing with worker issues, including role-plays
     - o Importance of record-keeping.
   - Stress Management –
     - o Physical and emotional dangers of stress
     - o Techniques for managing stress

Fall 2010 Training Sessions

The "Core" FLC Training Program was presented for the first time during the fall 2010. The entire program was delivered on three separate occasions. A person could choose to attend all four units during a single period, or choose to complete different units on separate occasions.

September 22-23, 8:00 a.m. to 5:00 p.m., two units each day.The morning sessions ran from 8:00 a.m. to noon; the afternoon from 1:00 to 5:00 p.m. Wed: General Administration and Transporting Workers. Thurs: Agricultural Safety and Personnel Management.

October 11-14, 10:00 – 3:00. One unit each day. The schedule attempted to accommodate FLCs by allowing them to start their crews in the fields in the early morning and rejoin them by late afternoon. Mon: General Administration. Tues: Agricultural Safety. Wed: Transporting Workers. Thurs: Personnel Management.

November 3-4, 8:00 a.m. to 5:00 p.m. both days, two units each day. The schedule was the same as the first training (Sept).

Each participant received notebooks that summarized lecture material. Each unit was taught in concurrently in both English and Spanish. Notebooks likewise were written in both English and Spanish. Everyone who attended a training unit received a "Certificate of Attendance" for that particular unit. For those people who attended all four units, they received a "Certificate of Completion."

Over the three sessions offered, a total of 182 people attended at least one Core unit (96 in Spanish and 86 in English). A total of 126 people completed all 4 units (76 in Spanish and 50 in English). The largest number of people attended the Transporting Workers unit (169). Attendance increased over the three training sessions, growing from 50 in September to 75 registrants for the November training. More than 75% (97) of the people who completed all four units were FLCs, the target audience for this training program (Table 1).

Plans for Fall 2011

The attendance levels and overall reaction to the FLC Core Training program during fall 2010 encouraged the UF/IFAS team to push forward and develop a plan for extending the program during fall 2011. Meetings were held with agricultural leaders in the Belle Glade and Wimauma area to expand the training program to those locations. In addition, program content was reviewed and modified. Several comments from participants in Immokalee as well as from the Belle Glade and Wimauma meetings indicated that more information would be needed on farm worker housing that is provided by FLCs. As a result, the Transporting Worker unit has been redesigned to include a housing section.

While there are some differences in the agricultural cropping cycles among the three areas, generally the best window for training in southern Florida remains from August to December. A two-day schedule that presents the entire FLC Core Training was deemed preferable by participants during the fall 2010 and was confirmed by prospective participants in Wimauma and Belle Glade. Fall 2011 training sessions will be held on six different occasions between late August and mid December. The program will be presented in each location, two times. Brochures have already been developed and are starting to be distributed announcing the following training schedule:

Aug 24 & 25 at the Gulf Coast REC – Wimauma

Sep 21 & 22 at the Everglades REC – Belle Glade

Table 1. Farm Labor ContractorsCore Training Program fall 2010 attendance summary by training date and unit.

Topic	Sep 22/23	Oct 11-14	Nov 3/4	Total
General Administration	51	28	75	154
Transporting Workers	47	52	70	169
Agricultural Safety	43	37	66	146
Personnel Management	34	36	64	134
Attendance at least (1) unit:				182
English				86
Spanish				96
Completion Certificates:				126
English				50
Spanish				76
Employment classification of class participants:				
FLC				97
Harvest Manager/Supervisor				17
HR/Office administration				12
Citrus companies				19
Vegetable companies				14

FLC = Farm Labor Contractors.

Oct 5 & 6 at the Southwest REC – Immokalee
Nov 2 & 3at the Gulf Coast REC – Wimauma
Nov 16 & 17at the Southwest REC – Immokalee
Dec 14 & 15 at the Everglades REC – Belle Glade

The long term vision of the FLC Core Training program is that it remains a voluntary program with respect to state regulatory authorities. Through continued improvement and evolution, it is hoped that the value of the program content will be recognized by all FLCs and their grower partners so that they will seek to participate and complete. Further, it is hoped that the FLC Core program will encourage FLCs to seek additional training opportunities. As specific needs and interest arises, the UF/IFAS staff involved with the FLC Core program will also produce and present supplemental training modules.

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 down 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 586 Midseason maturity. Fruit are large to extra-large, deep globed shaped with firm, uniform green fruits well suited for mature green or vine-ripe production. Determinate, medium to tall vine. Resistance: Verticillium wilt (race 1), Fusarium wilt (race 1,2), Fusarium crown rot and root-knot nematode.

BHN 602 Early-midseason maturity. Fruit are globe shaped 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.

Charger Early maturity. A transition variety that 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 shaped 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 shaped fruit with compact plants. Does best with moderate pruning and high fertility. Good flavor, color and shelf-life. For vine ripe use only due to nipple characteristic on green fruit. 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),

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 shaped, 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 UF breeding program variety 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. For Trial.

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).

Grape Tomatoes

Amai Indeterminate grape with deep red color and good flavor. 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.

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)

Sweethearts 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

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

Production System	Nutrient	Recommended Base Fertilization[z]							Recommended Supplemental Fertilization[z]		
		Total (lbs/A)	Preplant[y] (lbs/A)	Injected[x] (lbs/A/day) Weeks after transplanting[w]					Leaching rain [r,s]	Measured > low= plant nutrient content [u, s]	Extended harvest season[s]
				1-2	3-4	5-11	12	13			
Drip irrigation, raised beds, and polyethylene mulch	N	200	0-50	1.5	2.0	2.5	2.0	1.5	n/a	1.5 to 2 lbs/A/day for 7 days[t]	1.5-2 lbs/A/day[p]
	K_20	220	0-50	2.5	2.0	3.0	2.0	1.5	n/a	1.5 to 2 lbs/A/day for 7 days[t]	1.5-2 lbs/A/day[p]
Seepage irrigation, raised beds, and polyethylene mulch	N	200	200[v]	0	0	0	0	0	30 lbs/A [q]	30 lbs/A [t]	30 lbs/A [p]
	K_20	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). Preplant 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 preplant. Fertilizer injections may be done daily or weekly. Inject fertilizer at the end of the irrigation event and allow enough time for proper flushing afterwards.

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

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

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

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

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

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

[q] Supplemental amount for each leaching rain

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

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

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 (CO3) 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

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

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

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	1000–1200	3500–4000
First open flowers	600–800	3500–4000
Fruits one-inch diameter	400–600	3000–3500
Fruits two-inch diameter	400–600	3000–3500
First harvest	300–400	2500–3000
Second harvest	200–400	2000–2500

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

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

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

devices may be found in Munoz-Carpena (2004).

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

Successful crops have resulted where the total amounts of N and K_2O were applied through the drip system. Some growers find this method helpful where they have had problems with soluble-salt burn. This approach would be most likely to work on soils with relatively high organic matter and some residual potassium. However, it is important to begin with rather high rates of N and K_2O to ensure young transplants are established quickly. In most situations, some preplant N and K fertilizers are needed.

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

Sources of N-P_2O_5-K_2-0

About 30% to 50% of the total applied N should be in the nitrate form for soil treated with multipurpose 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.

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

Supplemental Fertilizer Applications

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

Levels of Nutrient Management for Tomato Production

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

Suggested Literature

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

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

Gazula, A., E. Simonne and B. Boman. 2007. Update and outlook for 2007 of Florida=s BMP program for vegetable crops, EDIS Doc. 367, http://edis.ifas.ufl.edu/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 recommended method to schedule irrigation for tomato is to use together an estimate of the tomato crop water requirement that is based on plant growth, a measurement of soil water status and a guideline for splitting irrigation (water management level 5 in Table 1; Table 2). The estimated water use is a guideline for irrigating tomatoes. The measurement of soil water tension is useful for fine tuning irrigation. Splitting irrigation events is necessary when the amount of water to be applied is larger than the water holding capacity of the root zone.

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

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

Tomato water requirement

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

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

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

$$ETc = Kc \times ETo$$

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

$$ETc = CF \times Ep$$

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 ETgage. 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 ETgage (ETg) was well correlated to ETo except on rainy days, but overall, the ETgage 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

Table 2. Summary of irrigation management guidelines for tomato.

Irrigation Management Component	Irrigation System[z]	
	Seepage[y]Drip[x]	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 system
[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 Transplanting[y]	Kc for Drip-Irrigated Crops
1	1-2	0.30
2	3-4	0.40
3	5-11	0.90
4	12	0.90
5	13	0.75

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

Table 4. Historical Penman-method reference ET (ETo) for four Florida locations (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

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 requirements 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 within 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 do not need to be 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 into 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%.

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/100ft to Wet Depth of 1 ft	Gal/100ft to Wet Depth of 1.5 ft	Gal/100ft to Wet Depth of 2 ft	Gal/acre to Wet Depth of 1 ft	Gal/acre to Wet Depth of 1.5ft	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

Guidelines for splitting irrigation

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

Units for measuring irrigation water

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

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

Example

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

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

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

3. The drip tape flow rate is 0.30 gallons/hr/emitter which is equivalent to 30 gallons/hr/100feet. It will take 1 hour to apply 30 gallons/100ft, 2 hours to apply 60gallons/100ft, and 2.2 hours to apply 75 gallons. The total volume applied will be 8,168 gallons/2-acre (75 x 108.9).

Irrigation and best management practices

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

with water quality standards (F.S. 403.067 (7)(d)), and (3); an eligibility for cost-share programs (F.S. 570.085 (1)).

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

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.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 0.31	(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) 75 DG 0.5 to 1 oz.	Broadleaf control and yellow/purple nutsedge suppression. A total of 2 application of halosulfuron per season.
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 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 to 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.
Napropamide 1.0 – 2.0	(Devrinol) 50 DF 2 to 4 lb.	Apply to bed tops after bedding but before plastic application. Rainfall or overhead-irrigate sufficient to wet soil 1 inch in depth should follow treatment within 24 hours. May be applied to row middles between mulched beds.
Oxyfluorfen 0.25 – 0.5	(Goal) 2 XL 1 to 2 pt. (GoalTender) 4 E 0.5 to 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 SL2.0 to 4.0 pt. (Firestorm) 3 SL - 1.3 to 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.

Active Ingredient lb. a.i./A	Trade name Formulation/A	Weeds Controlled / Remarks
PREPLANT / PREEMERGENCE		
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.
Trifluralin 0.5	(Treflan HFP, Trifluralin, Trifluralin HF) 4EC 1 pt. (Treflan TR-10) 5 lb.	Annual broadleaf and grass weeds. Do not apply in Dade County. Incorporate 4 inches or less within 8 hours of application. Results in Florida are erratic on soils with low organic matter and clay contents. Note label precautions against planting noncrops within 5 months. Do not apply after transplanting.
POSTEMERGENCE		
Carfentrazone up to 0.31	(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 nonionic 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.
Glyphosate 0.3 – 1.0	(Various formulations)	Emerged broadleaf and grass weeds. Apply to row middles with shielded or hooded sprayer. PHI 14 days.
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 day
Pelargonic Acid 3 – 10%	(Scythe) 4.2 EC	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.

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 2011).

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

Disease or Pathogen	Chemical (active ingredient)	Fungicide Group[1]	Maximum Rate/Acre/ Applic	Season	Min. Days to Harvest	Remarks[2]
Anthracnose	(copper compounds) Many brands available.	M1	SEE INDIVIDUAL LABELS		1	See label for details.
	(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	SEE INDIVIDUAL LABELS		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 (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.
	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 / 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.
	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	SEE INDIVIDUAL LABELS		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			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 fungicide. 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	(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 (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.
	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 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.
	Revus Top mandipropamid + difenocon(azole)	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	Limit is 2 apps per season at rates greater than 9 oz/A. Alternate with non-FRAC code 7 fungicides, see label
	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	Only suppresses Botrytis. Only 2 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	SEE INDIVIDUAL LABELS		1	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	SEE INDIVIDUAL LABELS		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
	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.
	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 lbx	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 + difenocon-azole)	40 / 3	7 fl oz	28 ft 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		1	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. Seel label for details.
	(mancozeb) Many brands available.	M3	SEE INDIVIDUAL LABELS		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 (chlo-rothalonil + mefenoxam)	4 / M5	3 lbs.	12 lbs	14	Limit is 4 appl./crop, 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.
	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 + difenocon-azole)	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	SEE INDIVIDUAL LABELS		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	SEE INDIVIDUAL LABELS		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	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 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	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.
	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	SEE INDIVIDUAL LABELS		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			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 (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 (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	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	24.6 lb	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
	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		1	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	SEE INDIVIDUAL LABELS		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 (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.
	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 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. Addition of a Latron surfactant will improve performance.
	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	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.
	Blocker 4F Terraclor 75 WP (PCNB)	14	See label	See label	Soil treatment at planting	See label for application type and restrictions
Target Spot	(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
	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.
	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.
	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.
	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.
	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
	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

[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).

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TOMATO BIOPESTICIDES AND OTHER DISEASE CONTROL PRODUCTS

Ordered alphabetically by commercial name. (Updated June 2011).

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

		Maximum Rate / Acre /			
Chemical (active ingredient)	**Fungicide Group[1]**	**Applic.**	**Min. Days to Harvest**	**Pertinent Diseases or Pathogens**	**Remarks[2]**
Actinovate *(Streptomyces lydicus* WYEC 108)	NC	See label	0	See label	See label for details. OMRI listed
AgriPhage (bacteriophage)	NC	2 pts /100gal.	0	Bacterial spot Bacterial speck	See label for details.
Armicarb 100 Armicarb “O” (Potassium bicarbonate)	NC	5 lbs/ 100 gal	0	Anthracnose Botrytis Phoma Powdery mildew Septoria leaf spot	See label for details.
Cease *(Bacillus subtilis strain* QST 713)	44	6 qts/ 100 gal.	0	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.	0	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.	0	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	0	Powdery mildew	See label for details.
Milstop (Potassium bicarbonate)	NC	5 lbs/ 100 gal	0	Anthracnose *Alternaria* spp. Botrytis Powdery mildew Septoria leaf spot	See label for details.
Oxidate (hydrogen peroxide)	NC	1 gal/ 100 gal	0	*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	0	*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	0	*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)	0	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.	0	Bacterial speck Bacterial spot Botrytis 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	0 0	*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 (*Trichoderma harzianum* Rifai strain KRL-AG2)	NC	5 oz/ 100 gal 32 oz	0 0	*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	0	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.
Serenade ASO (*Bacillus subtilis* strain QST 713)	44	6 qts	0	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.
Serenade Soil (*Bacillus subtilis* strain QST 713)	44	6 qts soil drench 13.2 floz/ 1,000 row foot in furrow	0	*Fusarium* spp. Rhizoctonia *Pythium* spp. Rhizoctonia spp. Verticil-lium spp.	Formulation compatible with soil drench, in-furrow, and chemigation applications. Mix with other effective fungicides for improved disease control. See label for details. OMRI listed.
Sil-Matrix (Potassium silicate)	NC	4 qts	0	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; chemigation	0 0	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	0	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	0	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 90°F. See label for details. Ingredients are exempt from FIFRA. OMRI listed
Trilogy (clarified hydrophobic extract of neem oil)	NC	1 % v/v solution	0	Alternaria spp. Anthracnose Botrytis Early blight Powdery mildew	See label for details. May cause leaf burn if applied during high temperatures. Avoid tank mixes with sulfur, chlorothalonil, or other chemically similar products. OMRI listed

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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 (bifenazate)	0.75-1.0 lb	12	3	twospotted spider mite	un	One application per season. Field grown only.
Actara (thiamethoxam)	2.0-5.5 oz	12	0	aphids, Colorado potato beetle, flea beetles, leafhoppers, stinkbugs, whitefly	4A	Maximum of 11 oz/acres per season. Do not use following a soil application of a Group 4A insecticide.
Admire Pro (imidacloprid)	7-10.5 fl oz (for rates for other brands, see labels)	12	21	aphids, Colorado potato beetle, flea beetles, leafhoppers, thrips (foliar feeding thrips only), whitefly	4A	Most effective if applied to soil at transplanting. Admire Pro limited to 10.5 fl oz/acre.
Admire Pro (imidacloprid)	0.6 fl oz/1000 plants	12	0 (soil)	aphids, whitefly	4A	Greenhouse Use: 1 application to mature plants, see label for cautions.
Admire Pro (imidacloprid)	0.44 fl oz/10,000 plants	12	21	aphids, whitefly	4A	Planthouse: 1 application. See label.
Agree WG (*Bacillus thuringiensis* subspecies *aizawai*)	0.5-2.0 lb	4	0	armyworms, hornworms, loopers, tomato fruitworm	11	Apply when larvae are small for best control. Can be used in greenhouse. OMRI-listed2.
*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 beatles, leafhoppers, leafminers (suppression), Lygus, stink bugs, 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, suppression of silverleaf whitelfy nymphs	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.
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, yellowstriped 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	1	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 Max (zeta cypermethrin)	2.4-4.0 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 24 oz 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.
Pyrellin EC (pyrethrin + rotenone)	1-2 pt	12	12 hours	aphids, Colorado potato beetle, cucumber beetles, flea beetles, flea hoppers, leafhoppers, leafminers, loopers, mites, plant bugs, stink bugs, thrips, vegetable weevil, whitefly	3, 21	
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.
SpinTor 2SC (spinosad)	1.5-10.0 fl oz	4	1	armyworms, Colorado potato beetle, flower thrips, hornworms, *Liriomyza* leafminers, loopers, *Thrips palmi*, tomato fruitworm, tomato pinworm	5	Do not apply to seedlings grown for transplant. Leafminer and thrips control may be improved by adding an adjuvant. Do not make more than two consecutive applications. Do not apply more than 29 oz per acre per crop.
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. Can be used in greenhouse. No available label for this product at this time. Use ends 2014.
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	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: 5-6 oz	12	21	Colorado potato beetle, flea beetles, leafhoppers, leafminers, thrips, whiteflies, suppression of green peach and potato aphids		Use only one application method (soil or foliar).
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 pin-worm, 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"	See label for use guidelines and additional considerations		
Telone EC[2]	9 -18 gal	Drip applied			
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"	See label for use guidelines and additional considerations		
Telone Inline[2]	13-20.5 gal	Drip applied			
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 2011. 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.
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, 2011 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.